



WATER STARGRASS RECOMMENDATIONS REPORT



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Water Stargrass Recommendations Report

Developed as Part of the Lower Yakima River Water
Quality, Nutrient, and Aquatic Vegetation Dynamics Study

by

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Executive Summary

Water stargrass (*Heteranthera dubia*) is an opportunistic native aquatic plant found in the lower Yakima River in central Washington. The aquatic plant's abundant growth over the past two decades has impaired the functional ecosystem of the lower river. Rapid growth of water stargrass is a product of the ideal conditions found within the river. During the growing season, mid-March through October, the lower Yakima River is warm and shallow with slow flows and high light availability (low turbidity). Summertime growth of water stargrass has deleterious effects on multiple beneficial uses of the lower Yakima River including: water quality, water flow, irrigation, fish passage, aquatic habitat, human health and recreation. Flowing through a semi-arid to arid basin in central Washington, the Yakima River supplies irrigation for local agriculture and urban residential needs. The Yakima River is also host to several native salmon species that start and end their life cycle within its waters. Water stargrass impounds river flows, creating slow, warm marshy waters. These areas that once flowed free have become ideal breeding grounds for disease carrying mosquitos and harmful algae and bacteria. Challenges with water supply, water quality, and fish habitat are pervasive in the lower Yakima River and are magnified by the excessive water stargrass plant communities.

Benton Conservation District (BCD) in collaboration with the U.S. Geological Survey (USGS) initiated a three year study of water stargrass and water quality dynamics in the mainstem lower Yakima River within Benton County. The study examined the driving forces between abiotic and biotic processes in order to identify the "push and pull" relationships that exist between the primary producers and water quality. Understanding the dynamics between water stargrass, water quality, and river hydrology provides water managers with insights for targeted remediation actions for improved ecosystem function of the lower Yakima. The results of the study are provided in the USGS Scientific Investigations Report (Sheibley et. al, 2022). Recommendations for plant management incorporate the results of the three year scientific study in addition to recommendations from a water stargrass Technical Advisory Group convened in the Spring of 2021.

In summary, we recommend the following actions to help manage nuisance growth of water stargrass within the lower Yakima River:

1. **Creation of a formal Water Stargrass coalition.** This coalition, composed of partner agencies and entities impacted by water stargrass, will oversee implementation of the recommendations outlined within the report. A formal coalition focused on water stargrass management can capture efficiencies between organizations, leverage funding, share cost expenses, and determine annual priorities for targeted management and removal actions.
2. **Targeted management and removal of biomass to improve beneficial uses of the lower Yakima.** Improved ecological river function will require targeted

management at key areas known to impact beneficial river uses. These areas include but are not limited to water supply intakes, fish ladders and dam reservoirs, breeding grounds for disease-carrying mosquitos or harmful algal blooms, fish migration, habitat and spawning areas, and public recreation areas. Known techniques such as mechanical harvesting, hand-pulling, weed barriers and chemical treatments can be readily used to improve targeted river functions.

3. **Management of water stargrass to meet state water quality goals.** Water stargrass impacts dissolved oxygen levels, pH levels, water flow and temperature. It also contributes to the highly corrosive nature of the lower river. Clearing dense areas of water stargrass will likely improve water quality conditions. Continuous water quality monitoring on the lower Yakima is also highly recommended so that the impact of targeted management actions on water quality can be evaluated.
4. **Continued research on water stargrass growth timing, life cycle and role in nutrient cycling.** We continue to learn new aspects about the complex relationships between water stargrass and its environment. Climate change and variability between water years with increased frequency of floods and droughts will continue to impact biological river functions. It is imperative that we expand our knowledge of water stargrass' life cycle, genetics, growth and its relationship to its chemical and physical aquatic environment in the lower river. This research can be conducted in parallel with targeted actions for improved river function and help refine management techniques and goals.
5. **Implementation of established techniques for short-term biomass control.** Mechanical harvesters, hand-pulling, chemical treatments, and weed paper/barriers (localized areas for small private irrigators) are established methods to control plant biomass. These methods can be quickly deployed and utilized during baseflow conditions and in drought years on the lower Yakima River. Ideally, for mechanical harvesting operations, a fleet of both large and small mechanical harvesters will be procured to clear multiple areas with varied hydrologic conditions.
6. **Pilot experimental treatments for optimal biomass control.** Future work to identify and study watershed-level controls and manipulations to help diminish biomass growth and/or improve water quality is recommended. Watershed control methods, such as flow management, in-stream velocity enhancers, and decreased light availability (turbidity alternation), are less tried-and-true techniques for plant control but may provide longer-term benefits and should be further investigated.
7. **Ongoing aquatic plant mapping and watershed monitoring.** With the continued threat of climate change on the lower Yakima River, it will be important to monitor the impacts of water stargrass biomass on ecosystem health and seek solutions for climate resiliency. We recommend regular biomass mapping and

monitoring to evaluate growth and spread of water stargrass into the upper Yakima. We also recommend development of a plan to enhance and restore the diversity of native aquatic plant communities in the lower Yakima River.

8. **Examine biomass alternatives to landfill disposal.** Disposal of cut biomass can be costly. As a native plant, there may be alternatives for removed plant material that are not typically available for invasive species. Techniques such as cut and drift may be appropriate in certain areas. Recycling or re-use of biomass as a nutrient source should also be investigated. Work by Pacific Northwest National Laboratory showed unlikely use of water stargrass as a cost effective biofuel, however, there may be other “green uses” and applications for cut biomass.
9. **Continued community outreach and education.** We recommend continued outreach and education to the local communities on water quality and watershed health. Engaging the community and landowners to educate, help monitor, observe spread, and combat the problem is invaluable.

This document integrates the work of three key reports pertaining to water stargrass and the lower Yakima River. The complimentary documents should be consulted in addition to this recommendation report:

- USGS Investigations Report, Lower Yakima River Water Stargrass Dynamics (Sheibley et. al 2022)
- Management and Control Techniques for Water Stargrass in the Lower Yakima River (Pelly et al. 2022).
- Emergency Drought Report for the Lower Yakima River (MCF 2022).

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1.0 Introduction

The lowest 50 miles of the mainstem Yakima River (lower Yakima) in Benton County, Washington are dominated by a rooted aquatic macrophyte called *Heteranthera dubia*, or water stargrass (Figure 1). Water stargrass thrives in the lower Yakima in a variety of habitats, ranging from finely silted slack water to higher velocity flows with cobble substrates. Despite its classification as a native aquatic plant, water stargrass in the lower Yakima acts like an invasive species, exploiting river conditions. Water stargrass can form bank-to-bank monocultures in summer months with magnified effects in low water years. Local scientists have observed moderate water stargrass densities in sections of the river between Prosser and Benton City where large rocky substrates dominate. Below Benton City, there are moderate to high densities of plant biomass, as the riverbed transitions from bedrock to cobble and silty bed substrates. Water stargrass is present upstream in South Yakima County, but its impact on river ecology seems to be less than that in the lower river reaches.

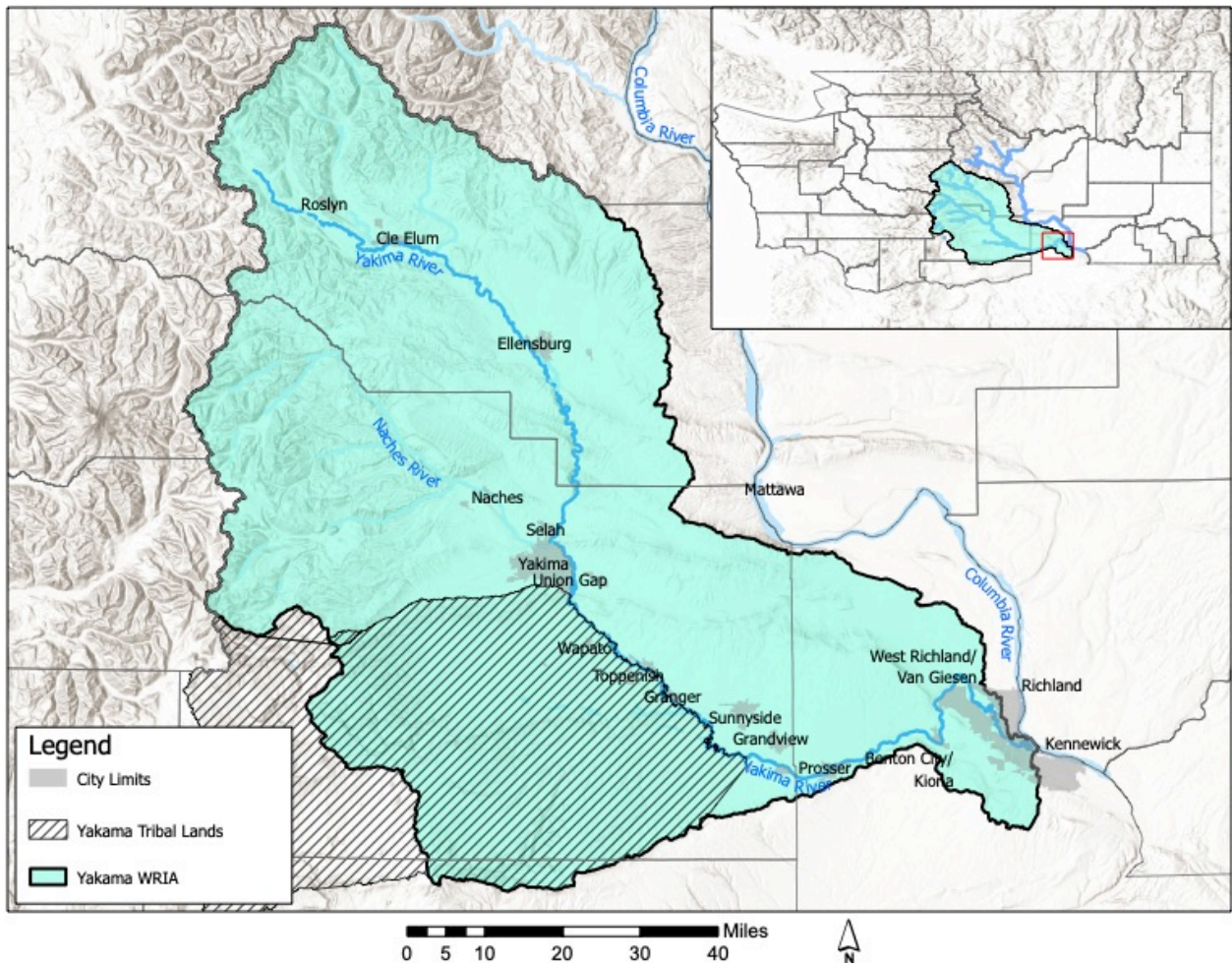


Figure 1. Map of Yakima Basin, Central Washington.

Water stargrass growth exploded in the lower Yakima in the late 1990s. By the early 2000s, water stargrass impacted multiple river functions. In response to its expansive growth, a study funded by the Department of Ecology and conducted by South Yakima Conservation District and US Geological Survey (USGS), investigated primary productivity and water quality in the lower Yakima from Union Gap to the confluence at Richland, WA. This work determined that improved water clarity from decreased sediment loading to lower Yakima likely provided ideal conditions for the plant growth. Water stargrass has a very high light requirement (Blackburn et al. 1961, Zhu et al. 2008), so the reduced turbidity in combination with low river flows and historic sediment nutrient load likely provided ideal conditions for its growth (Pelly et. al 2021). Initially, it was thought that the water stargrass was a primary successional species that would give way to a more diverse native plant community over time. While on a geological time scale this may turn out to be the case, twenty years later water stargrass outcompetes all other aquatic plant species to the detriment of the entire ecosystem health. The resulting negative impacts of the opportunistic growth on the lower Yakima can no longer be ignored. It is imperative that river managers take action to manage the abundant levels of biomass.

1.1 Impacts of Water Stargrass

Water stargrass causes a multitude of problems for the lower Yakima. The abundance of water stargrass physically displaces the river and influences sedimentation and river temperatures. Washington State Department of Fish and Wildlife (WDFW) documented a change in fall Chinook spawning in the lower river over the past twenty years. As a result of decreased spawning gravel quality, fall Chinook spawning has disappeared from the lower Yakima in Benton County (WDFW personal communication, 2020). The decreased access to lower river spawning beds forces stressed adult fish to migrate further upstream (Table 1). In the spring, juvenile smolts experience longer travel distances during out-migration to the Columbia River. The river warms rapidly in the spring, and juvenile fish may find they are exposed to or trapped within warm waters as a result of the lengthened travel times. Comparison of fall Chinook populations in the Yakima River and the neighboring Columbia River Hanford Reach over the last 20 years indicates that the Yakima River run remained stagnant, while the Hanford Reach run multiplied five times (Hoffarth, 2021). WDFW acknowledges water stargrass as a possible contributing factor to this difference. Dense water stargrass stands also degrade rearing side-channel habitat and clog irrigation ladders on the lower river dams further impacting river fish productivity (Prosser Dam and Horn Rapids Dam).

Table 1. Fall Chinook Redd Counts in the lower Yakima River 2000 – 2018, data compiled by BCD from WDFW annual reports. Yellow boxes highlight the highest redd count within each year. Red boxes highlight drought years, and blue box highlights flood year.

Redd Count by Reach Upper to Lower	Year																		
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Prosser to Chandler	199	95	587	392	377	56	33	29	40	67	53	58	0	37	37	18	12	26	4
Chandler to Benton City	150	101	188	286	48	2	10	3	1	1	0	14	0	1	0	0	0	2	5
Benton City to Horn Rapids	311	21	106	4	0	0	0	1	0	0	3	18	2	34	7	3	0	5	0
Horn Rapids to Confluence	29	71	150	112	24	2	2	8	1	2	1	62	13	43	31	0	4	10	---
Total	689	288	1031	794	449	60	45	41	42	70	57	152	15	115	75	21	16	43	9
		↑ drought				↑ drought						↑ flood				↑ drought			

In addition to impacting native anadromous fish populations, water stargrass impairs local water quality. Wise et al. (2009) reported that water stargrass greatly influenced river pH and dissolved oxygen levels during the irrigation season causing degraded water quality conditions. During base flow conditions, nighttime dissolved oxygen levels fall below the Washington State water quality standard of 8 mg/L for salmon-bearing waterways (Wise et al. 2009, Pelly et al. 2020). McMichael (2017) noted that high summer river temperatures, lower dissolved oxygen levels, increased pH levels, and dense water stargrass strands might provide favorable conditions for the recruitment and refuge of non-native piscine predator species to the detriment of native salmon species.

Water stargrass also impacts water quantity and supply. Dense vegetation behind dams impounds water, decreasing the necessary river flows required to fill irrigation canals (Figure 2, Figure 3). In 2015, a summer drought resulted in a combination of low water levels and high water stargrass densities in the Yakima River. Within the Horn Rapids Dam reservoir, water stargrass impounded flows near the Columbia Irrigation District head-gates that fill their canals. In an attempt to alleviate the issue, Columbia Irrigation District contracted a company to mechanically harvest the plant matter (Tri-City Herald; July 13, 2015 <https://www.tri-cityherald.com/article32232717.html>). The removal of water stargrass behind the dam resulted in an almost instantaneous filling of the Columbia Irrigation canals as flows were re-opened. The harvesting removal effort demonstrated the impact of water stargrass on water supply, especially in low-flow drought years when water availability is critical. Annually, water stargrass clogs irrigation fish screens as late summer/early fall biomass senesces and catches at dams and waterways. Clearing water stargrass from irrigation screens adds significant labor and costs to irrigation operations.



Figure 2. Photo left: Water stargrass removal at the Columbia Irrigation District Intake Screen.

Photo Right: Harvested path (2015) at the Columbia Irrigation District Intake.



Figure 3. Water stargrass in the forebay of the Prosser Dam, River Mile 47 on the Yakima River (Photo used with permission from Patrick Monk, US Bureau of Reclamation).

Small private irrigators on the lower Yakima River also contend with added maintenance, costs, labor and water supply challenges from nuisance quantities of water stargrass. Irrigation intakes located within water stargrass beds struggle to pull adequate water as nearby river velocities are slowed by the dense vegetation (Figure 4). Subsequent sedimentation near the intake also results in water stargrass growing within the sedimented fish screen further impeding water delivery. Altered redox conditions from plant photosynthesis in the lower river are highly corrosive for screening components. Irrigators spend enormous amounts of energy combating water stargrass every growing season.



Figure 4. Private irrigation intake located within dense water stargrass bed, Benton City, WA.

More recently, Benton County Mosquito Control District determined water stargrass may be impacting local public health. Flowing river water is slowed by dense water stargrass growth resulting in marshy, ponded areas that are excellent breeding grounds for nuisance and disease carrying mosquitos. These marsh areas are difficult to treat with traditional pesticide methods due to the standing stocks of biomass. Disease carrying mosquitos are increasingly common on the lower Yakima River, especially in areas of dense water stargrass growth, such as the Yakima Delta, West Richland, and Benton City (A. Beehler, Benton County Mosquito Control, personal communication). Public health may also be impacted by an increased likelihood for water-borne pathogens and harmful algal blooms (HABs) due to slowed river flows and warming the waters. HABs have become increasingly common within the Yakima Delta. “R. Dawson (Benton Franklin Health District) noted that in 35 years of public health, the first time he encountered a bloom was 5 years ago, now it is a regular occurrence” (Tri-City Herald, September 24, 2021; <https://www.tri-cityherald.com/article254474533.html>).

Likewise, river enthusiasts are finding the recreational quality of the river degraded. Water stargrass impedes anglers, boaters, and swimmers (Figure 5). Fishing lines are caught in the dense grass, kayakers and canoes are unable to paddle through the vegetation, and long strands of water stargrass clogs motor boat propellers. The lower Yakima River is a popular summertime destination for outdoor recreation enthusiasts in the Tri-Cities, however, continued nuisance plant growth has impaired the recreation value.



Figure 5. Dense water stargrass growth at Yakima River Recreation Access, Benton County.

1.2 Lower Yakima River Water Stargrass Research

In response to problematic water stargrass growth, the USGS and South Yakima Conservation District monitored the river and plant growth in the early 2000s. Their findings are presented in the *Assessment of Eutrophication in the Lower Yakima River Basin, Washington*; subsequently referred to herein as the ‘Eutrophication Study’ (Wise

et al. 2009). The study provided a first step in understanding large-scale relationships between water quality (temperature, pH, dissolved oxygen, conductivity, and turbidity), nutrients, and abundant aquatic plant growth. The Eutrophication Study surmised that light availability as influenced by turbidity, phytoplankton abundance, and water depth, was more likely to limit macrophyte growth than nutrient availability. Wise et al. (2009) mention that the development of management actions to mitigate water stargrass would require further detailed research into the complex relationships between aquatic plant growth, nutrients, dissolved oxygen, and pH, by utilizing continuous monitoring on a more refined reach-scale. The authors also noted that, "*Data from [additional] monitoring could help in model development and in assessing the effectiveness of future water quality management actions*" (pg. 58, Wise et al. 2009).

In 2018, Benton Conservation District (BCD) and USGS, initiated a three-year comprehensive study of the relationships between water stargrass biomass and water quality on the lowest part of the Yakima River in Benton County. We developed this project with multiple local, county, state, tribal, and federal agencies in response to the severe aquatic vegetation growth that has impaired function in the lower Yakima, especially in drought years. The Yakima River Basin is considered one of the most vulnerable watersheds in Washington State for climate change impacts, with summers predicted to become warmer and dryer (Pickett 2016). As water demands in the basin increase, it is imperative that the question of how to improve lower Yakima water quality, quantity and ecosystem function are addressed. The three year study was designed by BCD and USGS to support the development of management recommendations based on the most up to date science regarding the causes and effects of water stargrass growth, hydrology and water quality. To effectively manage the impacts of water stargrass on the lower Yakima it's imperative that the "push and pull" relationships between the river's primary producers and water quality are understood.

To aid in our understanding of these dynamic relationships, water quality sensors were installed on the lower Yakima at three locations with varied hydrologic conditions and established plant biomass populations. Continuous water quality monitoring sensors were installed at Prosser (RM 46.8) below the dam, Benton City (RM 30) and West Richland (RM 7.5). Each USGS station recorded temperature, dissolved oxygen, pH, turbidity, conductivity, photosynthetically active radiation (PAR) and river level. Continuous nitrates were collected at the lowest two stations providing the first comprehensive in-stream nitrate record for the lower Yakima River. During the growing season (June – September), biomass densities and percent cover were determined at each of the cross-sectional channels near the water quality monitoring stations. USGS analyzed the relationships between the water quality parameters and the plant growth.

The three-year USGS water stargrass dynamics study highlighted the complex interconnectivity between river hydrology, water quality and water stargrass growth on the lower Yakima River. Site-specific channel characteristics greatly influenced biomass growth properties with the greatest areal biomass (in grams dry weight per meter squared) measured at the location with the deepest, slowest waters (Prosser). Conversely, the location with the swiftest flowing waters displayed the lowest areal

biomass and percent cover (West Richland). Variability in hydrology between water-years impacted biomass growth densities with the greatest amounts of plant biomass measured at all sites in the 2019 water-year. Baseflow conditions in 2019 had the lowest sustained baseflows of the years monitored. In addition, 2018 showed the highest spring flows and the lowest end of growing season biomass. (Figure 6 and Figure 7).

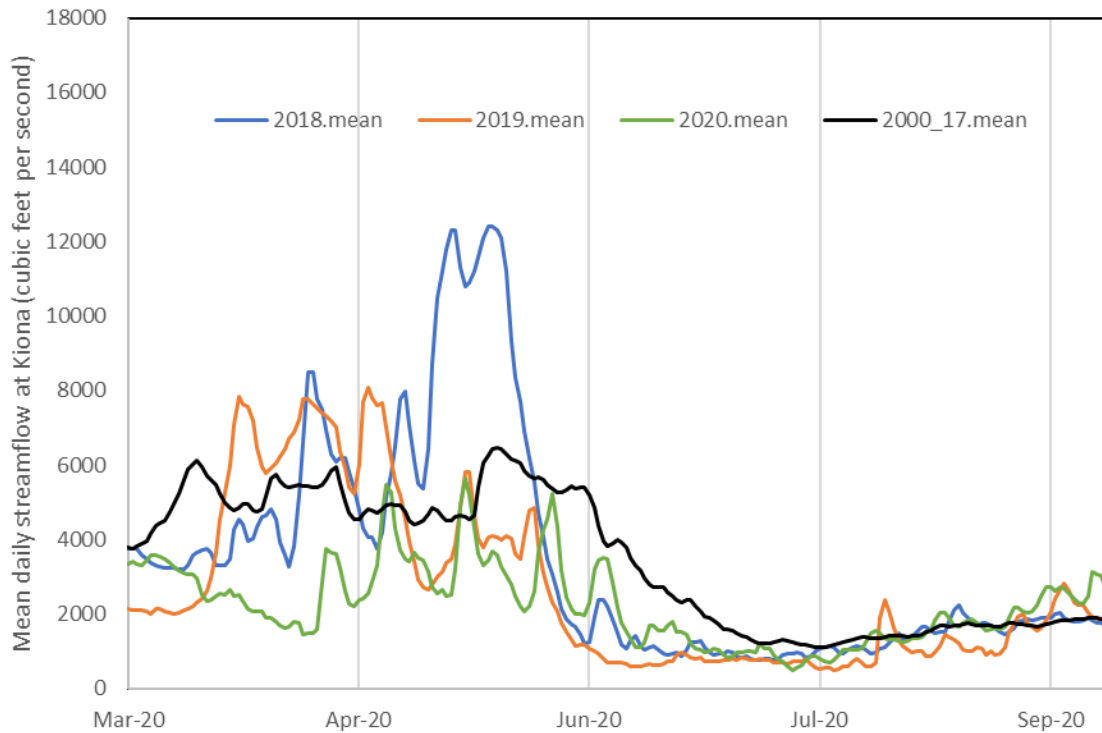


Figure 6. Comparison of lower Yakima River flow during growing season of plant biomass (March – October) at Kiona for USGS study period of 2018 - 2020. The 2000 – 2017 mean daily streamflow is provided for comparison (used with permission from Sheibley et al 2022).

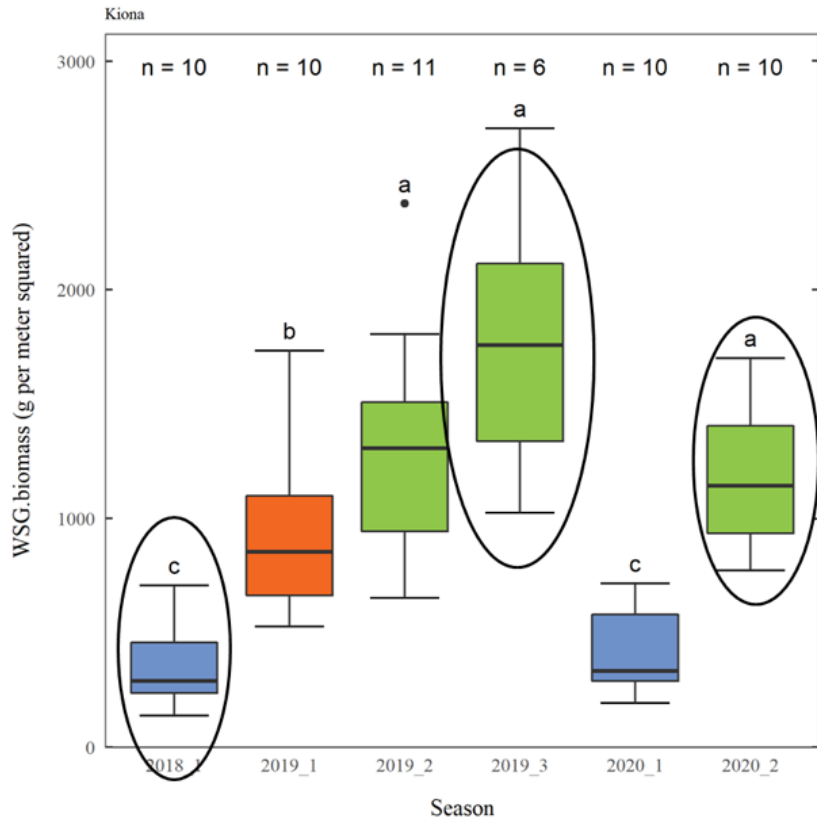


Figure 7. Example of Water Stargrass biomass at Kiona. End of growing season biomass for 2018, 2019, and 2020 are circled. 2019 had the highest end of season biomass (used with permission from Sheibley et. al 2022).

The complex relationships between water stargrass plant density and site hydrology impacted the daily magnitude in the highs and lows for dissolved oxygen and pH with similar trends for both parameters. Sites with shallower depths (Benton City and West Richland) experienced larger daily swings in dissolved oxygen due to plant photosynthesis and respiration (Figure 8). Daily dissolved oxygen swings, however, were most pronounced at Benton City. Shallower river levels at Benton City coupled with the moderate to high plant biomass resulted in the lowest minimum dissolved oxygen levels across all measured sites – with minimums falling well below the state dissolved oxygen threshold of 8 mg/L. Summertime dissolved oxygen conditions were largely favorable for the West Richland monitoring site that experienced both lower amounts of macrophyte growth and swifter waters.

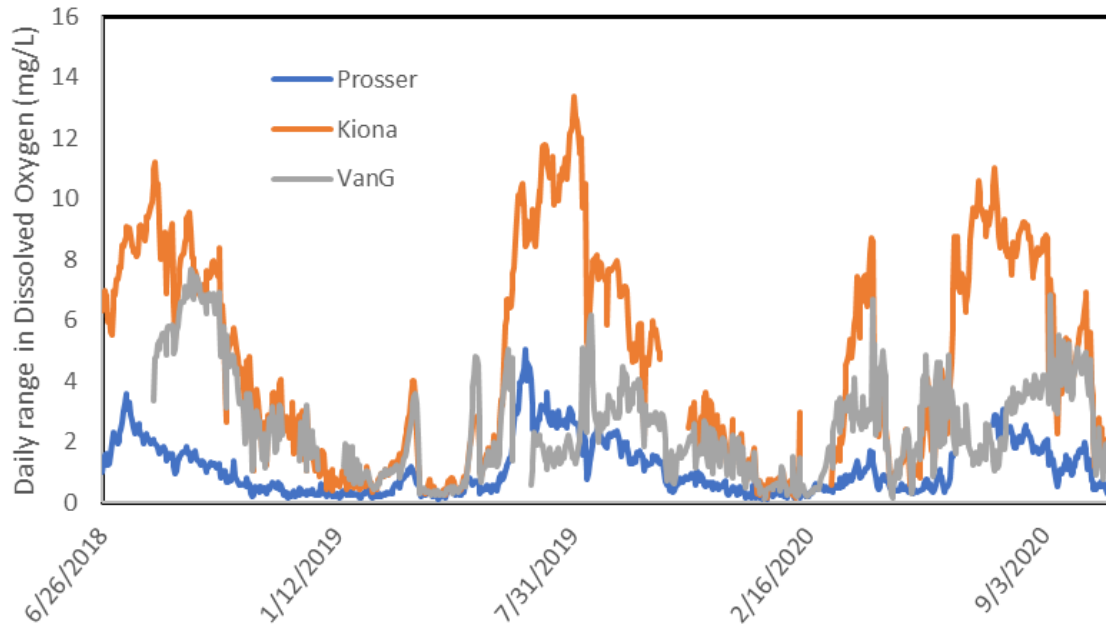


Figure 8. Daily Range in Dissolved Oxygen (mg/L) at Prosser, Kiona and Van Giesen (VanG).

Most surprisingly for the agriculturally driven basin, continuous mean daily nitrate levels remained below 2.0 mg-N/L during the period of record for this study and showed some interesting patterns throughout the growing season (Figure 9). Mean daily nitrate levels fall each spring as spring runoff increased streamflow within the lower Yakima. However, during the summer baseflow period, a steady increase in nitrates is observed indicating a constant source of nitrate to the river. There is evidence that this increase in nitrates over the summer baseflow period is from agricultural return flows as the nitrates start to level off after the irrigation season ends in October. This data shows that a source of nutrients is provided by the river to potentially fuel water stargrass growth throughout the summer months. However, it is uncertain if nitrates in the river bed are also contributing to plant growth and by how much. This is an area that needs further study. It also remains to be seen if the lower levels of nitrate measured at Kiona and Van Giesen are the result of a nutrient sink created by the abundant primary productivity of the lower Yakima River. If this is the case then targeted Best Management Practices (BMPs) for decreased nitrate loading to the lower Yakima may be warranted. The full results of the accompanying study for this recommendation report are detailed in Sheibley et al. 2022 and Appel and Sheibley 2022.

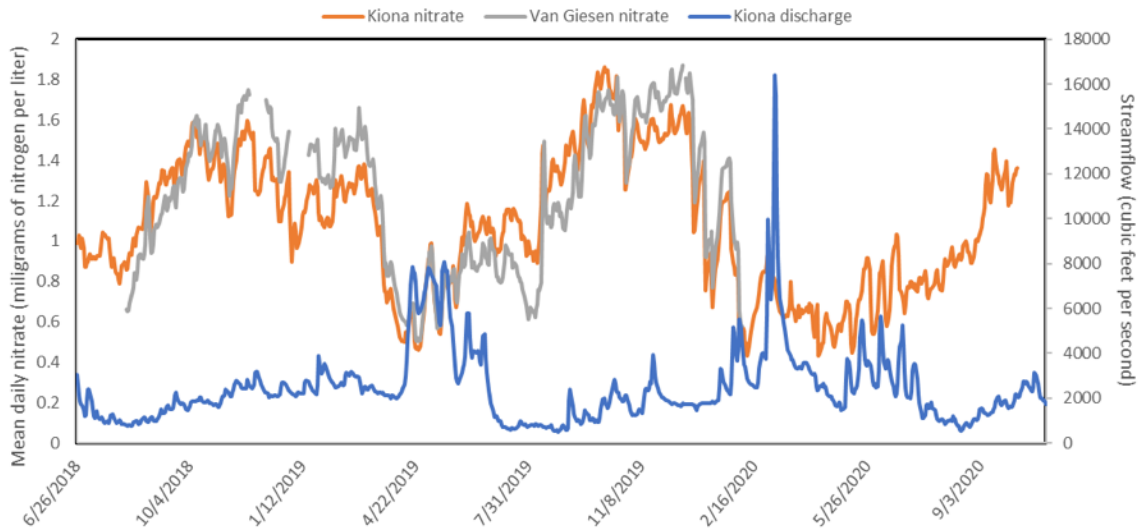


Figure 9. Continuous nitrate measurements at Kiona and Van Giesen in comparison to discharge at Kiona.

In 2020, Pacific Northwest National Laboratory investigated harvested water stargrass as a potential for biofuel feedstock. Using Hydrothermal Liquefaction (HTL) a biomass slurry can be converted to a biocrude and aqueous product which through further catalytic hydrotreatment and distillation can create fuel fractions (Billing and Schmidt, 2020). Water stargrass was screened through a standard characterization process to determine its use as an initial potential HTL feedstock. Results from the initial study indicate that the water stargrass is not an ideal candidate for direct HTL as the weight ash content of 37% is higher than the <15% ash target level. Similarly, the dry solids weight percent content of 7.43% is lower than the >15% weight by solids target level. Water stargrass may have potential viability for sequential HTL processes which converts the carbohydrates into fermentable sugars at a lower temperature first, with residual solids concentrated for HTL in a second stage (Billing and Schmidt, 2020). The costs and scale involved, however, may not render this process worthwhile and composting was determined to be preferable biomass removal option. While the initial results don't support likely viability as a biofuel feedstock, their work provided insights into the water stargrass composition with high levels of potassium and nutrients found in the plant material. Water stargrass may provide value for remediating some of the excess nutrients within the river. This information may influence the remediation strategy for water stargrass removal, such as leaving the standing stock versus full removal of the plant by the roots, as well as disposal applications (Billing and Schmidt, 2020).

2.0 Location

The lower Yakima River, located in south-central Washington State, flows through arid Yakima and Benton Counties (Figure 10). Agriculture is the dominate land use in

Yakima and Benton County, supported by irrigation from the Yakima River. The portion of the river from Union Gap to Prosser Canyon (Yakima County) is distinct from that of Benton County below Prosser Dam, located in Prosser, WA. The Yakima River in South Yakima County has an established broad alluvial floodplain with a dynamic river channel and extensive riparian forests. Conversely, the river reach in Benton County is dominated by Columbia River basalts that confine the river channel between Prosser and Benton City. There is minimal area for braiding and meander within the lower reach other than the floodplains found between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology. While water stargrass vegetation is present in Yakima County, the predominant area of concern for nuisance growth is located downstream of Prosser, WA within Benton County. As such, the river within Benton County is the target focus area for this recommendations report.

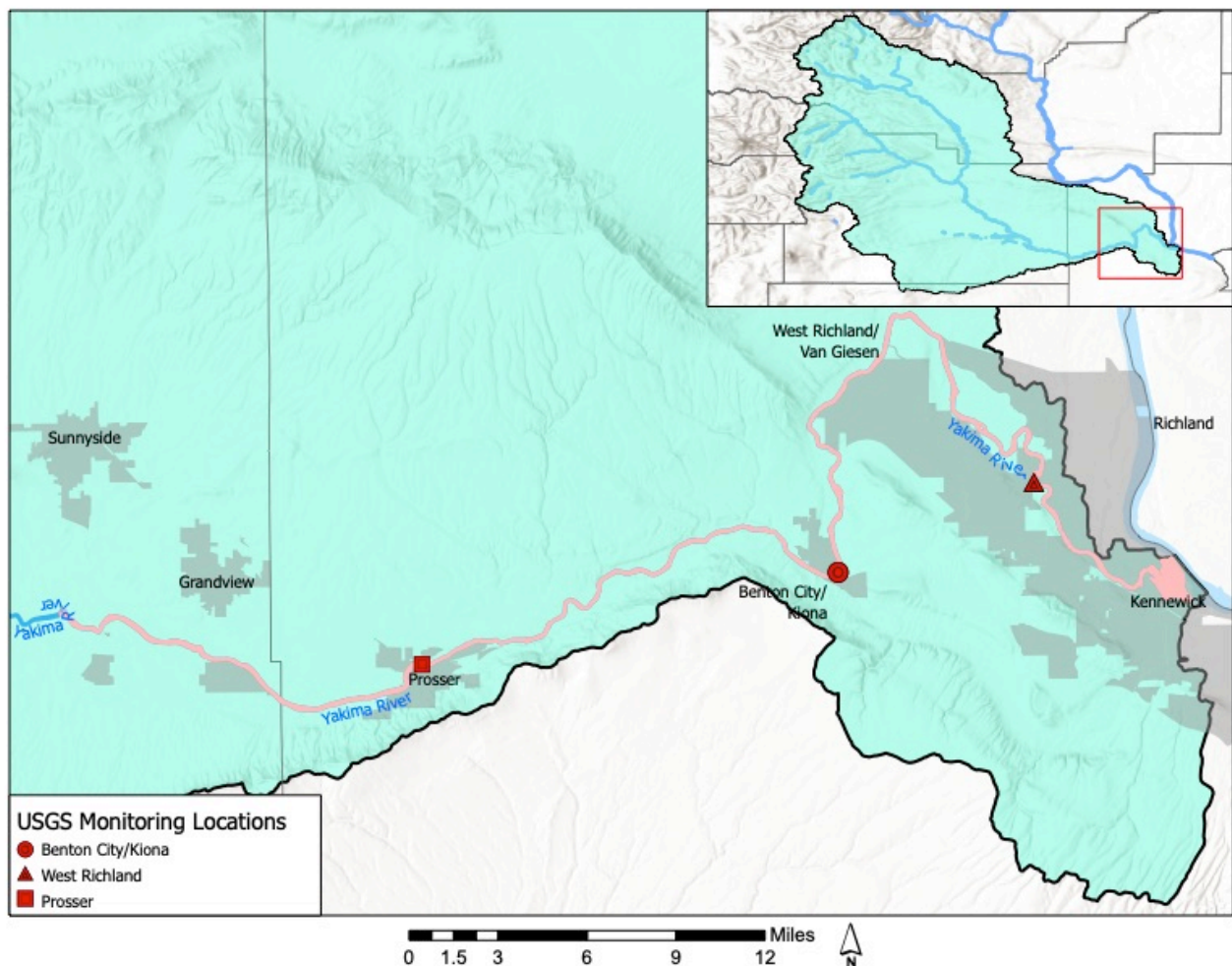


Figure 10. Lower Yakima River in Benton and South Yakima Counties with locations of USGS water quality monitoring monitoring stations.

The lower Yakima River in Benton County passes through the towns of Prosser and Benton City, forms the dividing line between Richland and West Richland, and then joins the Columbia River at its confluence in Richland. Previous USGS geology studies indicate the Yakima River to be a gaining reach from Prosser to below the Chandler Power House. Above Benton City, the river transitions from a gaining reach to a predominantly losing reach. The county's irrigation use for agriculture and growing urban/residential development heavily influence Yakima River water quality and seasonal flow. The Yakima River is a highly managed system with regulated yearly flow regimes. The spring freshet typically occurs between April and May, with low flows and high temperatures occurring June through August. River temperatures rapidly cool with the onset of fall sometime between late August and early September. The irrigation season, which draws water from the Yakima River, runs from mid-March to mid-October.

3.0 Problem Statement

A change in the abiotic and hydrologic conditions within the Yakima Basin have shifted the composition of the aquatic plant communities in the lower Yakima River. Water stargrass, although designated a native plant, dominates the river channel outcompeting other plants to the detriment of the entire ecosystem. Although native species tend to be excluded from the category of invasive species, they may be scientifically classified as invasive when barriers to their growth are suddenly removed, allowing them to dominate their habitat and harm other species (Schultz and Dibble 2012). In Washington State, water stargrass in the lower Yakima River currently falls under the category of native nuisance plants. Nuisance water stargrass impairs multiple beneficial uses of the lower Yakima. *This recommendations report is to aid water managers in the identification of priority actions for managing water stargrass in order to restore healthy aquatic plant communities and improve the beneficial uses of the lower Yakima River.*

4.0 Management Goals

The primary management goal is to mitigate and control water stargrass abundance in key locations within the lower Yakima River for the improvement of all identified beneficial uses of the river and public health. In the lower Yakima, these beneficial uses include recreation, water supply (i.e., domestic, industrial, agricultural, and stock water), wildlife habitat, commerce and navigation, boating, aesthetics, and aquatic life (Ecology 2011). Water stargrass also impacts human health by degrading water quality and increasing breeding grounds for disease carrying mosquitos and harmful algal blooms. The goal for water stargrass needs to be mitigation, not eradication. Water stargrass is a useful, healthy, and native part of the Yakima River. Longer-term goals should include the return of a healthy, diverse aquatic plant community within the lower River.

Recommendations within this report are designed to control water stargrass abundance levels in order to:

- Improve lower river hydrology (improved flows) to help meet water supply and use needs.
- Restore water quality conditions (decrease temperatures, improve levels of dissolved oxygen and pH) to meet state water quality criteria.
- Open up channels for fish passage by reducing water stargrass' contribution to physical and chemical (dissolved oxygen) barriers to fish migration.
- Clear native fall Chinook spawning grounds that were once predominant in the lower river to improve fish-rearing habitat.
- Decrease in-stream biomass abundance behind lower river dams for improved flows to support irrigation water supply, function of irrigation screens and operation of fish ladders.
- Decrease “marsh-like” water stargrass habitats that breed nuisance and disease carrying mosquitos.
- Support lower river private irrigators by decreasing accumulated biomass at irrigation intakes.
- Open up lower Yakima River recreation areas and improve river shoreline park and property aesthetics, that are impaired by dense stands of water stargrass.

5.0 Lower Yakima River Waterbody Characteristics

5.1 History of Lower Yakima River, Nutrients and Water Stargrass

Though native to the Central Washington region, water stargrass functions like a non-native invasive species on the lower Yakima River as it outcompetes other plants to colonize the majority of the river from bank to bank (Wise et al. 2009, Appel et al. 2011). Prior to dam construction on the Yakima River, peak spring flows (i.e., freshets) tended to be higher and faster than they are now with a longer duration into late spring/early summer. Due to these scouring flows, water stargrass and other macrophytes were most likely kept in lower abundance. After dam construction from the 1890s–1940s, much of the spring freshet was reserved for irrigation uses in reservoirs, while sediment and nutrient runoff from agricultural operations increased. Water stargrass abundance remained low in the river most likely due to the increased turbidity levels, even though agricultural practices also brought an ample nutrient source (Rinella et al. 1992, Wise et al. 2009, Pickett 2016). Historical sources of nutrients to the lower river included both overland irrigation return flows and irrigation wasteways returns on the lower Yakima. Irrigation fed subsurface groundwater also contributed to nutrient returns through subsurface pathways.

Land use in lower Yakima and Benton Counties is predominantly agriculture, urban agriculture and residential. Agriculture in the Yakima Valley is heavily reliant on the Yakima River for irrigation water supply. For decades, high temperatures and suspended solids, turbidity, DDT and other pesticides have been documented in the lower Yakima. As a result, several reaches of the lower Yakima and several of its tributaries did not meet numerous state water quality criteria and federal guidelines. Consequently, Ecology placed parts of the Yakima River on Washington State's 303(d) list.

In the late 1990s, a water quality improvement plan was put in place as a response to the State's 303(d) listings. A concerted effort by producers, irrigation districts and basin partners led to improvements in irrigation practices in the lower Yakima Valley. Sediment runoff dramatically decreased, leading to much greater light penetration in the river. Water stargrass has a very high light requirement (Blackburn et al. 1961, Zhu et al. 2008), so the reduced turbidity in combination with low flows and historical sediment nutrient load likely provided ideal conditions for its growth. The plant began rapidly spreading, and by 2005 water stargrass dominated the majority of the lower river from Prosser to the confluence with the Columbia River (Wise et al. 2009).

Historically, nutrients in the basin have been an issue and nitrates in the groundwater remain a challenge to this day. Primary sources of nitrate in the basin are livestock agriculture, agricultural fertilization activities, urban wastewater, septic systems, and residential/urban landscape fertilization including city parks and golf courses (EA 2017). Extensive dam and canal systems divert water for agriculture in the basin, exporting upper Yakima River nutrients and applying them to lower Yakima Valley agricultural lands. Historically, nutrients have returned back to the river through irrigation canals and wasteways, overland flows and groundwater inputs. Shifts in agricultural practices to more efficient water delivery methods, controlled water and fertilizer applications, and extensive work by irrigation districts and producers over the past thirty years has improved water usage, and decreased sediment and nutrient returns to lower river.

Nutrient pathways and dynamics for nutrients in the Yakima River basin are complex. Recent work by Greiger and Harrison (2021) investigated nutrient budgets in the Yakima Basin Watershed between 1945 – 2012 using past agricultural and water quality data to look at interactions between water flow and nitrogen and phosphorus exports. Their analysis found that nitrogen inputs to agricultural lands increased by over 18-fold during this time largely due to commercially applied fertilizers but nitrogen and phosphorus loads in the Yakima River decreased over the same time period (Greiger and Harrison 2021). Current nutrient monitoring by USGS on the lowest part of the Yakima River, indicates that in-stream nutrients remain low year round in the lowest stretch of the Yakima River. It is unknown if water stargrass is a nutrient sink or if there are other processes decreasing in-stream nitrate-levels. Historical inputs of nutrients within the sediment and hyporheic zone waters, coupled with continued nitrates through groundwater inflows may be a possible driver of the aquatic plant and warrants further research.

Other water quality issues of concern in the basin range from fecal coliform bacteria as well as chemical toxics, dissolved oxygen, pH and temperature. The water quality issues in the basin impact the beneficial uses of the water, potentially making it unsafe for drinking or recreation and threatening the health of aquatic animals and fish living in it. As water demands in the basin increase, it is imperative that the question of how to improve lower Yakima water quality, support migration, and mitigate water stargrass growth are addressed.

6.0 Beneficial Uses

Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC (Washington Administrative Code; Ecology 2011) established beneficial uses of waters and incorporated specific numeric and narrative criteria for parameters such as water temperature, dissolved oxygen, pH, and turbidity. The criteria define the level of protection necessary to support the beneficial uses. WAC 173-201A-600 and WAC 173-201A 602 list the use designations for specific areas. The state has not yet established regulatory criteria for river nutrients.

For the lower Yakima, the designated uses of the waters include the following:

- Primary Contact Recreation
- Water Supply Uses (Domestic Water, Industrial Water, Agricultural Water, Stock Water)
- Wildlife Habitat
- Commerce/Navigation
- Boating
- Aesthetics
- Aquatic Life

Water stargrass creates a multitude of problems for people who rely upon the Yakima River for their livelihood and recreation. The plant can plug irrigation intake screens and dense stands can interfere with fishing and impede recreational benefits of the river. Finally, water stargrass may increase risks to human health, as when the plant reaches the top of the water column in slack-water areas, it provides breeding habitat for mosquitoes carrying West Nile virus.

7.0 Water Stargrass Distribution

The distribution of water stargrass on the lower 100 Yakima mainstem river miles was mapped by Mid-Columbia Fisheries in the summer of 2021 as part of the development of the Yakima River Water Stargrass Emergency Drought Relief Plan (Emergency Drought Plan; MCF 2022). The Emergency Drought Plan identifies high priority target removal areas during drought years to help alleviate stress created in drought years by abundant water stargrass on fish passage and habitat. The mapping effort highlighted that water stargrass is ubiquitous in Benton County from the Prosser Dam reservoir

(river mile 50) to the confluence on the Yakima River with the Columbia River (Figure 11). Water stargrass is present above river mile 50 in Yakima County through river mile 57, near Grandview (Figure 12). After Grandview, the composition of water stargrass changes – while still present, it is a component of the aquatic plant communities and does not dominate the river channel as seen below river mile 57.

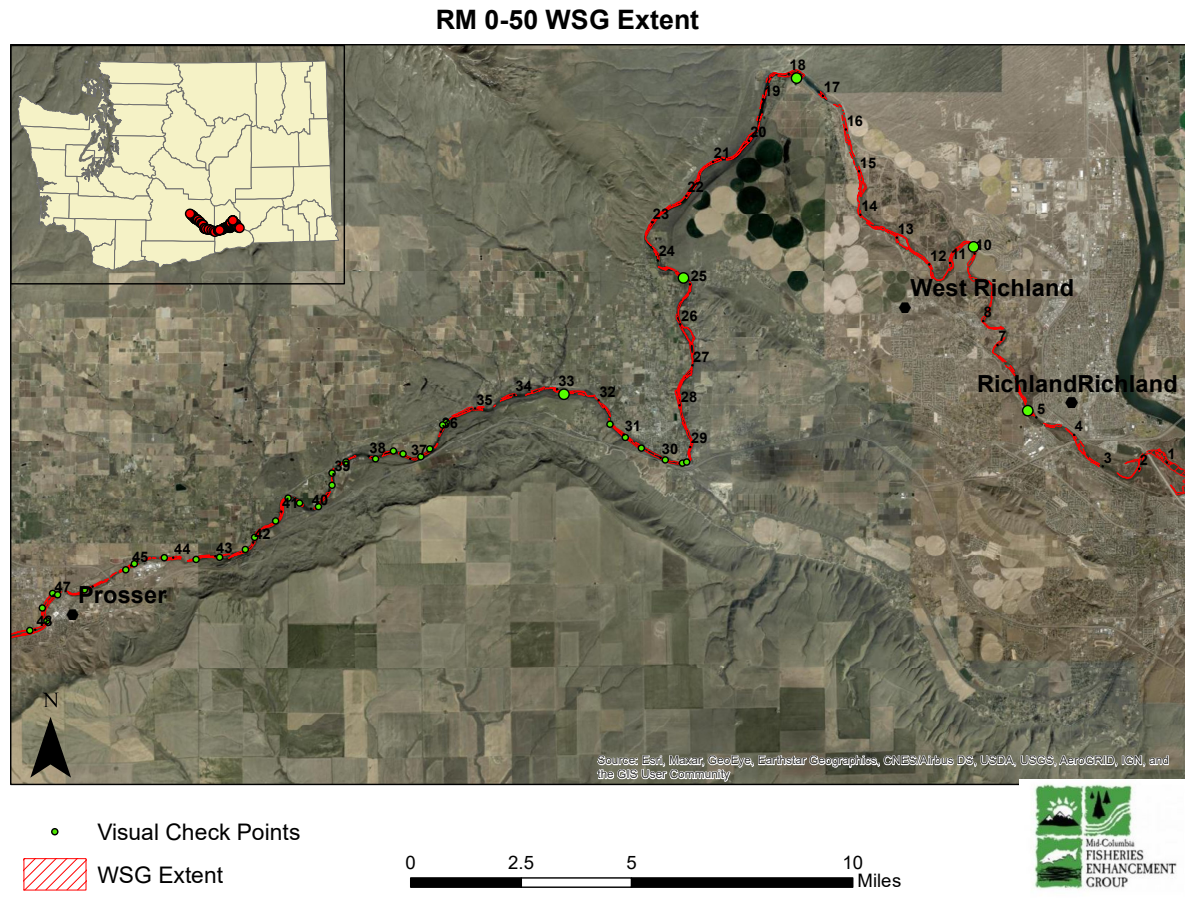


Figure 11. Water stargrass extent on the lower Yakima River from River Mile 0 – River Mile 50 (used with permission from MCF 2022).

RM 50-100 WSG Extent

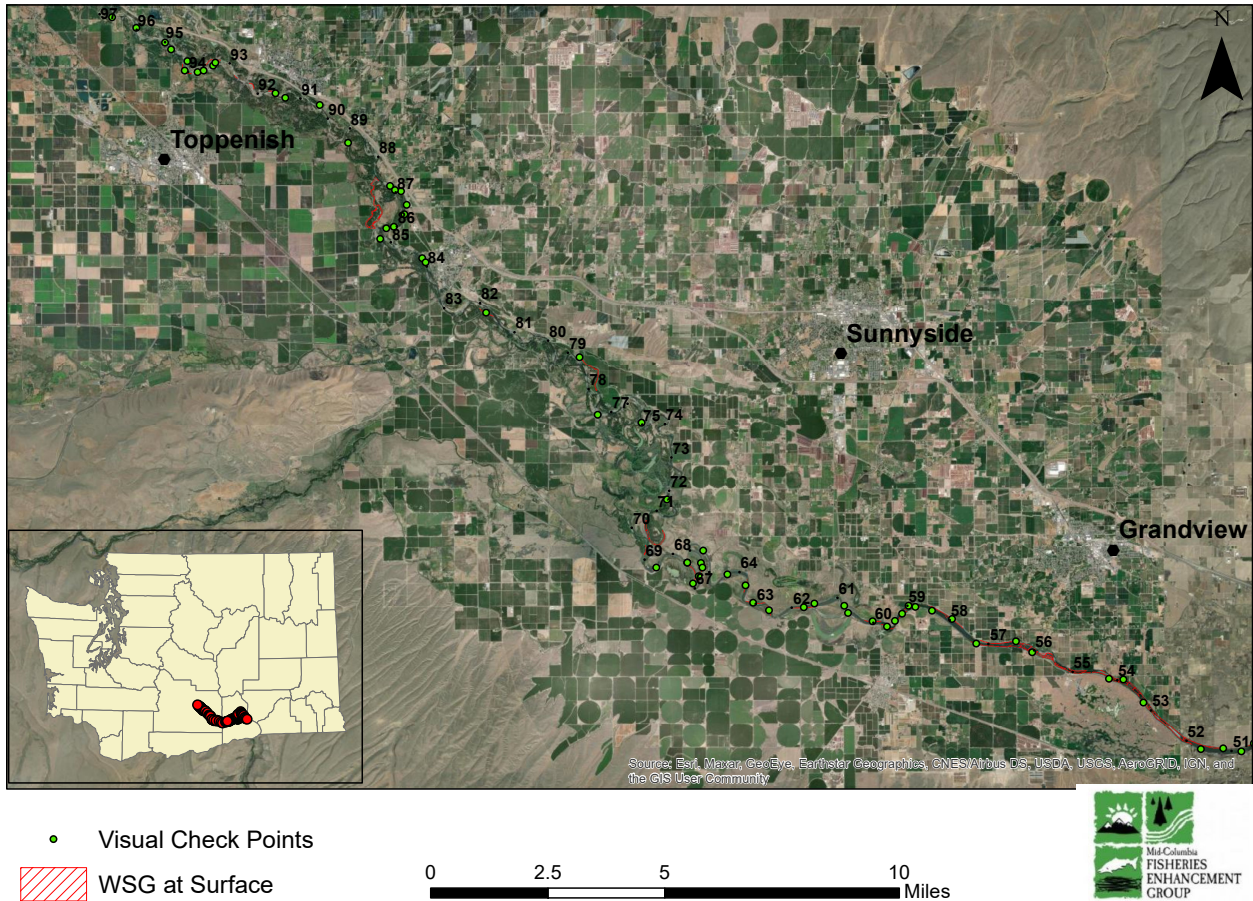


Figure 12. Water stargrass extent on the lower Yakima River from River Mile 50 – River Mile 100 (used with permission from MCF 2022).

Over the past twenty years, water stargrass continues to expand across the Yakima River channel in Benton County as well as extend its boundaries both up and downstream. The spread has been documented to an extent in the University of Washington Burke Herbarium: <https://biology.burke.washington.edu/herbarium/imagecollection/taxonmap.php?Taxon=Heteranthera%20dubia&SourcePage=taxon>. River managers have observed the expansion of water stargrass over the past decade in the lower river; areas that once were clear and free flowing are now clogged by dense plant matter as is the case for the Yakima River Delta. Moving forward it will be important to build on the mapping work initiated by Mid-Columbia Fisheries and continue to observe the geographical extent of water stargrass within the lower Yakima River.

8.0 Characterization of Other Aquatic Plant Species

There are multiple aquatic macrophyte species that are native to the Yakima River, but may not be currently present in the lower river. Submersed native species include: coontail (*Ceratophyllum demersum*), nuttall's waterweed (*Elodea nuttallii*), American

waterweed (*Elodea canadensis*), water moss (*Fontinalis antipyretica*), and Northern watermilfoil (*Myriophyllum sibiricum*) and whorl-leaf watermilfoil (*Myriophyllum verticillatum*). Aquatic plants with emergent leaves include: water smartweed (*Polygonum amphibium*), duckweed (*Lemna minor*), water horsetail (*Equisetum fluviatile*), three-way sedge (*Dulichium arundinaceum*), common cattail (*Typha latifolia*), Wapato/duck potato/arrowhead (*Sagittaria latifolia*, *S. cuneata*), bog bean (*Menyanthes trifoliata*), and Marsh cinquefoil (*Comarum palustre* formerly *Potentilla palustris*). (K. Kauer, Benton County Noxious Weed Board, personal communication, Parsons et. al 2006, Burke Herbarium: <https://biology.burke.washington.edu/herbarium/imagecollection.php>).

Non-native species have been observed in various locations within the Yakima River. These species include: flowering rush (*Butomus umbellatus*), curlyleaf pondweed (*Otamogeton crispus*), Brazilian elodea (*Egeria densa*), hairy willow herb (*Epilobium hirsutum*), parrotfeather (*Myriophyllum aquaticum*), yellow flag iris (*Iris pseudacorus*), Eurasian watermilfoil (*Myriophyllum spicatum*) and hybrid watermilfoil (*Myriophyllum spicatum* x *Myriophyllum sibiricum*) (K. Kauer, Benton County Noxious Weed Board, personal communication, Parsons et. al 2006, Burke Herbarium: <https://biology.burke.washington.edu/herbarium/imagecollection.php>).

The abundant water stargrass growth outcompetes many aquatic plant species, both native and invasive, on the lower Yakima River. Ideally, future work will restore healthy diversity in native plant aquatic communities, while mitigating the growth of nuisance invasive plants. Presently, small patches of invasive submersed macrophytes, including Eurasian watermilfoil (*Myriophyllum spicatum*) and curlyleaf pondweed (*Otamogeton crispus*), grow within water stargrass beds. The density of water stargrass appears to outcompete many noxious weeds, however, and limit their spread within the lower Yakima. River managers should be mindful of including invasive species control as part of the management actions so as to not trade water stargrass for a different nuisance invasive aquatic plant.

One invasive aquatic macrophyte, flowering rush, is extensive on the lower Yakima River. The Cooperative Weed Management Area Group (CWMA) tracks positive and negative identifications of flowering rush in the Columbia Basin (<https://wsda.maps.arcgis.com/apps/webappviewer/index.html?id=9d3b3f18dc3e4b33bb4ca9db923882e3>). An image of the positive (red) identifications for flowering rush within the lower Yakima River are provided in Figure 13. Flowering rush is ubiquitous on the lower Yakima with ongoing targeted management programs to mitigate its spread and growth. While it primarily is found on the riparian edge of the mainstem river, there are places where it grows across the channel intermixed with water stargrass (Figure 14). Management operations in these areas will need to take care to not further the spread of flowering rush.



Figure 13. Flowering Rush locations within the lower Yakima River (compiled positive identifications from 2015 – 2020). Source Columbia Basin CWMA database (2022).

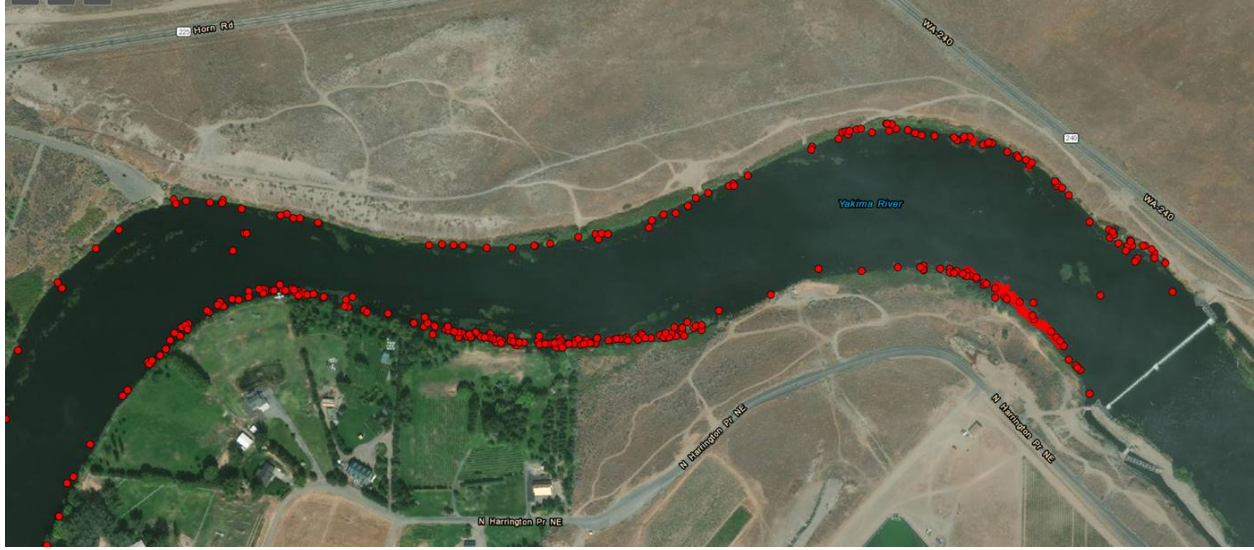


Figure 14. Flowering Rush locations on the lower Yakima River behind Horn Rapids Dam (2019). Source Columbia Basin CWMA database (2022).

9.0 Fish and Wildlife Communities

The lower Yakima River is a migration corridor for multiple salmon species and provides important habitat. Primarily, the lower Yakima hosts native anadromous runs of Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), sockeye salmon (*O. nerka*), coho salmon (*O. kisutch*), as well as Pacific lamprey (*Entosphenus tridentatus*). During peak migration season (March – November) juvenile salmon out-migrate through the lower Yakima to the Columbia River, and adult fish migrate from the Columbia up into the lower Yakima. Historically, the lower Yakima below Prosser Dam to the mouth hosted fall Chinook spawning habitat. Abundant water stargrass growth in the lower Yakima has resulted in a shift of fall Chinook spawning to above Prosser Dam. As a result, adult and juveniles must migrate further, decreasing their chances of survival. Other native resident fish species are also found in the lower Yakima River. These include whitefish, sculpins, sticklebacks, suckers, and western brook lamprey.

During the summer months, the Yakima River in Benton County is the warmest stretch of river with most of its lower 40 river miles inhospitable for adult salmon migration at baseflow (summer) conditions. Specifically, in-stream water temperatures often exceed 21°C during baseflow conditions which is limiting for adult migration of sockeye, Chinook, and Pacific lamprey. Rapidly warming spring/summer waters can also limit success of late season juvenile out-migration. These challenges are compounded by the fact that warmer water temperatures provide more favorable conditions for warm water invasive fish predator populations like smallmouth and largemouth bass, channel catfish, brown bullhead and walleye. Additional warm water species like pumpkinseed and carp are also present, but not problematic for native salmonid species. Carp are commonly seen sunning themselves near the surface in thick water stargrass beds.

The aquatic life requiring protection are federal- and state-listed and other sensitive and vulnerable species, designated as priority species by the Washington Department of Fish and Wildlife (WDFW 2008). At this time there are two fish species listed as Threatened under the federal Endangered Species Act: mid-Columbia bull trout and mid-Columbia steelhead. Conley et. al (2009) summarized studies in the upper and middle Yakima River that indicated temperature, toxic chemicals, and lack of foraging habitat and refuge from predators were creating obstacles for survival of these species.

River otters, beaver, mink, and deer are common on the lower Yakima River corridor along with song birds, raptors, wading birds, ducks, geese and many other avian species.

10.0 Community Involvement

Benton Conservation District recognizes that community involvement, education, outreach and support will be a critical part of water stargrass management moving forward. Outreach events through media in the tv, public radio, local event flyers/mailings, and newspaper provide information to the community about water

stargrass, removal work parties, and management actions. BCD has provided public presentations over the past few years to the following organizations:

- Tri-Cities Rivershore
- Enhancement Committee
- Benton County Parks Board
- Columbia Basin Native Plant Society
- Tapteal Greenway
- Richland Rod & Gun Club
- Lower Columbia Basin Audubon Society
- Kiwanis Clubs
- Rotary Clubs

Members from these organizations provided input on their experiences with water stargrass, priorities for management and/or removal, and have also given their time and volunteer service for water stargrass removal work days. Additional local volunteer resources include local landowners, WSU Tri-cities Environmental Club, and Boy Scouts of America.

11.0 Technical Work Group and Planning

Benton Conservation district in collaboration with our basin partners, Mid-Columbia Fisheries and Yakama Basin Fish and Wildlife Recovery Board, convened a water stargrass technical workgroup to help inform this recommendations report. This work group was designed to provide input on water stargrass control alternatives and management techniques, integrate the current science with the management recommendations, and identify uncertainties and knowledge gaps that need to be addressed moving forward. This group was comprised of county, state and federal agency partners, ecology and aquatic plant scientists, irrigators, and specialists who have expertise in aquatic plant ecology, permitting and/or treatment. The technical advisory group met twice in the spring of 2021 and helped guide the priorities and recommendations developed in this report. The individual responses from the work group members on their recommendations for water stargrass priorities, top preferred management techniques and identified uncertainties are provided in Appendix A. These responses were taken into consideration when finalizing this recommendation report.

12.0 Control Alternatives and Management Techniques

The Yakima Basin Fish and Wildlife Recovery Board commissioned a review by Benton Conservation District of the common plant removal techniques; referred to herein as the WSG Management Techniques Report (Pelly et al. 2021). The resulting report addressed a critical data gap and provided a comprehensive literature search and review of potential control methods specific to the conditions and beneficial uses of the lower Yakima River. The investigated techniques included: manual and mechanical

removal, chemical treatments, and environmental and biological manipulation controls. In addition, novel larger scale watershed control methods were investigated, such as altering flow regimes and creating velocity and bed scour for flushing of plant biomass. All investigated management methods were reviewed in the context of water stargrass biological properties as well as the feasibility and applicability of each method within the lower Yakima River. The technical work group meetings provided review and refinement of the researched technical methods by plant specialists, freshwater ecologists, fish biologists, and basin stakeholders. Table 2, adapted from the Management Techniques Report (Pelly et al. 2021), summarizes the management and control alternatives with the greatest potential for success in the lower Yakima River. A larger table summarizing all of the investigated management and control alternatives for water stargrass is provided in Pelly et al. 2021. As the Water stargrass Management Techniques Report provides an in-depth review of the pros and cons of technique we will not go into them further within this document. However, the primary findings of the report are detailed in Section 12.1.

12.1 Recommended Control Alternatives

The top-tier recommended methods for water stargrass on the lower Yakima River include: mechanical methods (harvesters, dredging, mailbox blowers, UV-C light), environmental/physical manipulation methods (bottom barriers and bubble curtains), manual methods (hand pulling in combination with hand-digging), and chemical treatments (Table 2). Investigated chemical methods highlighted only a few options that show promise for treatments in the lower Yakima River. Of these, only endothall and imazamox provided the greatest promise for chemical control, though each has potential drawbacks for application in the lower Yakima River. The regulations for applications of chemical treatments are designed around applications for invasive species. The regulatory requirements for use on a native species may be more stringent. Also, chemical treatments are typically studied for the application of native species. As such, their effectiveness on water stargrass is more uncertain, and pilot studies may need to be conducted for treatment rates and efficacy. Chemical treatments within a flowing river can be challenging, and may work best when performed in conjunction with other treatments such as water level draw down or use of a bubble curtain to alter the local river conditions. Prior to implementing chemical control methods, small-scale test pilots or laboratory treatments should be explored.

Novel watershed control methods were also investigated such as flow management, velocity enhancers, and sedimentation and are recommended at the pilot scale level (Table 2). These methods may provide novel techniques to combat water stargrass abundance with benefits gained for plant biomass control on a larger reach scale. However, they are less tried-and-true for plant control, may be costly, and will require extensive coordination in the basin. While not traditional, these novel watershed control methods may have added side benefits for native fish and habitat that are inherently coupled with the treatment method. For instance, timed turbidity releases in the late spring and/or increased sustained flows may aid in fishery goals for juvenile out-migrants. Also, late spring water releases that slowly decrease in volume have added benefit in support of cottonwood recruitment throughout the lower basin. Development

of possible watershed control techniques to enhance velocity such as artificial islands may create added habitat. All watershed control techniques will require more research regarding their potential applications and feasibility, as well as coordinated discussions with basin-wide partners.

The WSG Management Techniques Report highlighted that targeted control of water stargrass will require the integration of multiple management techniques, likely at different times throughout the plant's life cycle, in order to effectively combat the problem. The selection of appropriate treatment methods will depend on the goals of the removal (fish protection, irrigation, recreation, and/or human health), the spatial extent of area needing to be cleared, location within the river and associated river hydrogeology, and the available cost structure for implementation. Each identified alternative has benefits and constraints, and the selection of removal techniques will require recognition of the trade-offs when selecting a treatment application. For instance, mechanical harvesting and hand-pulling are both demonstrated effective treatment options for aquatic plant removal but will have different suitability in their applications. Mechanical harvesting will likely be effective for clearing large areas of the river quickly, such as in the Yakima Delta or behind dams. Mechanical harvesting, however, can be costly and requires ongoing operation and maintenance with specialized knowledge of machine operation and safety training. This method is also not suited for clearing plants from shallow waters or narrow confined areas, such as those found in side-channels. For these areas, hand-pulling may be better suited. This method is less costly than harvesting if volunteer labor is utilized. While potentially cheaper, hand-pulling is time and labor intensive. Timing of treatment application will also be a critical consideration, as some techniques may have a greater impact when applied earlier in the plant's life cycle. However, this timing may be in conflict with lower river's in-season work window which is protective of the native anadromous species who migrate through the lower river corridor.

Table 2. Management and control methods for lower Yakima River. Table adapted from Pelly et al. 2021.

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
<p>No action</p> <p>Scale: Reach Duration: N/A</p>	N/A	Not effective	<ul style="list-style-type: none"> • WSG may be outcompeting invasive plants slowing their spread, mitigation may create other remediation issues • No direct cost • May aid in nutrient cycling and sequestration for the lower river 	<ul style="list-style-type: none"> • Dissolved oxygen and pH impacts • Spawning gravel covered • Irrigation and recreational use harmed • Continuing public health threat • Reduce river flow velocity; river warming 	None	Disadvantages of doing nothing outweigh the advantages
Manual Methods						
<p>Hand-pulling and/or Hand-digging</p> <p>Scale: Small, local</p> <p>Duration: Longer term if roots removed (multiple seasons)</p>	Jun 1–Sep 15	Very effective if roots are removed	<ul style="list-style-type: none"> • Can be implemented quickly, no lengthy permitting process • Minimal environmental impacts • Useful in shallow or hard to reach areas • Expected to cause minimal environmental impacts 	<ul style="list-style-type: none"> • Very labor-intensive • Requires low-flow and safe wading conditions 	2015 pamphlet (WDFW)	Most effective when hand-pulling and digging are used in combination to enable removal of roots
Mechanical Methods						
<p>Harvesting</p> <p>Scale: Large areas</p> <p>Duration: Long-term</p>	Jun 1–Sep 15	Possibly effective long-term (pulling type); likely short-term effective (cutting type)	<ul style="list-style-type: none"> • Can remove plants across a large area • Removed plants are automatically captured and prevented from floating downstream 	<ul style="list-style-type: none"> • May be inoperable during periods of low or high flows • Limited work areas • Expensive equipment & maintenance 	Hydraulic Project Approval (WDFW)	Benton CD purchased a pulling-type harvester for pilot study summer 2021 to determine effectiveness

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
<u>UV-C Light</u> Scale & Duration: Unknown	Unknown	Unknown	<ul style="list-style-type: none"> • Not bed disturbing, no impact on in-stream turbidity • Easy to install on small or large boats for control in different aquatic systems • Relatively cost effective method, if boat is already available 	<ul style="list-style-type: none"> • May result in high biomass decay impacting dissolved oxygen • Requires multiple treatments • May have impacts to other aquatic organisms 	Hydraulic Project Approval (WDFW)	Pilot study for effectiveness on WSG would need to be investigated
<u>Diver-assisted suction harvesting</u> Scale: Small, local Duration: Long-term	Jun 1–Sep 15	Likely very effective	<ul style="list-style-type: none"> • May be useful in areas not accessible to other mechanical methods • Does not require low-flow conditions • Plant fragmentation minimized 	<ul style="list-style-type: none"> • Very labor-intensive and slow; most appropriate for localized areas • Significant turbidity created • Expensive 	Hydraulic Project Approval (WDFW); shoreline permits;	Diver-assisted suction harvesting may be a good choice
<u>Mailbox blower</u> Scale & Duration: Unknown	Unknown (likely Jun 1 – Sept 15)	Unknown	<ul style="list-style-type: none"> • May be useful to clear spawning gravels • Relatively simple & inexpensive to install on any boat and pilot test method 	<ul style="list-style-type: none"> • Impact on removal of aquatic vegetation is unknown • Minimal information available for its treatment on aquatic macrophyte removal 	Hydraulic Project Approval (WDFW)	
Environmental Manipulation Methods						
<u>Bottom barriers</u> Scale: Small, local Duration: Long-term	Jun 1–Sep 15	Possibly effective	<ul style="list-style-type: none"> • Can be implemented quickly, without a lengthy permitting process • Does not require disposal of plant biomass • Relatively low cost 	<ul style="list-style-type: none"> • Will most likely require WSG to be cut before installation • Largest environmental impact is to salmonid spawning habitat 	2015 pamphlet (WDFW)	May be a possible choice for WSG control when combined with hand-cutting

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
<u>Water level drawdown</u> Scale: Reach Duration: Unknown	Irrigation Season	Possibly effective	<ul style="list-style-type: none"> • May allow for application of chemical treatment of emerged plants • Could be coordinated with irrigation supply needs 	<ul style="list-style-type: none"> • May pose risks to salmonids and could only be utilized when salmon are unlikely to be in river (>74F). • Needs to be coupled with chemical treatment 	Hydraulic Project Approval (WDFW)	May be a possible option if coupled with chemical treatments effective only on emergent plants
<u>Bubble Curtain</u> Scale: Small, local Duration: Short-term	Jun 1 – Sept 15 (Depends on chemical treatment window)	Unknown	<ul style="list-style-type: none"> • May allow for application of chemical treatment of emerged plants • May provide treatment for areas (side-channels) that are not accessible by large equipment 	<ul style="list-style-type: none"> • Requires dye tracer study prior to implementation – may be challenging to fund • Implementation depends on flow, mixing, and location hydrology for success 	Aquatic plant and algae management (Ecology); Hydraulic Project Approval (WDFW)	Requires chemical treatment application
Chemical methods - Warranting further consideration						
<u>Endothall (Aquathol® K, Aquathol® Super K, Cascade®)</u> Scale: Reach Duration: Seasonal	Jul 15–Sep 1	Possibly effective	<ul style="list-style-type: none"> • Very little environmental risk during timing window • Very few irrigation restrictions when applied at labeled rates • Rapid-acting herbicide; symptoms appear within a day • Does not require removal of plant biomass from water • Water stargrass listed as susceptible on label with recommendations for application rates in flowing water 	<ul style="list-style-type: none"> • Contact herbicide; • Some toxicity to fish; application restricted to July 15–September 1 • Restrictions for potable water intake • 24-hour swimming advisory required, boating advisory recommended • Ineffective for water stargrass in flowing water in two studies 	Aquatic plant and algae management permit (Ecology)	A possible choice for water stargrass control; a trial study may be required to determine level of control

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
Imazamox (Clearcast®) Scale: Reach Duration: Long-term	Late winter before Mar 15	Possibly effective	<ul style="list-style-type: none"> • Very little environmental risk • Systemic herbicide • Rapid-acting herbicide; inhibits plant growth within one day; symptoms appear in about a week • Does not require removal of plant biomass from water • Water stargrass listed as susceptible on label 	<ul style="list-style-type: none"> • Potential sublethal effects to juvenile salmonids • Serious irrigation restrictions- application during irrigation infeasible • Application limited to brief (after plant growth starts, before irrigation begins) • Decomposing biomass may deplete oxygen from water column; requires mitigation method(s) • 	Aquatic plant and algae management permit (Ecology)	A possible choice for water stargrass control; a trial study may be required to determine level of control
Non-traditional Watershed Controls						
Flushing or Pulse flows Scale: Reach Duration: Unknown	Spring to early Summer	Unknown	<ul style="list-style-type: none"> • Sustained flows longer into the spring may suppress summer growth • Frequent pulse flows early in growing season may disrupt plant growth • Flushing and pulse flow events already designed to help migrant fish may also help control WSG 	<ul style="list-style-type: none"> • Restrictions on water use and constraints on operational water supply • Requires extensive coordination among multiple agencies and stakeholders 	Uncertain	Currently researching feasibility
Turbidity increases and sedimentation Scale: Reach Duration: Unknown	Spring to early Summer	Unknown	<ul style="list-style-type: none"> • High turbidity likely held WSG in check under previous conditions • Where WSG overwinters as rhizomes, it is vulnerable to sedimentation • Springtime turbidity also benefit migrating smolts 	<ul style="list-style-type: none"> • Increased sedimentation is already a problem; covers spawning gravel • Contradicts lower river TMDL for suspended sediments 	Uncertain, likely multiple permits with several federal, state and local entities	Currently researching feasibility

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
<u>Islands and restrictions</u> Scale: Sub-reach Duration: Long-term	N/A	Unknown	<ul style="list-style-type: none"> ● Pinch points could be artificially created to force bed-scouring flows ● May have additional benefits for fish passage, habitat and/or dissolved oxygen concentrations ● Incorporates natural river processes that may be self-sustaining (longevity) 	<ul style="list-style-type: none"> ● Implementation may be costly ● Will need to take into consideration the impact for flood control 	Uncertain, likely multiple permits with several federal, state and local entities	Currently researching feasibility

13.0 High Priority Areas for Water Stargrass Removal

The high priority target clearing areas are those that most impact the beneficial uses of the lower Yakima River. Targeted management areas should include the following:

Fish Habitat Impacted Areas:

- Fish migration corridors. Areas where the thalweg and mainstem create passage barriers due to bank-to-bank plant growth should be cleared. This includes areas within Benton City, West Richland/Richland, and the Yakima Delta.
- Side-Channels. Side-channels can be important for late spring rearing of juveniles in the lower Yakima. Clogged side-channels should be cleared for improved juvenile habitat and migration.
- Cold water refuges and confluence of tributaries. Water stargrass impacting access or decreasing quality/quantity of cold water refuges and tributaries should be cleared from these sensitive areas for adult migrants.
- Historical spawning grounds. Historically redds were found throughout the lower 47 miles of the Yakima River. These areas are well documented by WDFW. These areas should be targeted for clearing in order to re-open the lower river spawning gravels.
- Vicinity of fish ladders at Prosser and Horn Rapids Dams. Access to fish ladders is critical for migration. Areas above and below fish ladders located on the lower Yakima should be targeted for clearing. Biomass above dams senesces and clogs ladders. Water stargrass below ladders impedes access.
- Piscine nursery areas. Clearing water stargrass from identified piscine nursery areas to help alter local conditions for flows and temperatures.

Irrigation Impacted Areas:

- Irrigation headgates. Water stargrass impacts water supply and flow for large irrigators such as Columbia Irrigation District and Barker Ranch. Clearing near irrigation headgates is important to mitigate these impacts and help water supply and delivery.
- Dam forebays. Dredging or clearing of water stargrass in lower dam forebays (Prosser and Horn Rapids) will help with dam operations and function.
- Small private irrigation intakes. Areas surrounding small private irrigation intakes with dense growth of water stargrass should be cleared to help with water supply and delivery.

Human Health:

- Slow moving, shallow marsh-like areas from Benton City to Richland. To combat the growing concern of disease carrying mosquitos, newly created marsh areas should be cleared and opened up. This allows for both increased flows as well as better access for targeted mosquito applications and treatments.

Water Quality:

- Slow moving, shallow waters with high levels of biomass. These conditions create areas that are at-highest risk for water quality violations of dissolved oxygen and pH levels.

Recreational and Shoreline Aesthetics:

- Areas near boat launches and river access areas. There are several public access locations on the lower Yakima River. These areas should be maintained and kept free of stargrass for safe use by the public.
- Areas of high use for aquatic enthusiasts. The Tapteal water trail, Yakima Delta, and mainstem river from Twin Bridges to Duportail are favorite areas for fishermen, floaters, boaters, and paddlers. Locations within these sections that are impassable because of water stargrass should be examined for management options to improve recreational use and safety.
- Upland public vista areas and/or private shorelands. Improved aesthetics for economics and enjoyment of the Yakima River.

14.0 Uncertainties and Data Gaps

The water stargrass technical workgroup identified several key uncertainties and data gaps for future research and discussion (Appendix A). These uncertainties can be grouped into unknowns about the plant characteristics (growth, life cycle, and propagation), research gaps regarding the relationships between the plant and its ecosystem, and uncertainties involving the identified treatment methods. We recommend that future funding be sought to understand and evaluate the highest priority data gaps as identified by the water stargrass technical work group. The identified uncertainties and data gaps are outlined below:

1. Plant Characteristic Uncertainties:

- What is the water stargrass life-cycle growth model for the Yakima River? Developing this model will help managers understand which treatments will most impact different stages and reduce the population.
- How does plant translocation work in water stargrass? This question will help in identifying optimal chemical treatment options.
- What are the genetics of this water stargrass population and how do they compare to other non-dominating water stargrass plant communities? This may help answer why water stargrass is so prevalent within the Yakima River whereas many river restoration locations strive to curate a healthy water stargrass population.
- What is the plant ploidy of water stargrass? Multi-ploid type plants can be more problematic than diploid strains and plant ploidy should be investigated.
- What threshold water velocities correlate to water stargrass' ability to take root and grow within the Yakima River?
- What is the plant's annual life cycle in the lower Yakima River? Knowing how the plant overwinters, timing of when the plant breaks dormancy and

what river temperatures trigger growth and die-off are important for optimizing treatment and management timing.

- How does water stargrass preferentially absorb its nutrients and what are the driving sources of nutrients in the Yakima River? Understanding if the nutrients are derived from the water column or sediments may help in targeting management actions.

2. Ecosystem and Plant Relationship Uncertainties:

- What is the impact of plant growth on fish passage for summer run adult salmonid species? Are there physical or chemical passage barriers from biomass?
- What impact does water stargrass have on outmigration of late smolts?
- What impact does water stargrass removal have on recruitment and rearing of piscine predators?
- What is the fate of plant biomass and related dissolved oxygen levels as it moves downstream through the system?
- What is the relationship between light availability, temperature and flow?
- What is the role of water stargrass in nutrient cycling within the lower river? Is water stargrass contributing to a nutrient sink and exporting nutrients to the Columbia River?
- What is the impact of climate change on the plant population and vice versa? Do changes in the in-stream river temperatures impact the growth season?
- What is the rate of plant expansion within the Yakima River system? Regular mapping and qualitative examination of biomass densities should be considered to observe biomass growth changes overtime.
- How is water stargrass driving succession from shallow open water to marshy areas that support new emergent vegetation? Could water stargrass channel expansion eventually result in a narrowing of the mainstem river channel? If so, could this be a desirable or successional process?
- How might the increasing frequency of droughts and/or floods be impacting water stargrass biomass and life cycle?
- What impact does removal of water stargrass have on invasive and other native aquatic plant species? Can aquatic plant community diversity be established, or does the system become vulnerable to invasive plants?
- What roles does water stargrass play in lower Yakima benthic invertebrate populations and how will removal of plant matter change their populations?

3. Treatment Method Uncertainties:

- What hurdles need to be overcome for the permitting of chemical treatments in moving water?
- Do chemical treatments provide competitive cost and effectiveness to other treatment methods? Pilot or bench top studies should be implemented to test emergent spraying technique and effectiveness

during low-flow conditions. Additionally, pilot or bench top studies should be conducted to understand the impact of chemical treatments on water stargrass and surrounding plants and coupling chemical treatments with other methods (e.g., bubble curtain, flows, different chemicals, etc.)

- What are the best timing windows to optimize mechanical and chemical treatments for maximum effectiveness?
- How can manipulation of spring flows and flushing flows affect biomass through increased velocities and biomass flushing? Can pilot studies or models be utilized to examine this question?
- How do we best dispose or reuse biomass from large scale removal or mechanical treatments? What permits are needed for removal, staging and disposal of biomass at different treatment sites?
- What small-scale methods are best suited based on cost and labor for treating smaller channels and smaller areas inaccessible by larger equipment (e.g., weed barrier paper, small harvesters, hand pulling)?
- How can multiple techniques be used together for optimization of control (e.g, mechanical removal of bulk biomass with chemical treatment of remaining volume)?
- How can efficiencies be garnered by coupling water stargrass flushing with in-basin flow operations for fish migration and cottonwood regeneration?
- How do we balance optimal plant treatment timing with the in-stream work window timings established for fish protection, recreation and agricultural uses?
- What is the impact of cut and drift practices for water stargrass on downstream ecosystem processes? It is important to understand the fate of biomass and related dissolved oxygen levels as biomass moves through system.
- What is the lifespan of the various treatment methods and at what frequency do treatments need to be repeated within a season to improve the desired beneficial uses of the river?
- Where does funding for a long-term water stargrass management program including operation and management costs come from? What entities or programs house the program and oversee operations?

15.0 Long-term planning for water stargrass management

15.1 Partnerships

Mitigation of deleterious water stargrass impacts will require annual treatments and long-term management. Formation of a water stargrass coalition is recommended in order to coordinate treatment efforts, share agency resources, evaluate an annual scope of work and treatment plan, identify priority areas, seek funding and evaluate treatment success. There are many impacted stakeholders on the lower Yakima River ranging from local to federal government agencies, tribal partners, special purpose

districts, and organizations with targeted interests in improving lower river habitat and/or water supply. While not an exhaustive list, coalition partners may include:

- Benton County Mosquito Control Board,
- Irrigation Districts,
- Benton County Noxious Weed Control Board,
- Benton and South Yakima Conservation Districts,
- Benton and Franklin Health District,
- Yakama Nation Fisheries,
- Mid-Columbia Fisheries Habitat Enhancement Group,
- Bureau of Reclamation,
- U.S. Army Corps of Engineers (Walla Wall Division),
- Washington State Department of Ecology,
- Washington State Department of Fish and Wildlife
- Local city and county parks and recreation staff.

Additionally, engagement of Benton County government, local state representatives and the Washington Conversation Commission strengthens organizational support and may help leverage program needs and funding.

Developing partnerships with private landowners on the lower Yakima, recreationists, and water related clubs such as the Tapteal Greenway Association, Richland Rod and Gun Club, and paddling clubs, will also be important to the long-term success of water stargrass management. Club members and private landowners are often willing to engage in solutions, monitor growth and expansion of plant matter, and volunteer labor and time for work days. Building community involvement and awareness through outreach and support programs helps elevate the issue and garner citizen support.

Of special note is the collaborative partnership implemented for the purchase and operation of the lower Yakima Aquatic Harvester (Figure 15). The unit was purchased through state funding sought through collaborative efforts between multiple agencies and local legislators and highlights in importance of multiple agencies working towards a mutual goal. Currently, the equipment is managed and operated by Benton Conservation District, with maintenance and storage provided by the Mosquito Control District. The equipment will be used for initial pilot treatments near the Benton City Boat Launch, Horn Rapids Boat Launch and the Yakima River delta. One harvester alone will not resolve the extent and problem of water stargrass on the lower Yakima River, but it does provide a tool in which to test treatment impacts and ecological responses. If pilot treatments with the harvester are sustainable and impactful, a fleet of harvesters could be deployed and utilized to manage accessible critical areas annually. Partnerships will be required for a sustainable program of this magnitude to help operate, manage, fund and coordinate equipment and staff.



Figure 15. Water Stargrass Harvester purchased 2021 for lower Yakima River, Benton County.

15.2 Funding

Due to its status as a native plant, available funding for water stargrass control is limited. Re-classification locally of the nuisance native to a noxious weed may open alternative funding pathways. While grant funding opportunities for noxious species are more prevalent, reclassification may create other challenges related to plant removal and disposal. Given its native status and ubiquitous nature disposal of water stargrass biomass does not require special considerations or handling.

Ecology's Water Quality Combined Funding Program has provided funding for water stargrass research in the past and may provide short term future funding for future implementation. However, these grants are designed for remediation actions that have a lasting benefit whereas management of water stargrass will require annual maintenance. The Yakima Basin Integrated Plan may provide a subsequent funding avenue for water stargrass management; stargrass impacts water supply, flow, and fish habitat which are all integral components of the watershed-scale approach for helping Yakima Basin water supply and conservation management.

To elevate funding requests and needs, creation of a water stargrass coalition is recommended. An effective coalition can advocate and lobby for funding at the state level. Ideally, agencies whose operations are impacted by water stargrass biomass will allocate money annually within their operation budgets to help with water stargrass control in areas that benefit their operations (e.g., fish ladders and dams, irrigation intakes, mosquito breeding areas). Additional funding will need to be procured to clear high priority areas that do not fit within the operation mission of local agencies. This could include funding to clear spawning grounds, improve recreational access, and support small private irrigators.

In drought years Washington State Emergency Drought programs should be sought to help implement the Lower Yakima River Drought Emergency Plan (MCF 2022). Conservation districts and other local entities are often eligible to receive emergency drought funding for projects that provide relief for drought impacted waters and are ready to implement. The Emergency Drought Plan allows organizations eligible for state released funds to move quickly and implement drought dedicated projects based on the actions outlined within the plan.

15.3 Operation and Maintenance (O&M)

Water stargrass will require annual maintenance for many years to come. As such, implementation of treatment techniques will require planning to include staff and funding for localized treatments as well as maintenance for necessary control equipment (e.g., aquatic harvesters, dump trucks, conveyors, chemical treatment equipment). As water stargrass impacts many beneficial uses of the lower river, coordinated efforts between multiple organizations and agencies working closely together will be necessarily for long-term operation and maintenance.

16.0 Other Considerations

16.1. Permitting

Under Washington State law (WAC 220-660-290), to protect fish, wildlife, and critical habitats, any physical or mechanical removal and control of aquatic plants is required to be covered by a written Hydraulic Project Approval (HPA), issued by WDFW (Chartrand et al. 2017). For some types of plant control and removal, WDFW has issued a pamphlet (WDFW 2015) that serves as the required HPA. This pamphlet covers permit requirements for many methods for controlling and removing noxious weeds. However, because water stargrass is native to Washington, it is covered under the category of aquatic beneficial plants, which have much stricter permit requirements. Therefore, for management of water stargrass, the pamphlet will cover only removal by hand (which includes hand-pulling, using hand-held tools or equipment, or using equipment that is carried when used) and bottom barriers and screens. All other physical and mechanical control methods will require individual HPAs to be issued by WDFW. Permitting for less traditional methods such as UV light, dredging or mailbox blowers will require working closely with the WDFW to obtain an individual HPA.

Compared to removal and control regulations for aquatic noxious weeds (i.e., the legal category of invasive plants), control of aquatic beneficial plants faces additional area size and permitting restrictions (WDFW 2015). For chemical methods of plant management, which are regulated by the Washington State Department of Ecology, water stargrass is included in the category of aquatic nuisance plants where the goal is not eradication. Compared to noxious weed management, control projects for aquatic nuisance plants face restrictions on which herbicides may be used and the percentage of the waterbody that may be treated (Ecology 2021a). In rivers, this percentage will most likely be determined based upon the size of the reach (N. Lubliner, Ecology, personal communication). Under state and federal law, any herbicide or nutrient-inactivation product applied in the lower Yakima River will require coverage under a National Pollution Discharge Elimination System (NPDES) permit. In Washington, this is Ecology's APAM permit, regulates when, where, how, and the amount and type of products that can be applied for aquatic plant control.

In addition to obtaining permits for the treatment techniques, permits for staging and disposal of biomass may also be required. This will require coordination with local health districts as the biomass may require a solid waste disposal plan and solid waste permit depending on the circumstances. In-stream cut and drift of biomass may be an alternative option to deal with large quantities of biomass during harvesting or large mechanical plant removal. Cut and drift will also require coordination with WDFW and HPA permits, and will require demonstration that plant biomass will not harm or impede downstream irrigation users, or result in downstream dissolved oxygen depletion.



Figure 16. Staging of harvested water stargrass near Horn Rapids Boat Launch, Benton County, 2021.

16.2 Continued Water Quality Monitoring

The three river gaging stations installed as part of the accompanying USGS Water Stargrass Dynamics Research study (Sheibley et. al 2022) were utilized by multiple basin partners working to improve lower river conditions. These stations provided critical data on dissolved oxygen, temperature, pH, nitrates, and highlighted numerous water quality violations in the lower Yakima. Given the interplay between water quality, hydrology and primary productivity we recommend continuous monitoring of lower river conditions as biomass continues to expand. While synoptic sampling is helpful for providing a snapshot of river conditions, it may not reveal the full story as interactions between daily respiration and photosynthesis processes and plant biomass are complex. Continuous water quality monitoring should include at a minimum temperature, dissolved oxygen, pH and nutrients. Monitoring of treatment areas pre- and post- treatment is also recommended to evaluate and monitor treatment effectiveness.

Continuous water quality monitoring can be costly as equipment requires regular maintenance and staff time for field checks and data review. Unfortunately, few programs are set up to continue long term monitoring and it is costly for smaller organizations to staff and maintain. Longer term continuous monitoring on the lower Yakima would be best housed under a larger agency with regular annual operating budgets. It is important that a work group focused on water stargrass management also

support conversations between Yakima Basin stakeholders, funders, and river managers about the need for collaborative lower water quality monitoring.

16.3 Climate Change Resiliency

The Yakima River basin is identified as susceptible to dynamic shifts in the frequency of flood and drought scenarios brought about by climate change. While floods and late season precipitation events will likely dampen seasonal water stargrass growth, drought conditions with longer, hotter, drier summers have the potential to greatly magnify growth. Increased annual forest fires may also alter nutrient and carbon loading to the Yakima River. In the long-term we hope climate change mitigation efforts will be enacted globally to delay the negative predicted consequences, however, we must also prepare for the reality that climate change impacts will need to be considered for near-term water stargrass management actions.

16.3.1. Drought Emergency Response

In an effort to mitigate impacts from increasingly common drought conditions, Mid-Columbia Fisheries developed the Water Stargrass Drought Emergency Plan (MCF 2022). This plan identifies key areas for water stargrass removal on the lower Yakima River and provides a shovel ready approach for fast mobilization in emergency drought years. This plan provides a vital tool for water stargrass and should be consulted and implemented when warranted. This plan will utilize basin-wide agency coordination and act as an adaptive management strategy in years of drought.

17.0 Recommendations

In order to effectively manage and improve lower river conditions, we have developed a list of recommendations based on the findings of the USGS Scientific Investigations Report (Sheibley et. al 2022), the Management and Control Techniques for Water Stargrass on the lower Yakima River (Pelly et al. 2021), and integration of the water stargrass technical advisory group input. These recommendations are as follows:

- 1. Create a formal coalition to manage the lower Yakima River water stargrass and support implementation of listed recommendations:** Convening a formal coalition will be necessary to foster collaborative partnerships and coordination for water stargrass management. Given the scope and magnitude of the problem, coordination between impacted organizations, agencies, and governments will be critical. An organized coalition will be able to capture efficiencies for plant management, advise best management practices and techniques, advocate for program needs, seek funding, guide long term operation and maintenance, and revisit and revise management goals and objectives as needed.
- 2. Targeted management and removal of biomass to improve beneficial uses of the lower Yakima:** We recommend treatments for water stargrass removal in key areas that will have the greatest impact on the identified beneficial uses of the lower Yakima. Plant removal techniques known to remove or impair biomass growth such as mechanical techniques (e.g., harvesting), manual techniques (e.g., hand pulling or barrier paper) and/or chemical treatments are recommended for small to medium size treatment areas. Key areas include locations with degraded water quality caused by dense biomass growth. Targeted removal is likely to improve microhabitat water quality conditions and flow. Clearing water stargrass in areas that impact irrigation intakes, public health, and recreation activities should also be targeted. Furthermore, targeted biomass removal may improve fisheries habitat and productivity by clearing in-channel migration pathways, spawning gravels, and biomass near fish ladders. It is not feasible to remove all water stargrass within the lower Yakima; however, targeted treatments to mitigate their impacts may be sufficient to improve lower Yakima conditions for beneficial uses.
- 3. Management of water stargrass to meet state water quality goals:** We recommend removal of water stargrass in areas with slow to moderate flows and higher levels of biomass growth, as these areas are most likely to experience negative impacts on key water quality parameters. We also recommend rigorous continuous water quality monitoring of temperature, dissolved oxygen, and pH to monitor impacts of treatments and management of nuisance plant growth. These parameters were found to be in violation of the state standards during baseflow conditions. Continuous monitoring of water quality parameters highlights violations that are not captured by daytime synoptic sampling. Continuous water

quality monitoring of key parameters for fish survival and habitat will be vital towards achieving lower basin restoration goals especially with continued threats from climate change. We also recommend continued monitoring of nitrates given the relationships between plant biomass and nutrients.

- 4. Continued research on water stargrass growth timing, life cycle and nutrient cycling:** We recommend additional research to better understand critical knowledge gaps regarding the water stargrass plant life cycle and role in lower river nutrient cycling. Understanding plant biology (how it overwinters, propagates, derives nutrients, etc.) may help refine treatment techniques and timing for more efficient and effective control. While nutrients in the water column do not seem to be driving biomass growth, sediment nutrient levels may be. It is important to investigate the nutrient cycle between plant biomass, sediments, and the water column. A recent review of the last 20 years of nutrient data (Grieger and Harrison 2021) indicate that the lower Yakima is a nutrient sink. It is important to determine if the extensive water stargrass biomass is contributing to the lower than anticipated level of nutrients at Kiona and Van Giesen.
- 5. Implementation of established techniques for short-term biomass control.** Mechanical harvesters, hand-pulling, chemical treatments, and weed paper/barriers (localized areas for small private irrigators) are established methods to control plant biomass. These methods can be quickly deployed and utilized during baseflow conditions or in drought years on the lower Yakima River. Ideally, for mechanical harvesting operations a fleet of both large and small mechanical harvesters will be procured to clear multiple areas of the river that have varied hydrologic conditions.
- 6. Pilot experimental treatments for optimal biomass control:** Given the apparent relationships between hydrology and plant biomass, future work to identify and study hydrologic controls to help diminish biomass growth and/or improve water quality is recommended. Watershed control methods, such as flow management, velocity enhancers, and sedimentation, are less tried-and-true techniques for plant control. There is opportunity in the Yakima River basin to test pilot these novel methods. While it will take a coordinated basin-wide effort with multiple agency involvement, there are opportunities to use in-basin flow strategies for water stargrass control with other flow work already underway for fish migration and/or cottonwood regeneration. Reservoir releases utilized in the Yakima basin for salmon migration may also benefit management goals for diminished biomass growth in late spring due to the fast changing flows, velocity, and corresponding sediment releases (decreased light availability). Furthermore, in-stream structures to enhance velocity may help decrease biomass in localized areas by increasing scour and shear stress.

Pilot or bench scale tests for chemical treatment options should also be investigated. Given the uncertainty in these methods for both riverine use and to treat native plants we recommend trial methods to determine if imazamox or

endothall as either stand-alone treatments or coupled with other treatments like bubble curtains and draw down can be used to treat areas that are inaccessible by larger mechanical methods.

- 7. Ongoing aquatic plant mapping and watershed monitoring:** With the continued threat of climate change on the lower Yakima, it will be important to monitor the impacts of water stargrass biomass on the Yakima River. We recommend regular biomass mapping and monitoring to evaluate spread of water stargrass into the upper Yakima. We also recommend proactively planning for emergency control measures to be implemented in drought years where sustained lower flows are likely to give rise to greater amounts of biomass in the lower Yakima. Emergency plans to mitigate biomass in drought years will be critical for building climate change resiliency.

Plant community diversity is essential for a healthy aquatic ecosystem. We recommend that development of an aquatic ecosystem restoration action plan for the lower Yakima with the long term goal of reducing the monoculture that currently dominates the lower Yakima plant biome. Re-introducing and establishing diverse native aquatic plant communities, with water stargrass as one component, will benefit multiple ecosystem functions. Consulting with aquatic plant specialists will be central to development of this plan.

- 8. Examine biomass alternatives to landfill disposal.** Disposal of cut biomass can be costly. As a native plant, there may be alternatives for removed plant material that are not typically available for invasive species. Techniques such as cut and drift may be appropriate in certain areas such as the Yakima Delta. Recycling or re-use of biomass as a nutrient source should also be investigated. Work by Pacific Northwest National Laboratories showed unlikely use of water stargrass as a cost effective biofuel, however, there may be other “green uses” and applications for cut biomass.
- 9. Community outreach and education:** We recommend continued outreach and education to the local communities on water quality and watershed health and the impacts of excessive macrophyte growth in the lower Yakima. Mitigating the impact of water stargrass is a complex problem. Engaging the community and landowners to educate, help monitor, observe spread, and combat the problem will be critical. We also recommend continued engagement with agency partners and river managers to continue to seek novel solutions for control of water stargrass and improved water quality health.

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Appendix A: Water Stargrass Advisory Comments and Priorities

Lower Basin Priorities as compiled from the Technical Advisory Group:

Washington State Fish and Wildlife (Paul Hoffarth)

Top Priorities: Spawning habitat, removing vegetation from primary historical spawning grounds

Lower Priorities:

Adult passage: thermal barrier in the lower river blocks passage during summer months
Fish move quickly through lower river during periods of cooler water temps. Water stargrass does not appear to effect passage. Agencies are working toward pulsed flows during the summer to enhance passage when there is a summer cooler weather trend.
Pulsed flows may assist mosquito control

Top Techniques:

Chemical: would be awesome if we can get the right chemical coupled with a work window that reduces impacts to fish and other species.

Mechanical: removal of entire plant

Key Uncertainties: **Chemical treatment** will likely be a challenge to get permitted. Cost could be prohibitive. effectiveness in moving water will be challenging

Washington State Fish and Wildlife (Mike Ritter)

Top Priorities: fish and historic/existing redds

Treatment Comment: We are at or near an emergency situation in the lower Yakima and need to formalize an Integrated response. All of our current treatments are focused on when the plant is already a problem during low flow.

Yakima Basin Fish and Wildlife Recovery Board (Alex Conley)

Top Priorities

Fish and Water quality: WSG is a driver of WQ problems and need to understand impact of WSG on summer salmonids as well as outmigration of late smolts (fall and summers).

Top Management Techniques:

- 1) See harvester use;
- 2) Plan 2022 field season w/harvester in targeted way to test hypotheses;
- 3) investigate emergent spray technique during low-flow;
- 4) investigate light availability/temp and relationship to flow

Key uncertainties/concerns:

- 1) Fate of biomass and related DO as biomass moves through system;
- 2) Sketch life-cycle/growth model and how to impact different stages to reduce population

Department of Ecology (Jenifer Parsons)

Top priorities: water quality impacts, fish passage.

Top Management Techniques: UV light method is interesting, could look into that more. Explore herbicides, try to do some trials because that has the most potential for treating a large area.

Key uncertainties/concerns: If there is research funding, would be good to compare genetics of this population with others to see if some weird strain is here, also check ploidy since triploid (or other multi-ploid types) can be more problematic than the diploid strains. Also climate change could be causing some of the increased growth.

Benton County Mosquito Control Board (Angela Beehler)

Top priorities:

Public health then recreationists, tourism, residents
Healthy and cool river reduces mosquitoes;
Irrigation flowing properly helps with mosquito control;
Very interested in sides of river not middle because of where mosquitoes live.

Top Management Techniques:

- 1) How spring flows affect biomass through increased velocities/flushing;
- 2) Mechanical control is best bet for the BCMCB;
- 3) Chemical control using treatment drone to treat specific areas in small amount of time may be useful for WSG.

Key uncertainties/concerns:

Issues involved in herbicide applications;
What to do with biomass;
How to clear smaller channels (harvester may be too big for smaller channels; get smaller harvester).

Walla Walla Army Corps of Engineers (Damien Walters)

Top priorities: Fish passage

Top Management Techniques: Chemical use; environmental flows

Key uncertainties/concerns: Where are key locations in system; is there a migration-type corridor in the system? How does translocation of herbicides work in WSG and how can that help us identify optimal chemical treatment option?

Department of Ecology (Jenifer Parsons)

Top priorities:

water quality impacts, fish passage.

Top Management Techniques: Damien's mention of the UV light method is interesting, could look into that more. Explore herbicides, try to do some trials because that has the most potential for treating a large area.

Key uncertainties/concerns: If there is research funding, would be good to compare genetics of this population with others to see if some weird strain is here, also check ploidy since triploid (or

other multi-ploid types) can be more problematic than the diploid strains. Also climate change could be causing some of the increased growth.

Mid-Columbia Fisheries (Kat Strathmann)

Top priorities: Protecting and restoring fish passage, survival and reproduction, during typical years and particularly during low-flow (drought) years causing extremely toxic conditions; Concern that low flow years will be more typical under future climate change scenarios.

Top Management Techniques: Don't favor one particular technique but myriad of techniques that fit specific areas of the river and timing of fish use. Let's move forward on several techniques simultaneously due to the magnitude of the problem and different conditions along the infested areas of the river. A number of mechanical/manual, chemical and environmental flow techniques seem to have promise and potentially be used in concert. How can techniques that efficiently remove top biomass be combined with higher-cost techniques that remove roots? (ie, a common terrestrial approach is to remove prolific biomass and follow-up with chemical treatments so that smaller volume of chemical application is more effective).

Key uncertainties/concerns: So many – effectiveness and environmental impacts of the many untested chemical, mechanical and environmental flow treatments; future response of WSG to climate change. Need to carefully document any treatment attempts to learn and move efforts forward. Tie environmental flow work in with other multi-species environmental flow work (ie, fish migration, cottonwood regeneration).

Charles Horn – Professor Newberry College

Top priorities:

- 1) need better understanding of annual/seasonal changes in population;
- 2) how do sediments move through system (if this is unknown in lower Yakima River) and do plants cause higher sedimentation?

Top Management Techniques:

- 1) Mechanical treatment is a good idea, but where do you start? What are priorities? Downstream? Upstream? May be different effectiveness of treatment at specific location, and may have different downstream effects.

Key uncertainties/concerns:

Climate change -- how might droughts affect WSG? Is plant biomass moving downstream creating problems for habitat downstream? What do fish need, and how to manage WSG to meet priorities of fish?

Justin Billing – Scientist at Pacific Northwest National Laboratory

Top Priorities

Fish passage, recreation, & tourism – need to be mindful that Ag and irrigators aren't negatively impacted by how flows are managed

Top Techniques

Favor Mechanical/Physical Removal

Look for offseason times to harvest and couple with flushing flows
Look for natural ways to increase stream velocity

Cut and drift might be possible if flows were temporarily higher w/ planned protection of irrigation intakes (notice to shut off?)

Sarah Roley – Assistant Professor, Washington State University -Tricities

Top Priorities: Research to investigate the effect of flushing flows as related to WSG and plant life cycle model

Nancy Rybicki – Emeritus Research Hydrologist, US Geological Survey

Top Priorities: Research to understand lifecycle and look for threshold velocity that correlates to water stargrass growth. In Potomac, WSG all above ground biomass and decompose over the winter, leaving black stems laying on the bottom, vulnerable to sedimentation.

Rich Sheibley – Hydrologist, US Geological Survey

Top Priorities:
Water Quality

Top Techniques:
Harvesting and then UV method for the slow, choked areas

Key Uncertainties/Concerns:
Understanding the life cycle of plants and when different treatment timings are effective.
Role of WSG and sediments as a nutrient sink for the lower river