Yakima River - Water Stargrass Emergency Drought Mitigation and Response Plan

Prepared by:

Mid-Columbia Fisheries Enhancement Group

Benton Conservation District

Developed in cooperation with the Yakima Basin Integrated Plan

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Cover photo: Water Stargrass in the Yakima River, Benton County. Photo by Stephen Ingalls, Benton County Mosquito Control Board.

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Executive Summary

The Lower Yakima River in southeastern Washington is experiencing prolific growth of water stargrass (*Heteranthera dubia).* Organisms that outcompete all others and proliferate within ecosystems can pose substantial risk as natural systems are altered. While we typically associate such impacts with invasive species, some native species can exhibit these traits, particularly as disturbances or modifications change existing conditions. Management approaches are necessary to mitigate the impact of prolific water stargrass growth on fish habitat, water quality, and recreational opportunities in the Lower Yakima River.

Historic and current changes in river conditions are a result of dam construction, irrigation and return water management, and modifications of waterways for development. These changes have altered natural ecosystem process and resulted in current conditions that are favorable for water stargrass (WSG) to out-compete nearly all other species within the waterway. The intensively regulated river flows reduce the frequency of bed-scouring flood events and greatly reduce turbidity from April through June. While agricultural-related activities helped alleviate the WSG expansion, basin-wide restoration efforts in the 1990s to reduce sediment loading and toxic chemicals to the Yakima River have been successful. While these improvements were vital to river health, reduced turbidity has increased light penetration. In conjunction with greater sediment on the river bottom resulting from dam and reservoir construction, dense aquatic macrophyte growth was rapid. This growth was almost exclusively WSG and has had negative impacts on water quality (temperature, pH, and dissolved oxygen), chinook salmon spawning grounds, and migration pathways for anadromous salmonids. The current conditions require management in the lower Yakima River due to exceedances of Washington State water quality standards for temperature, dissolved oxygen and pH. These values are impacted by WSG as thick vegetation restricts flow and plant respiration impacts dissolved oxygen and pH. Additionally, stagnant water caused by WSG provides ideal habitat for mosquitoes that have been found to carry West Nile virus. Although understanding of the negative consequences of WSG on fish, human and overall river health has expanded over the past twenty years, there has been minimal management to reduce its abundance in the basin.

Active management of WSG needs to occur yearly with monitoring to ensure targeted management approaches are effective (BCD 2022). However, the greatest risk to river health occurs during years of drought. The dense matts that WSG forms across the thalweg of the lower Yakima River can block migratory pathways for salmonids, increase reproductive success of mosquitoes, block irrigation intakes, and decrease fish passage through dams in the basin. Beyond the already observed fish habitat loss associated with WSG, an effective management response to drought conditions will be crucial in limiting the impacts of WSG on the function and water quality of the lower Yakima River. This will also bring continued awareness, funding, and management strategies to help reduce the WSG footprint in the lower Yakima River.

This document provides a plan to aid in effective removal of WSG during drought. Removal will be isolated to identified crucial locations designated by accessibility, fish usage, and overall blockage risk associated with WSG. The spatial extent of critical areas to be harvested, best suited methodology based on river hydrogeology, and cost estimates for mitigation of blockage of fish passage, river function, and water quality in years of drought will be outlined in this document. The work builds on existing

evaluations of WSG on the lower Yakima river detailed in the Water Stargrass Mitigation Recommendation Report by Benton Conservation District and Management and Control Techniques for Water Stargrass in the Lower Yakima River by Pelly et al., 2021.

Plan Goals and Objectives

Drought Emergency Response Plan Goals

This plan for WSG removal and management identifies key locations (Section 8.0) to maintain the greatest water quality and habitat benefit in drought years. It highlights acreages and geographic locations for high priority fish benefit based on presence/absence mapping of WSG. This plan aims to:

- Improve fish passage and survival in drought years
- Minimize reductions in water quality, quantity, and wildlife habitat
- Maintain river function for a diverse set of aquatic wildlife

Drought Emergency Response Plan Objectives

To accomplish the goals and maximize efficiency the following objectives will be prioritized:

- Secure staff and resources necessary for WSG removal in anticipation of future drought conditions along the Yakima River as the need for additional management becomes apparent
- Targeted removal and management of WSG in high-priority areas
- Use of adaptive management strategies for each hydrogeological area and
- Update strategic approaches as the effect of WSG and associated management practices become better understood.

1.0 Background

Water stargrass (*Heteranthera dubia,* WSG*)* is a macrophyte native to Washington State that functions like an invasive species in the lowest reach of the Yakima River by out-competing other aquatic plants and occupying much of the riverbed and water column (Wise et al. 2009, Appel et al. 2011). The Benton Conservation District (BCD) has been a lead entity when addressing WSG abundance and impacts to the lower Yakima River. BCD has provided key efforts in showing the detrimental impacts of overabundant plant growth on water quality, recreation, salmon spawning grounds, and irrigation supply. More recently, BCD has worked with the Benton County Mosquito Board to understand the impact of water stargrass beds on vector-carrying mosquitos that impact public health.

Water stargrass likely had low abundance before dam construction on the Yakima River due to scouring flows and turbid snowmelt through June. After dam construction, water stargrass abundance remained low, most likely due to high turbidity, despite higher nutrient concentrations (Wise et al. 2009, Pickett 2016). In the late 1990s, a water quality improvement plan in the lower Yakima River led to dramatic reductions in sediment runoff, leading to lower turbidity and thus greater light penetration in the river (Washington Department of Ecology 1998, Washington Department of Ecology 2006, Washinton Department of Ecology 2012). Water stargrass has a high light requirement (Blackburn et al. 1961), so reduced turbidity in combination with lower flows and historical sediment nutrient load likely provided ideal conditions for growth. By 2005, water stargrass dominated much of the lower river from Prosser to the confluence with the Columbia River (Wise et al. 2009).

Wise et al. (2009) investigated several parameters within the Benton reach including nutrient loading, gross primary productivity, pH, dissolved oxygen, and temperature. This study found that greater amounts of plant growth resulted in larger daily fluctuations in dissolved oxygen concentrations and pH levels that exceeded the Washington State water quality standards for July-September. The daily swings in dissolved oxygen and pH were greater during low-flow periods. Additionally, pH levels were above the Washington State standard of 8.5 during almost all the irrigation season in low flow years and following spring runoff in high flow years. During much of the irrigation season (March-October), the dissolved oxygen concentrations were below 8 mg/L with the onset of low dissolved oxygen occurring earlier in the spring during low-flow years. It was determined that daily dissolved oxygen concentrations were negatively correlated with the preceding day's maximum water temperature (Wise et al. 2009).

The spread of WSG in the Lower Yakima River has resulted in reduced water quality. As dense networks of WSG become established, flows stagnate, leading to increases in water temperature, reduced dissolved oxygen, and increases to pH. In addition to water quality concerns, WSG also poses fish passage issues. Dense conglomerations of this macrophyte make migration difficult as it can block fish ladders at dams. Fish movement through these mats of vegetation can be observed with visible corridors but is most often attributed to Carp. The most compelling case for fish passage issues goes back to the fish ladders becoming clogged during key migration periods. Even when thalweg cleared, the dense matts could provide increased predation risk by narrowing corridor width. The dense nature and sheer mass of WSG has been shown to displace water by upwards of 3 feet, and drastically reduce the velocities in large sections of the lower river.

Figure 1. Water stargrass dominated river channel, lower Yakima River. Photo by Stephen Ingalls, Benton County Mosquito Control

Increasing prevalence of high temperatures and lower flows both exacerbate reductions in water quality that stem from an overabundance of WSG. Climate change models for the Yakima Basin (Malek and others, 2020; UW Climate Impacts Group; Yakima River Basin Integrated WIRE Management Plan) show that irrigation unmet demand (a drought indicator) is sensitive to changes in basin water supply stemming from altered snowpack amounts and a shift to precipitation as rainfall. This shift results in greater water stress as the Yakima River is a snow-dependent basin with much of its summer water supply met through storage in the upper watershed's five major reservoirs. Altered snowpack and a shift in precipitation from snow to rain is predicted to negatively impact water supply storage in the upper basin leading to greater irrigation unmet demand in the lower basin. This water supply shift, coupled with a prediction of warmer air temperatures in the lower river (anticipated increase of +0.17 °F/decade) will lead to a greater frequency of water shortages from historical records, placing pressure on available water supply (https://climate.washington.edu/climate-data/trendanalysisapp/).

The Benton Conservation District (BCD) has been a lead entity when addressing WSG abundance and impacts to the lower Yakima River. BCD has provided key efforts in showing the detrimental impacts of overabundant plant growth on water quality, recreation, salmon spawning grounds, and irrigation supply. More recently, BCD has worked with the Benton County Mosquito Board in understanding the impact of water stargrass beds on vector carrying mosquitos that impact public health. While BCD has observed the steady increase of WSG over the last two decades, WSG distribution in the lower Yakima River has not been formally mapped. As part of the development of the Drought Emergency Response

Plan, Mid-Columbia Fisheries (MCF) initiated several floats to identify WSG presence and extent within the lower Yakima River. This is the first project to map the upper boundary of WSG and provides priority actions to alleviate WSG impacts on salmonid migration and survival in years of drought. WSG mapping is important for understanding critical areas to target during an emergency drought, as well as to establish a baseline for monitoring the spread of WSG upstream. This report will give background information by reach on WSG characteristics and relationships to fish usage in the lower Yakima River. While many of the fish usage questions are currently based on hypotheses that need further research, this report hopes to highlight a potential fish passage issue and provide a roadmap for priority actions and management during drought years when WSG growth creates an added burden to native salmonid passage and survival. This response plan has additional targeted benefits for streamflow, agriculture and irrigation, public health, and recreation.

2.0 Coordination with Other Management Plans

Benton Conservation District has taken the lead on WSG management in the lower Yakima River, and in addition to initial pilot projects, has developed the Water Stargrass Recommendations Report (BCD 2022). This is the overarching document in which the Management and Control Techniques for WSG in the Lower Yakima River (2021) and the Emergency Drought Plan (2023) fall under. The coordination amongst these plans aims to better secure and utilize public funds for effective future management of WSG. Shared objectives and management goals of these documents increase the cohesiveness of agencies and efforts to mitigate the impairment of water resources. This report works alongside the existing documents on WSG in the lower Yakima River, with the specific goal of establishing targeted emergency actions during drought years.

3.0 Project Area

The Yakima River, which heads at the outlet of Keechelus Lake near Snoqualmie Pass, drains 15,939 km^2 area of the central Cascade Range of Washington and western margin of the Columbia Plateau before joining the Columbia River at the city of Richland (Figure 1). As the Yakima River passes Union Gap it has the highest average streambed slope in the project area at approximately 11 ft/mi. This average streambed slope drops to 7ft/mi over the rest of the Lower Yakima Valley. A higher gradient and wide alluvial floodplain define the uppermost reaches while the middle river reaches exhibit a more complex river morphology with many abandoned channels, oxbow lakes, and scroll bars. Finally, the lower river has a narrow alluvial floodplain with less streambed gradient and a more silt-dominated river substrate. The lower Yakima River is comprised of several geomorphic distinct segments, including a segment within a wide alluvial floodplain between the Sunnyside diversion dam at river mile (RM) 103.8 and Mabton (RM 60), a low-gradient, straight segment within a narrow alluvial floodplain between Mabton and Prosser diversion dam (RM 47.1), and a high-gradient, bedrock-controlled segment within a narrow alluvial floodplain around Benton City (RM 30) before transitioning to a former delta reach at the confluence of the Yakima and Columbia Rivers (RM 0.0). With the gradient change and the resultant lack of bed movement, WSG proliferates starting at Mabton and gets progressively more abundant as you move downstream.

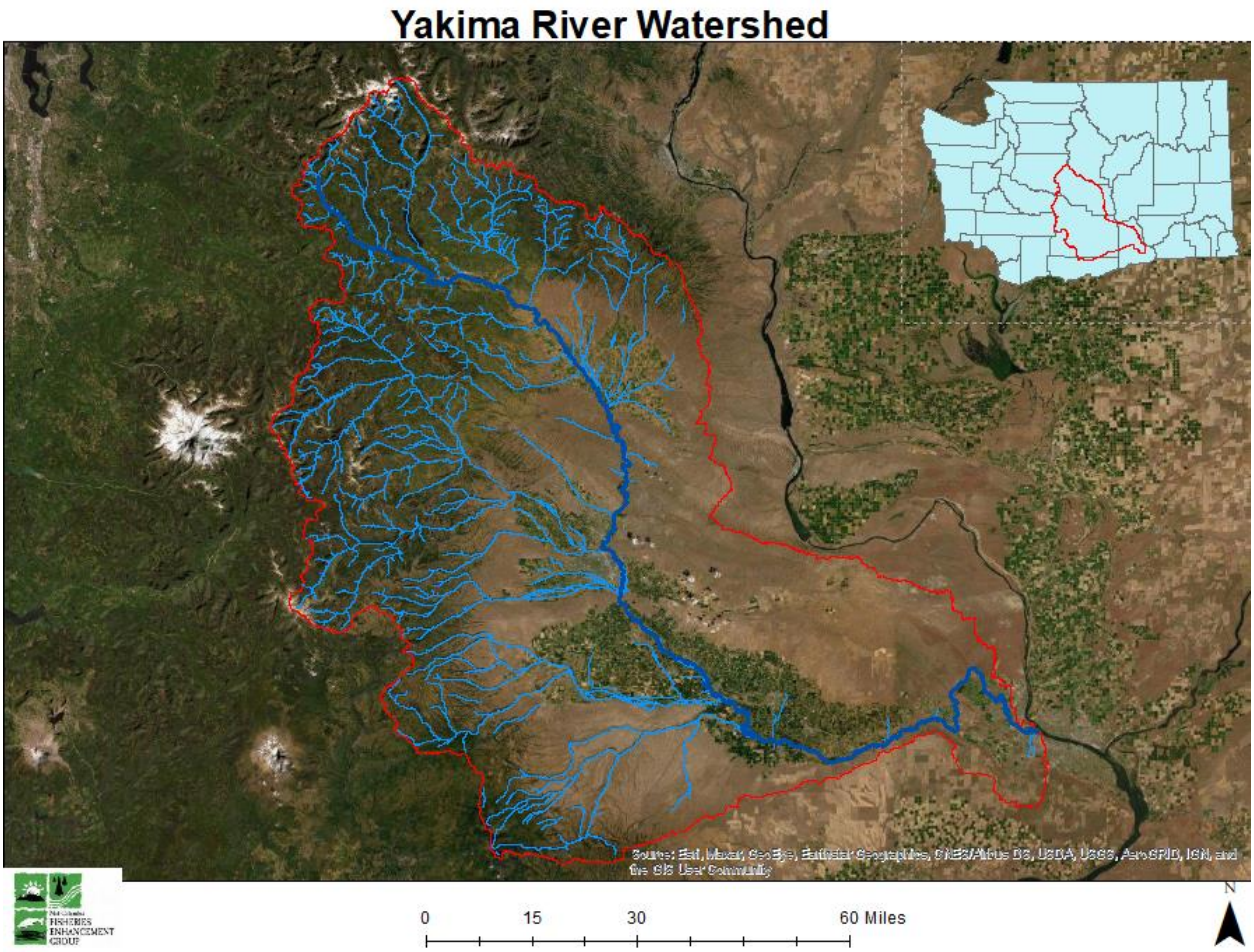

Figure 2. The lower Yakima River Basin in Washington State.

As part of the development of the Drought Emergency Response Plan, Mid-Columbia Fisheries (MCF) initiated several floats to identify WSG presence and extent within the lower Yakima River. WSG mapping is important for understanding critical areas to target during an emergency drought, as well as establish a baseline for monitoring the spread of water stargrass upstream.

The area of mapping investigations and subsequent drought response actions focuses on the lower portion of the Yakima River (River Mile (RM) 110) to the confluence with the Columbia River. The lower Yakima River was separated into nine reaches based on hydrology: Parker (~ RM 100 to 89), Toppenish (~RM 90 to ~RM 81), Granger (~RM 80), Mabton (~RM 60), Prosser (~RM 50), Chandler (~RM 38), Benton (~RM 30), Snively (~RM 20), and the Confluence reach (~RM 10) (Figure 2). Focusing emergency drought actions based on reach will allow for precision and efficiency in planning, aid in identifying target methodology for WSG removal, and better display the geographic extent of WSG in the lower Yakima River.

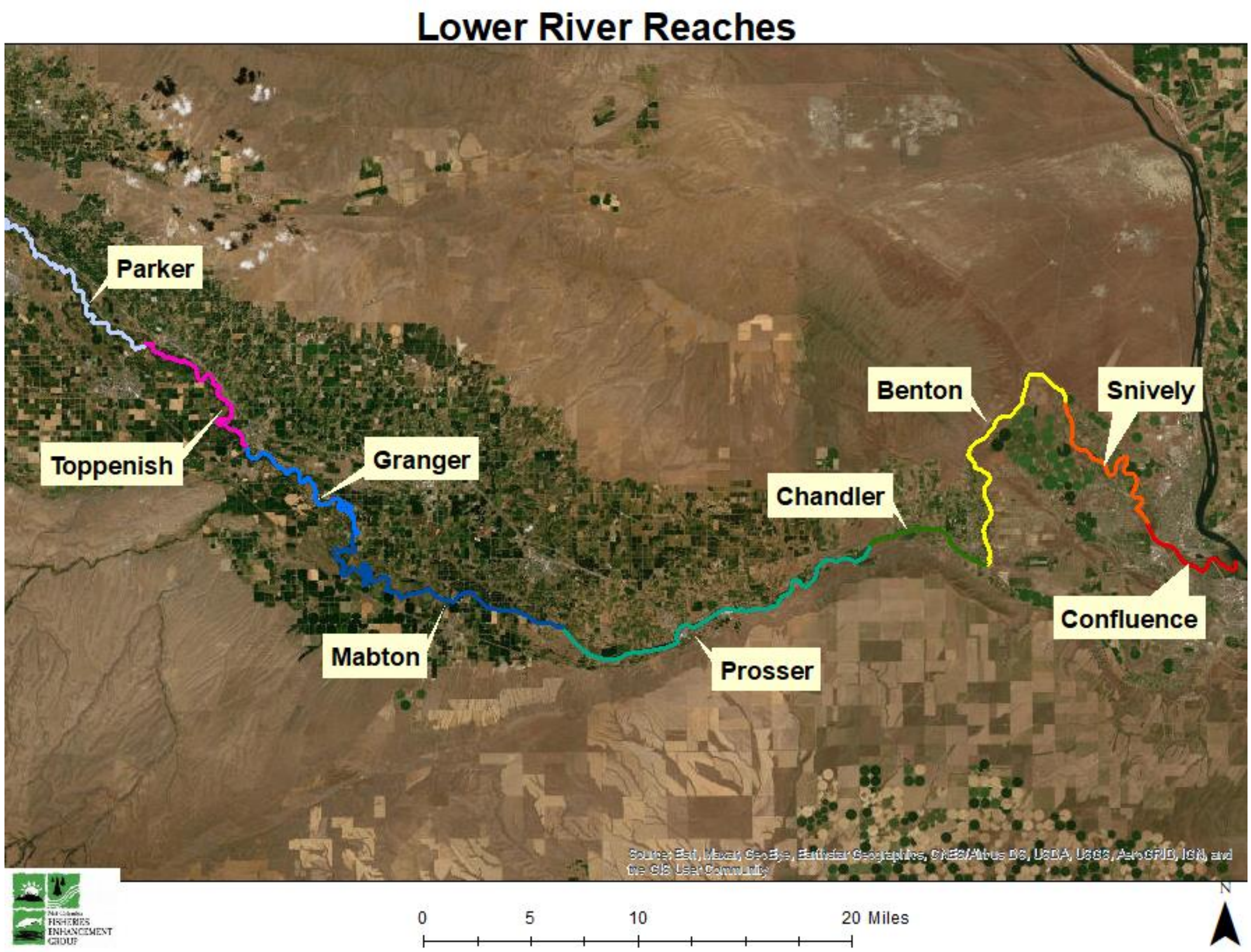

Figure 3. Study area of the Lower Yakima River broken into mapped reaches.

4.0 Water Stargrass Extent in the Lower Yakima River

Changing hydrological regimes, nutrient inputs, water quality, and subsequent floodplain degradation are all likely contributing factors impacting the proliferation of WSG across each reach. These changes have all altered the water dynamics across much of the lower Yakima (Appel et al. 2011). Additionally, a reduction in hydrograph magnitude led to a decrease in peak flow during the summer growing season. These changes are attributed to causing the dramatic increase in WSG expansion beginning in the late 1990's. Light penetration through water as sediment loads decreased is considered the single greatest factor for increasing WSG abundance due to the high light requirement for the growth of this macrophyte (Blackburn et al., 1961, Zhu et al, 2008).

Additionally, nutrient dynamics within the Yakima River Basin are not well understood. While nutrient inputs from agricultural and urban development have increased within the basin, river nutrient exports of nitrogen and phosphorous have decreased or plateaued (Grieger and Harrison, 2021). The lack of coordination between inputs and outputs of nutrients within the basin indicates that nutrients are being retained in soil or aquifers or are in transit to be exported with a long transport time. Alongside unknowns from historic inputs, nutrient dynamics within the river may also be affected or affected by widespread WSG growth. Note that it is currently unclear if WSG is drawing nutrients primarily from riverbed sediments or the water column, and if nutrient availability is a limiting factor. More research and monitoring is needed to understand the relationship between WSG and nutrients of the Yakima River.

In 2021, Mid-Columbia Fisheries (MCF) staff estimated the distribution of water stargrass in the lower 100 miles of the Yakima River by digitizing the visible extent of water stargrass from aerial imagery and by conducting field visits to confirm water stargrass extent. These distribution maps helped shape the prioritization of key harvest areas to begin WSG management. The upper extents of WSG from Union Gap and below were at very low abundances compared to the extremely high density below Mabton. Based on the results of these surveys, MCF determined that an emergency drought plan should focus effort exclusively from the Mabton reach to the confluence where the composition percentage of water stargrass across the channel ranges from 36 – 100% (Figure 4).

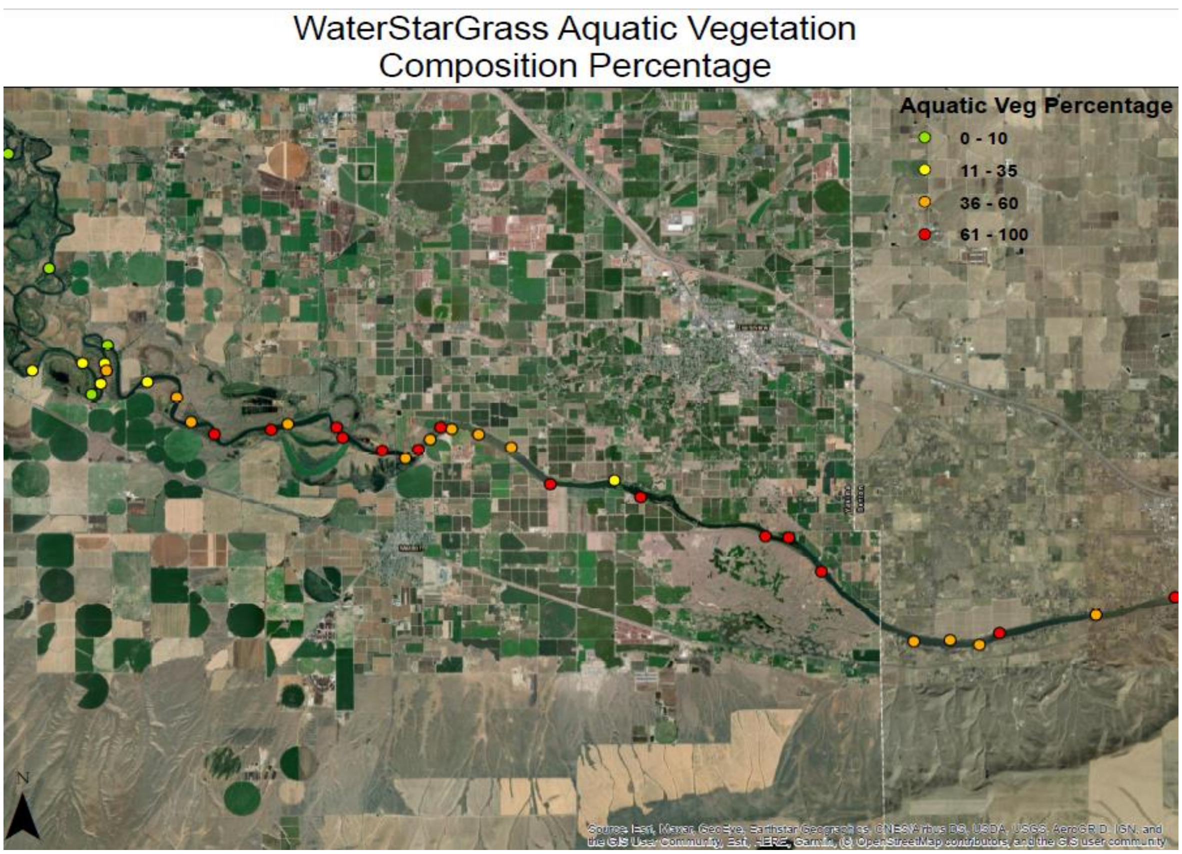

Figure 4. Estimated aquatic macrophyte composition map demonstrating the shift in Mabton reach to full WSG dominance in vegetation and the start of channel spanning presence.

4.1 Parker

The Parker reach spans 11 miles of the Yakima River and begins downstream of the Sunnyside diversion dam. This reach is classified as a wide floodplain, and is characterized by a complex, anastomosing morphology with multiple channels (Gendaszek and Appel 2021). This system has high relative stream-bed gradient compared to the other lower river reaches and is a high priority restoration reach within the Yakima Basin due to most extensive floodplain connectivity (Snyder and Standford 2001). This reach is dominated by gravels and cobbles and has alternating depositional and transport zones, partly due to gradient but also due to proximity to the Naches transport zone (Snyder and Standford 2001). The Parker section has minimal matts of WSG and areas of sediment deposition were occupied by other aquatic macrophytes. WSG in this reach also occupied riffle areas, and had a composition that rarely outcompeted other aquatic plants species, from this map the overall presence of WSG is shown to occupy a minor portion of the reach (Figure 5).

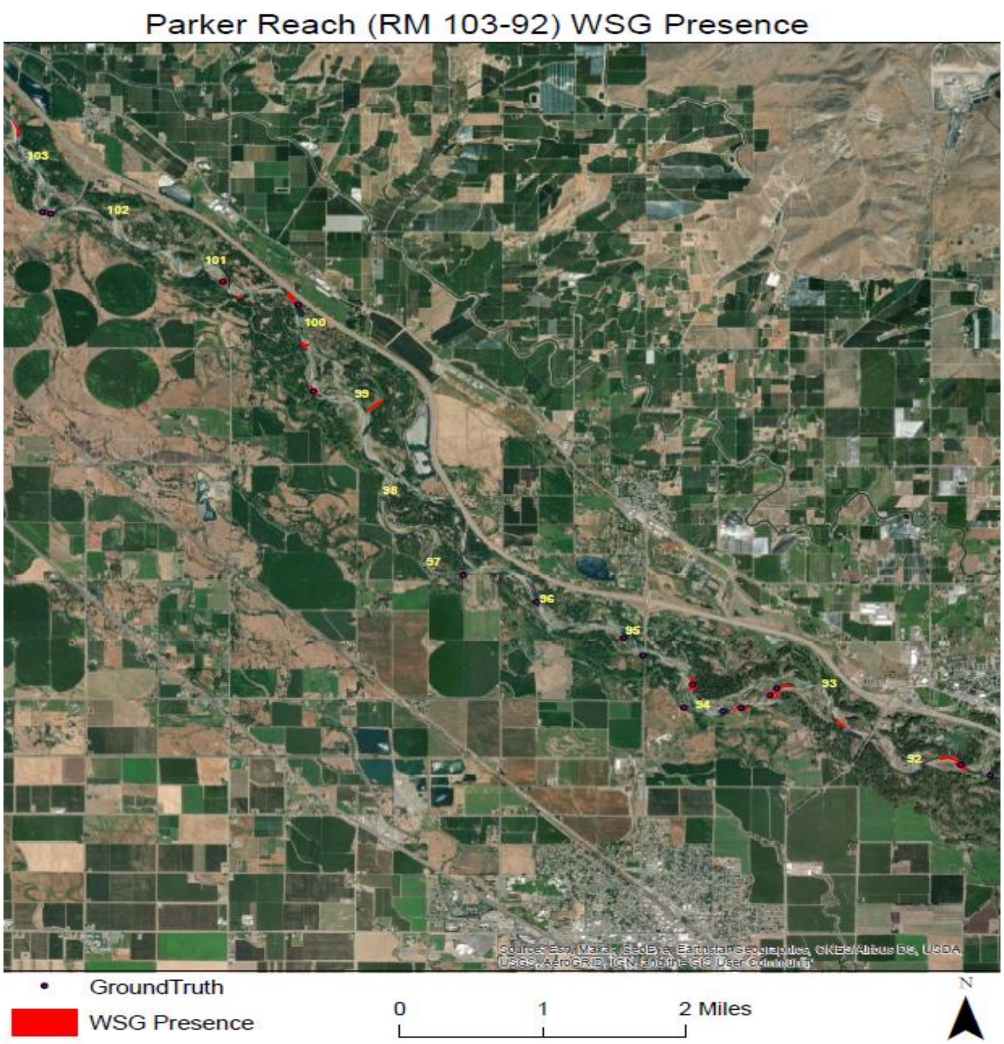

Figure 5. Parker Reach WSG presence locations with ground truth points.

4.2 Toppenish

The Toppenish reach spans roughly 10 miles and is like the upstream Parker reach in terms of channel complexity and wide, intact floodplain. However, the gradient of this reach is significantly lower than that of the Parker reach (Gendaszek and Appel 2021). This section is dominated by large gravel bars, secondary channels, and abandoned channels. This section also sees several water returns entering the Yakima River via canals, agricultural fields, irrigation canals, and sewage treatment (Vaccaro 2011). WSG in the Toppenish reach becomes more abundant but still has other aquatic macrophytes located within the low velocity habitat units. There are no areas in the reach where WSG occupies the thalweg and does not display any channel spanning areas within the reach. Similar to the Parker reach, the overall species compositions are split among other aquatic species (Figure 6).

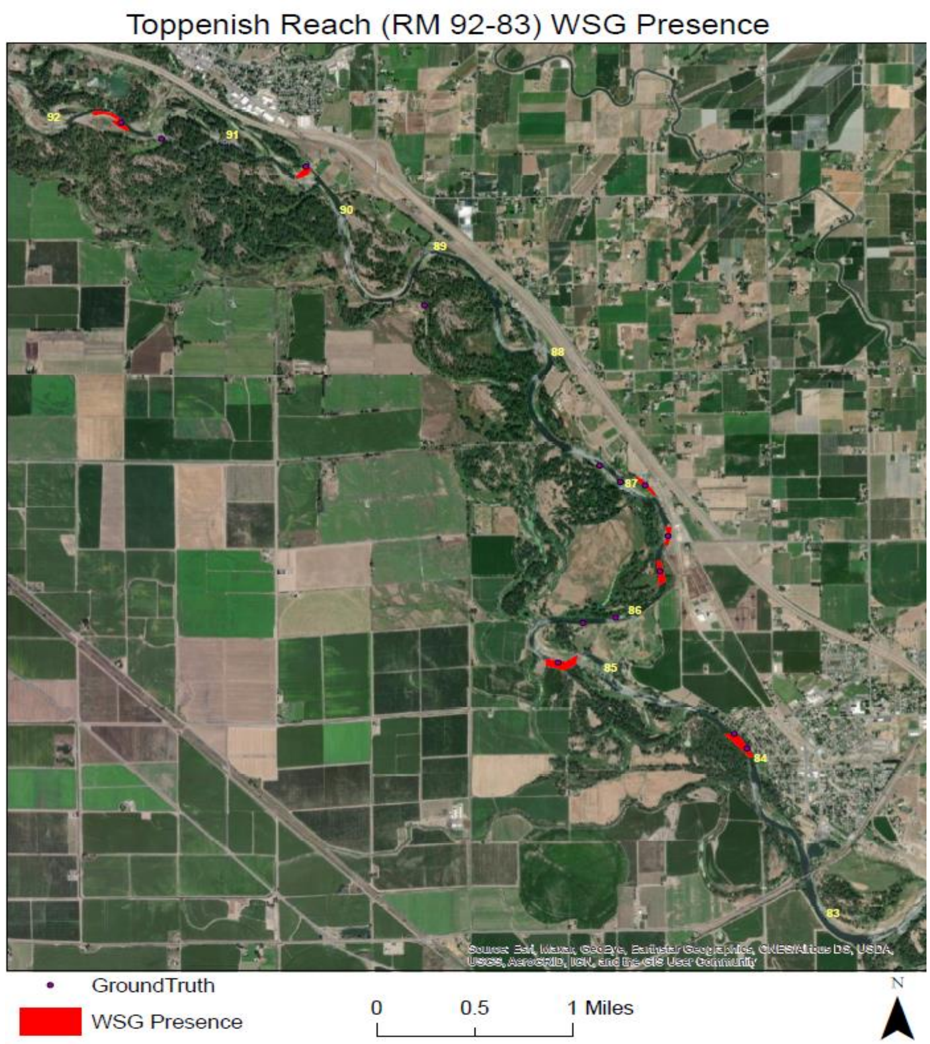

Figure 6. Toppenish Reach WSG presence locations with ground truth points.

4.3 Granger

The Granger Reach is a 9-mile reach beginning at the city of Granger, WA. This reach is classified as a wide floodplain bound by touchet beds and basalt. The gradient continues to fall from the upstream reaches, resulting in a transition in material composition from gravels toward fines as compared to the upper reaches. This reach has three major lower river drainages in the Marion Drain, Toppenish Creek, and Coulee Drain. The WSG in the Granger reach has sporadic hot spots where WSG outcompetes the other macrophytes and has large mats beginning to form in the reach. This is the first reach in which WSG issue begins to take form as WSG begins to clearly outcompete other plant species. However, these dense patches of WSG are relatively isolated within this reach and do not raise major concerns in terms of WSG biomass at the reach level. (Figure 7) .

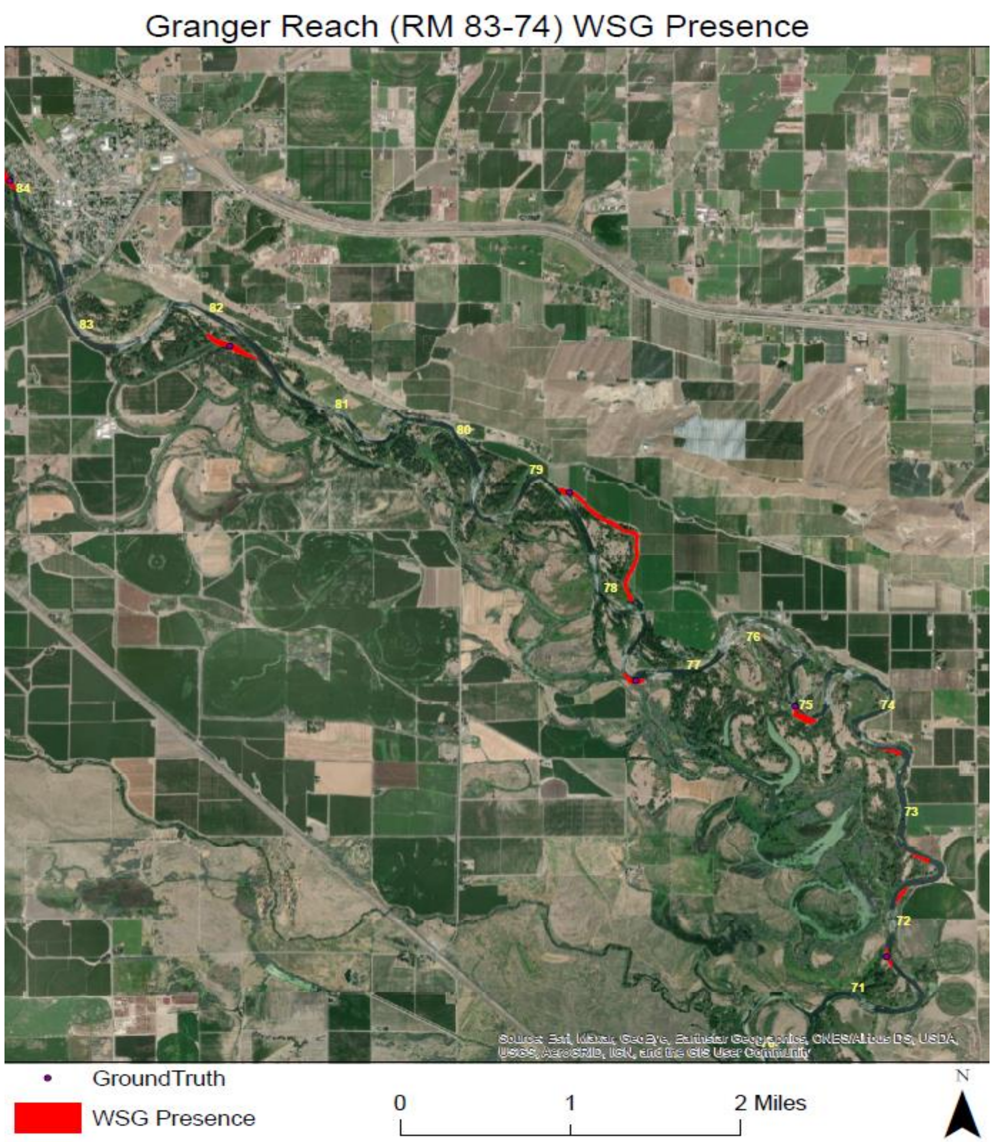

Figure 7. Granger Reach WSG presence locations with ground truth points.

4.4. Mabton

The lowest gradient reach of the lower river is the Mabton reach, and this planform channel is a highly sinuous single braid channel throughout the 15-mile reach. The low gradient floodplain does not contact any terraces at the margins and there is no apparent source of gravels or cobbles that are recruited in this reach. Thus, the riverbed is primarily consistent with finer materials such as sand and silts. This is where WSG abundance begins to become apparent. Here, as you pass the mouth of Satus Creek, the overall composition and WSG matting really begins to outcompete other species and even spans the thalweg. At low flows, this stretch would have WSG occupying the entire water column and completely blocking the channel. Here is the first opportunity to harvest at a large scale and begin to manage the biomass of WSG (Figure 8).

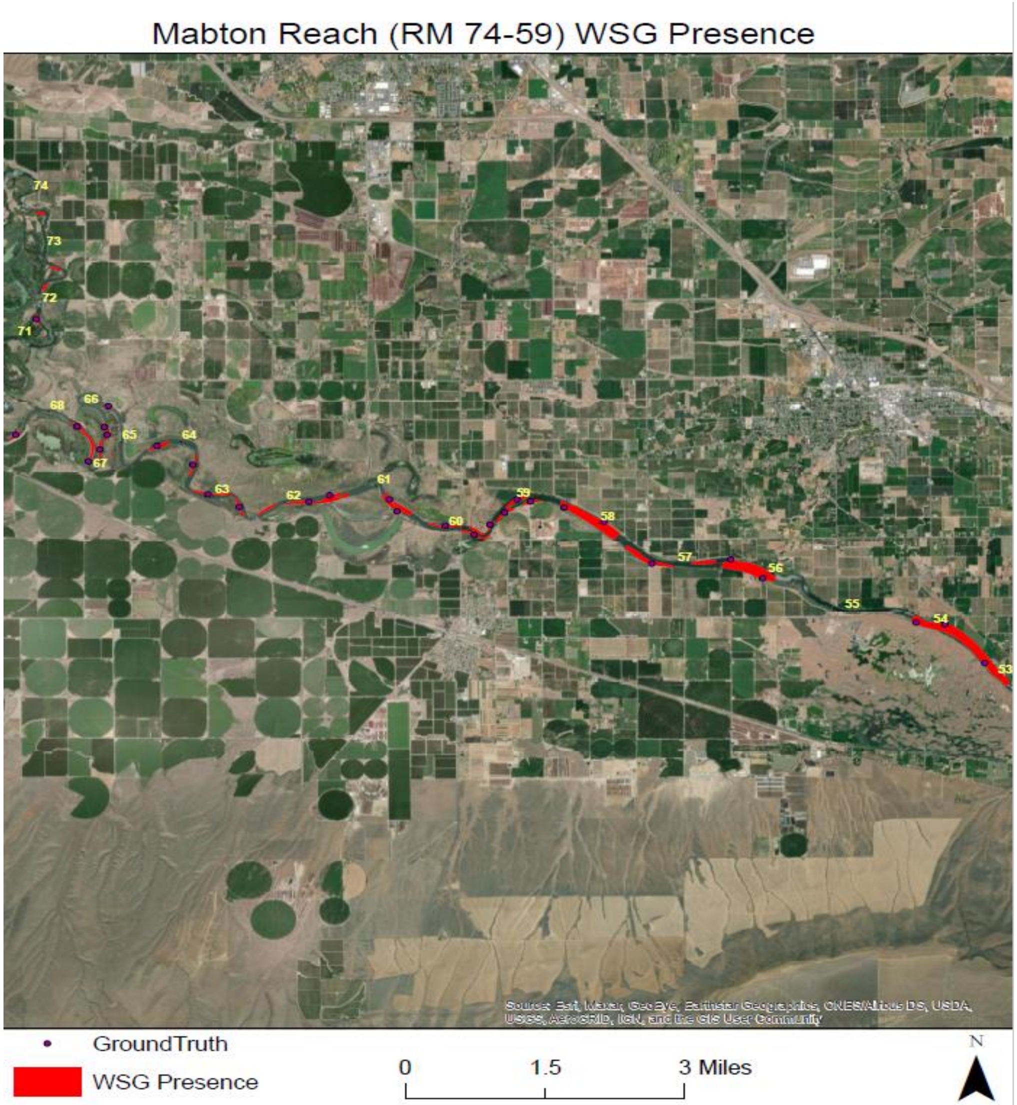

Figure 8. Mabton Reach WSG presence locations with ground truth points.

4.5 Prosser

The Prosser reach begins at the diversion dam that diverts water to the Chandler Canal. This 11-mile reach is amongst the highest gradient reaches of the lower river. Unlike the reaches above, this reach does not have nearly the dominate-cobble riverbed but has a combination of basalt boulders, fines, and is relatively shallow. The fine layer is most likely covering a cobble-dominated riverbed, but the flow management, sediment, and WSG have altered the observed composition. The mixture of be WSG in this reach continues to show water column dominance and occupying the thalweg of the Yakima River. In this reach, Prosser Dam is the first facility that is clearly impacted by the enormous mats of WSG that continually drift downriver. Navigation of this reach also begins to be impacted by WSG as it 'clogs' the flowing water to the surface (Figure 9).

Figure 9.Prosser Reach WSG presence locations with ground truth points.

4.6 Chandler

The Chandler reach is characterized by the large water return from the Chandler Power Plant that is part of the Kennewick Irrigation Operations. This stretch is similar to the upstream reach in that it is largely bedrock, and the coble dominated bed is highly embedded with fine sediment, aquatic vegetation. The first half of the reach with a beginning transition to cobble and sediment near the end of this reach at RM 30 (Benton City). This reach is bounded by the Saddle Mountain Basalt. This reach continues to exhibit channel spanning, water column dominating WSG (Figure 10).

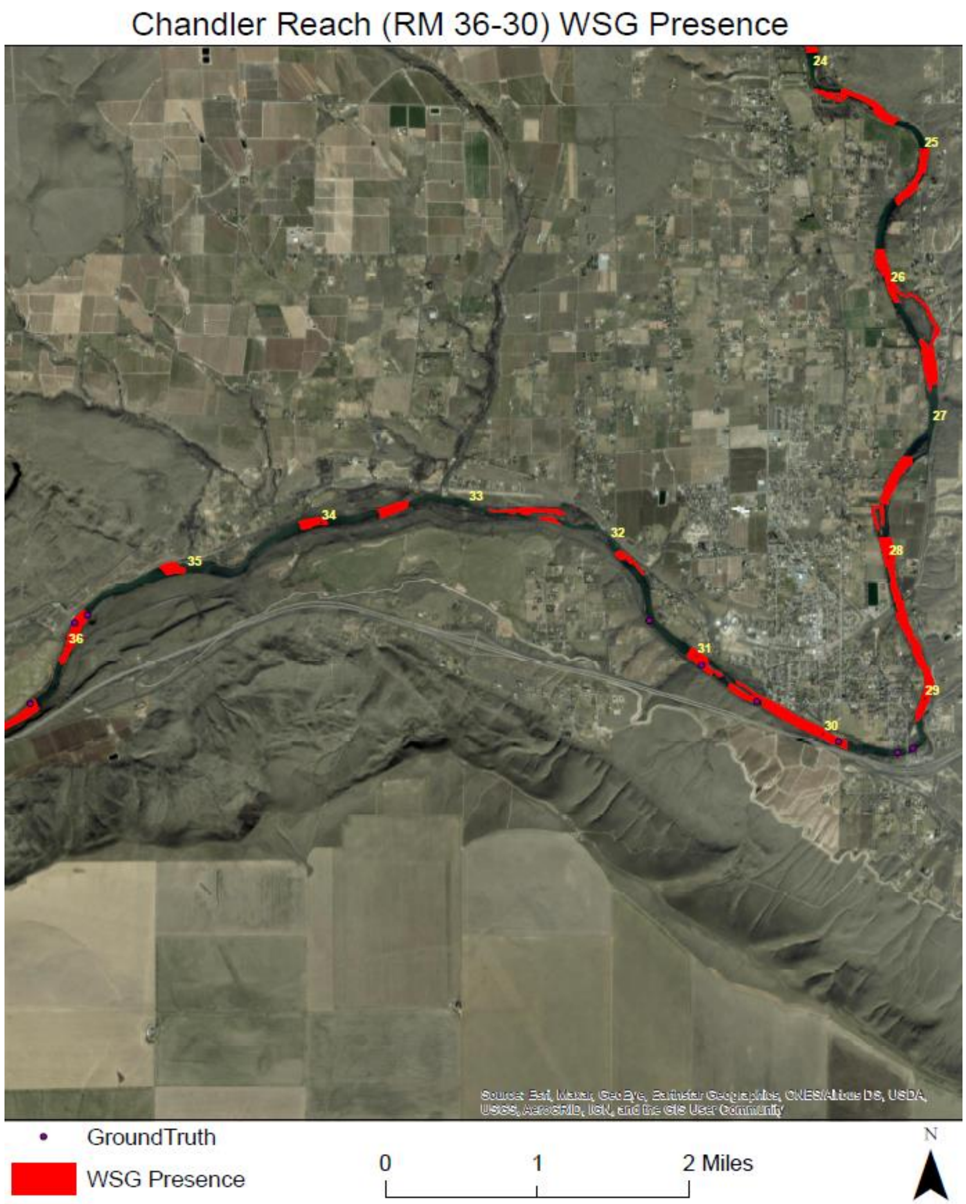

Figure 10.Chandler Reach WSG presence locations with ground truth points.

4.7. Benton

The Benton reach is composed of traditional riffles separated by pools. However, the channel is bounded by terraces of touchet beds and basalt bedrock. Historically, this reach had high Chinook spawning grounds due to gradient, pool features, and had been the start of the most productive spawning gravels of the Yakima River. Just like the reaches above, this reach has lose the function cobble bed structure due to embeddedness, fines, vegetation, and lack of bedload scouring flows. The overall biomass of WSG continues to dominate the Benton reach and outcompetes the majority of the other aquatic plants. Like the upstream reaches, enormous mats of WSG occupy the thalweg and extend to the water surface (Figure 11).

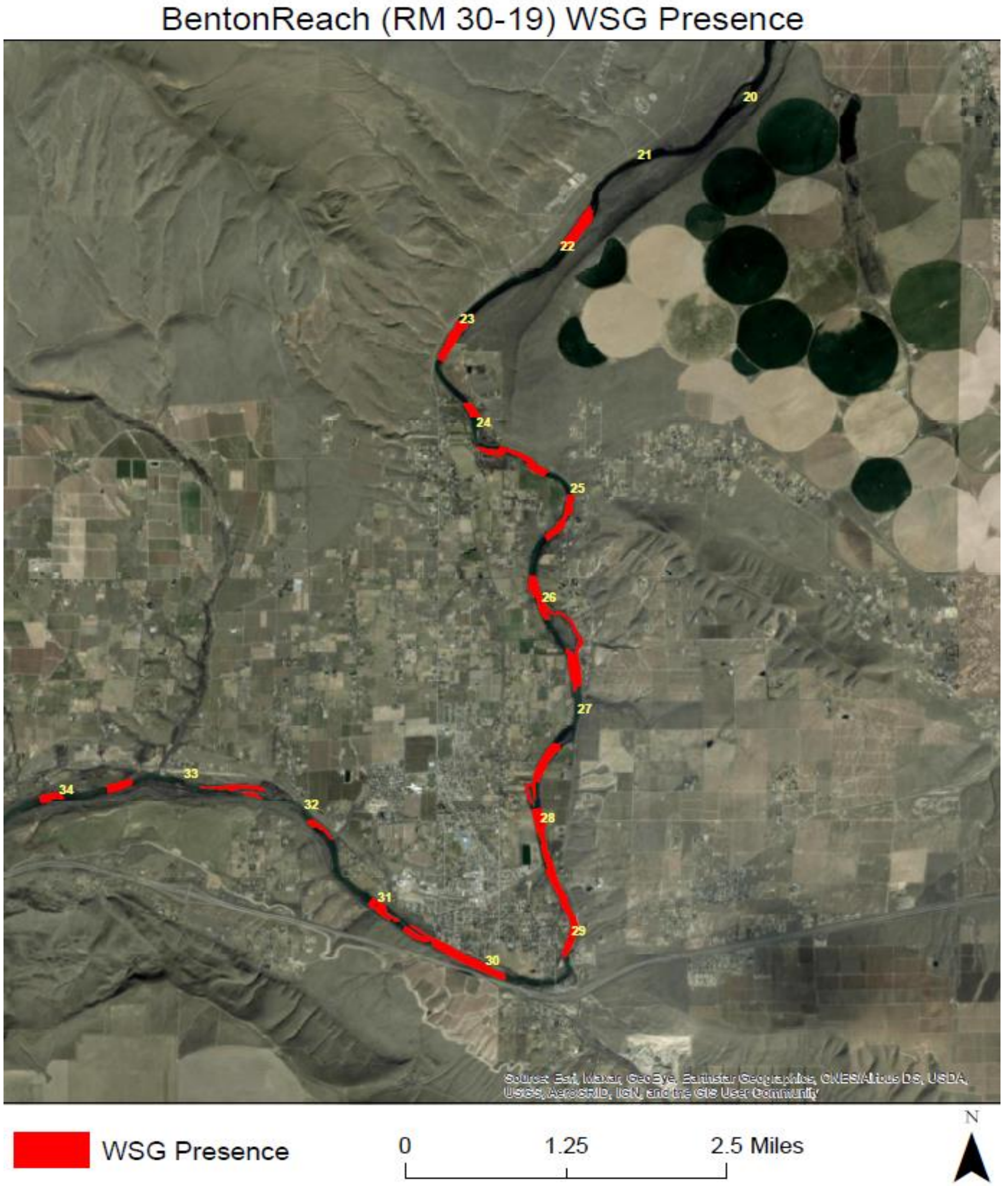

Figure 11. Benton Reach WSG presence locations

4.8 Snively

The Snively reach begins downstream of the Horn Rapids (Wanawish Dam) and has several vegetated islands dividing the channel. However, few exposed gravel bars exist within the active channel. This reach has evidence of channel avulsions and migration. However, compared to upper Yakima River reaches, the Snively reach has limited recent channel movement. The margins of the alluvial floodplain are mostly terraces formed by glacial outburst flood deposits (Reidel and Fecht, 1994). Rural and suburban residential development and irrigated agricultural lands are the predominant landcovers adjacent to the Snively Reach and the Columbia Irrigation District Canal, which begins at Horn Rapids diversion dam and follows the right bank of the Yakima River throughout the Snively Reach . WSG is dominant in this reach, oftentimes channel spanning and emergent (Figure 12).

Figure 12. Snively reach WSG presence locations.

4.9 Confluence

The confluence reach historically would have been an a more functional delta as the Yakima dumped into the Columbia River with a larger degree of the Columbia River impacting delta processes. Presently, it is a low gradient river (partially due to backwatering of the Columbia River from McNary Dam). The suburban and urban surroundings of the Confluence reach have limited channel migration and habitat complexity. The substrate is dominated by fine sediments, and the WSG extent has largely taken over and dominates the confluence reach (Figure 13). The thickness and pervasive nature of WSG in this reach makes jetboat navigation up the Columbia even challenging.

Confluence Reach (RM 6-0) WSG Presence

Figure 13. Confluence Reach WSG presence locations.

5.0 Impacts of Water Stargrass on Native Salmon Populations

The Yakima river was once a significant producer of salmonid species, including Chinook Salmon (*Oncorhynchus tshawyscha*), Coho Salmon (*O.kisutch*). Sockeye Salmon (*O.nerka*), and Steelhead (*O.mykiss*). While some of these species and life histories were extirpated from the basin by the early 1980's, there has been a robust restoration and reintroduction strategy implemented by the Yakama Nation, Yakima and Klickitat Fisheries Program, and other entities to restore and reintroduce the native salmon runs of the basin. Regardless of spatial and temporal differences, each of these species utilize the lower Yakima River to some degree, but mostly as a migratory corridor to their respective spawning grounds and as out migrating smolts. The below section provides details regarding Chinook Salmon and the direct impact of WSG on migration timing and locations of spawning areas. However, it should be noted that all species are likely impacted by the proliferation of WSG in the lower Yakima River. All migratory fish must pass through this section twice and hindrances to fish passage decrease survivability, particularly as water quality is reduced.

5.1 Chinook Salmon

Chinook salmon have three distinct subsets in run timing into the Yakima; these are referred to as spring, summer, and fall Chinook. Spring Chinook return in the spring and move rapidly through the Lower Yakima to hold and spawn in upstream portions of the basin; fall Chinook return in the fall and spawn in the lower elevation portions of the basin (Appel et al. 2011, Yakama Nation Master Plan 2019). Spring Chinook rear higher up in the Basin for a full year before migrating downstream to the Pacific as yearling smolts in the spring. Fall Chinook migrate to the ocean as sub-yearlings in the spring and early summer of the year they are born. By 1970, the summer Chinook was extirpated, and the fall run had to be maintained by hatchery production using out-of-basin brood stock. Summer Chinook return when the river is the most inhospitable (June through September) as temperatures are rising rapidly and available thermal habitat, flow is decreasing, and increased avian predation is prevalent with lower, less turbid water.

Currently, fall Chinook returning to the Yakima River is a combination of hatchery-origin, progeny of local brood stock captured in the vicinity of Prosser Hatchery, and wild-origin fish. Hatchery and brood stock fall Chinook are reared and released as sub-yearling smolts from the Prosser Hatchery or acclimation sites in the lower Naches or middle Yakima Rivers. Yakama Nation Fisheries is working to re-introduce summer-run Chinook to the basin. The work continues in two phases with phase one including the release of 500,000 fish annually above Prosser Dam to recolonize habitat. Phase two includes the transition to using local, natural-origin broodstock for the production of a self-sustaining population. Summer Chinook adults move through the lower Yakima in June through early September, right when WSG and water quality are most problematic. Adults await cool temperature periods and move rapidly upstream when/if they occur. Juvenile summer Chinook out migrate mostly as sub-adults, with a significant number of smolts moving in late spring and early summer when water quality and predation can severely limit their survival. Successful re-introduction of summer run Chinook will in part depend on lower river thermal and water quality improvements.

The continuum of run timing displayed by Chinook salmon highlights the different stressors associated with life stage and lower river usage. Adult Spring Chinook enter the Yakima in March through June with the bulk of the run in May and early June. Juvenile spring Chinook pass through the lower Yakima as smolts from early winter through June, with the bulk of outmigrants leaving in March through May. While in most years lower Yakima water quality is not limiting in this window, in drought years such as 2015, conditions can become inhospitable as early as April, impacting both adult and juvenile migrations.

Fall chinook adults enter the Yakima October through December when water quality conditions are not limiting, but juvenile fall chinook is the latest out-migrating smolts, with much of the run leaving in June and July when poor temperatures and water quality and associated high predation rates greatly reduce their survival.

Comparison of fall Chinook populations in the Yakima River and the neighboring Columbia River Hanford Reach over the last 20 years indicates the Yakima River run remained stagnant, while the Hanford Reach run multiplied five times (Little, BCD with data from WDFW, Pelly et al. 2021). WDFW attributes the stagnation of the Yakima River runs to decreasing water quality and spawning habitat due to WSG growth covering the river, particularly in historic spawning grounds.

According to the Washington State Department of Fish and Wildlife (WDFW), before 2001 about 70% of the Yakima River fall Chinook salmon spawned downstream of Prosser with historical spawning grounds throughout the entire lower river (Figure 14). In contrast, during 2004 to 2008 about 80% of the estimated spawning adults made nests upstream of Prosser (Mueller 2010). Limiting habitat factors for fall Chinook include the amount of spawning habitat and the amount of juvenile rearing habitat (Haring 2001).

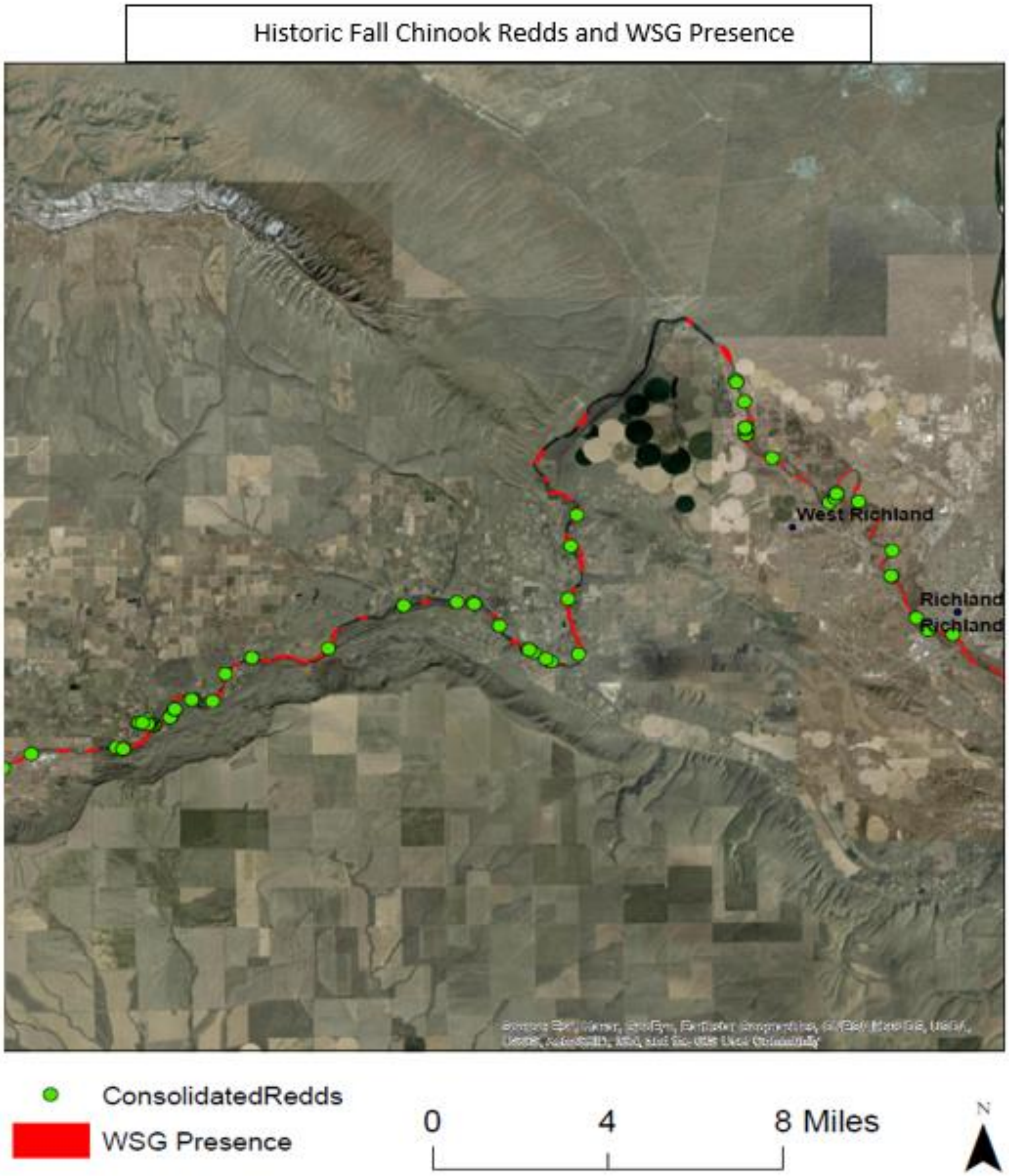

Figure 14. Consolidated historic fall chinook redds (2000-2011) in lower Yakima River, consolidated redds over multiple years. Redd surveys have been abandoned in this reach of the river due to WSG and sedimentation over the historic spawning gravels.

The recent proliferation of WSG and sedimentation of spawning gravels has been a primary cause of the loss of spawning habitat in the lower Yakima River (Hoffarth 2009). In 2002, the WDFW counted more than 1,000 redds in the lower Yakima but by 2008, the count had dropped to 42 (Figure 15, Hoffarth 2009). In 2021 and 2022, no redds were detected from the mouth of the Yakima River to Prosser dam. The loss of all available spawning habitat below Prosser Dam is concerning. Additional losses above Prosser Dam are likely as WSG growth is present in these reaches. Not only does WSG account for direct habitat loss in the spawning area, but it can be inferred that moving spawning further upstream lengthens migration, increases passage constraints, and reduces the survivorship of both juveniles and adults.

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			

Figure 15. Decreasing Redd Counts in the lower Yakima River. Image courtesy of Rachel Little, BCD. Data from WDFW.

5.2 Sockeye Salmon

The Yakima River historically produced a large number of sockeye salmon with highly productive lakes in the upper watershed. In the early 1900's these fish became extirpated from the basin when storage dams blocked access to these lake systems and extremely low summer flows limited adult migration in mid-summer. It is likely the lower Yakima river flows impacted from irrigational ditching and withdrawal had killed off majority of the sockeye prior to the dams. In the 2000's efforts were taken to reintroduce anadromous salmon into the Yakima Basin, with Yakama nation and Bureau of Reclamation evaluating fish passage at the five reservoir dams. This led to the reintroduction of Sockeye to the Cle Elum Reservoir in 2009. Extensive monitoring has shown that these planted adults are successfully producing progeny that eventually migrated to the ocean (Brian Saluskin, Yakama Nation, oral commun., July 2017).

Sockeye salmon are some of the most at risk in terms of run timing and the conditions of the Lower Yakima River. Sockeye migrate through the lower Yakima in June through September in order to spawn in the upper Yakima Basin (Cle Elum) from late September through November (Matala et al. 2019). In order to get to these spawning grounds, Sockeye routinely encounter water temperatures in the lower Yakima River that commonly exceed 24 degrees Celsius. Recent studies highlight that these conditions impede passage, increase mortality, and limit the overall success of sockeye in the Yakima Basin. In drought years, water quality conditions may be impassable to sockeye starting before they first arrive in mid-June through September. In other years, adult sockeye may move rapidly upriver in windows when temperatures at Prosser Dam drop below ~72 degrees F, with migrations not occurring at warmer temperatures. As a result, in a significant number of years, a large portion of the expected Sockeye run is never detected in the Yakima River. The lack of easily passable migration windows through the lower Yakima is one of the primary factors limiting the reintroduction of sockeye to the Yakima Basin.

Sockeye have been shown to stage for extended periods of time in the Columbia to wait for conducive conditions to run up the Yakima River, with some fish waiting until September for conditions that allow them to move in and up the Yakima. They demonstrate rapid movement upstream, and rapid movement back downstream if they are unable to pass diversion dams (Koch et al. 2020) and spend little time in thermal refuge. It can be inferred that WSG could cause increased time spent in this rapid movement pattern which would decrease successful migration. It is also routinely observed that WSG impacts fish ladders at the diversion dams, which would cause rapid movement out of the Yakima. Both instances increase mortality, increase straying, and decrease production of Yakima River sockeye.

5.2 Coho

Similar to other salmon runs in the Yakima Basin, Coho was part of a large annual run in the Yakima Basin. By the 1980's they were extirpated from the Yakima Basin, and in the mid- 1980's through today the population is supported by a hatchery program that collects natural brood and hatchery-raised fish (Yakama Nation Master Plan 2019). The run timing for adults returning to the basin is generally not limited due to fall return however in years of drought the early returning fish will have to hold longer in the Columbia resulting in reduced fitness. The largest limiting factor to naturally reproducing Coho is the outmigration timing of smolts which occurs in June through July. This outmigration leads to drastically reduced survival due to conditions of the lower Yakima becoming increasingly less hospitable for out-migrating smolts due to temperatures, predators, and water quality.

5.3 Steelhead

The Yakima River hosts ESA-listed Mid-Columbia Steelhead. These fish utilize some of the most extreme spaces in the Yakima River due to the plasticity of steelhead. This plasticity leads to a wide migration window (September through July) that Steelhead will utilize and a wide spawn timing which ranges from January to May. Water temperatures in the lower Yakima River create a fish passage barrier, delaying the historical migration of adult steelhead (Yakima Basin Steelhead Recovery Plan, 2009). As stated in the Recovery Plan, ". . . there appears to be a significant correlation between fish movements and periods when flows increase and temperatures drop below 70oF (Yakima Basin Steelhead Recovery Plan, 2009)". Steelhead tend to move in the lower Yakima in response to flow and temperature. Historically, it is thought that some portion of the Yakima River run would have occurred during the summer months, but changes in the summer flows and in-stream water temperatures altered the migration run timing (Yakima Basin Steelhead Recovery Plan, 2009). Current steelhead timing does not appear to be currently impacted by WSG as run timing largely escapes the majority of the high thermal stressors of the lower Yakima River; however, as climate change has disrupted seasons the impact of WSG on future runs cannot be discounted. WSG growing seasons are longer, with biomass sometimes starting earlier in the year and reaching peak growth later in the fall. The shift in growing seasons, especially during drought years impacts water quality, temperature and flows and could have detrimental consequences for Yakima River steelhead population. WSG could also play a critical role in the fall movement of steelhead into the basin as fall senescence causes large rafts of WSG that has been shown to impact fish ladders and dam operations.

5.4 Fish Habitat and Water Stargrass

WSG impairs fish passage in the lower Yakima River and impacts all migratory fish species of the Yakima River Basin. Physical and chemical barriers are causing migration mortality through impairments in water quality and covering of spawning gravels, fish ladders and channel narrowing. Water stargrass can form incredibly dense mats of vegetation that 'carpet' the river through the thalweg and to the surface of the water column. Many observations have been made of fall Chinook, sockeye, beaver, and other organisms avoiding the thick matts to travel in narrow channels in the water column between patches of WSG. Water stargrass also impacts dissolved oxygen, temperature, and pH in the lower Yakima River. Water stargrass causes large fluctuations of dissolved oxygen within the lower Yakima, with daily minimum levels occurring in the morning (Wise et al. 2009) that fall below the state water quality standard of 8 mg/L. Large masses of water stargrass produce oxygen as a byproduct of photosynthesis when light intensity is high. However, during the night oxygen consumption by respiratory demands of plant tissue leads to decreasing levels of dissolved oxygen that reach minimum levels in the morning.

Figure 16. The matting of WSG occupying the entire water column (left), animal and fish navigation lines going through the dense vegetation mats.

The dissolved oxygen and pH fluctuations likely stress local aquatic organisms. In low flow years, maximum pH in the Yakima River was almost always greater than the Washington State standard of 8.5. This high pH can also be lethal to fish, with studies showing that impacts on baseline physiology can begin at pH values of 9.5 (Scott et al., 2005, Wilson et al., 1998). However, in the spring of years with high flows, there were extended periods when the maximum daily pH levels were less than 8.5 (Wise et al. 2009). Additionally, low dissolved oxygen can be lethal to salmon. Studies examining growth saw effects on growth with concentrations at or below 8.6 mg/L (Carter 2005).

During years of drought, increased density of WSG results in a greater extent of the water column occupied by the plant biomass creating less space in the river for fish navigability. While dense matts of WSG may not directly inhibit salmonid movement, constriction of available passages are decreased, and migration duration is expected to increase. Narrow migration corridors increase predation rates

(McMichael 2017) and increased exposure to the thermally lethal conditions that are common in the lower Yakima River will be prolonged and can increase metabolic wasting and death.

Figure 17. Snively Boat launch with channel spanning WSG present

Figure 18. WSG mats impacting fish ladder gates, irrigation gates and overall dam operations. These structures are designed for larger wood material and require constant maintenance by BOR.

5.5 Predation

Predation from both aquatic and terrestrial organisms is a major factor for survival of out-migrating and in-migrating salmonids in and to the Yakima River basin. Predation rates in the Yakima River have seemingly been increasing over time due to conditions of the lower river becoming more conducive for invasive predatory warm-water species. Fall Chinook mortality rates are high in the lower Yakima River where mortality is directly associated with predation rates (McMichael 2017). Water stargrass allows for ponding, constricted flows, and increased warm-water predator habitat. Juvenile smolts that drift with flows are impaired by increased water stargrass biomass volume that grows on the edge margins. Biomass pushes migratory species into a narrower corridor that provides great opportunity for predatory species. The increase in mortality rates in recent years coincides with the expansion and proliferation of WSG in the lower Yakima River and raises concerns over future salmonid survivorship if WSG is not managed.

6.0 Emergency Drought Relief

This plan hinges directly on the ability to utilize Emergency Drought Relief funds to address water quality, fish habitat, and public health. In years of drought, the ability to act quickly and utilize available funding is critical to preserving the health of migratory fish populations. The section below outlines the definition of a drought, available funding, and a summary of the timeline that this plan will utilize for implementation.

6.1 Drought Definition

The drought definition as defined by Washington State Legislature RCW 43.83B.400 is:

> *"'Drought condition' means the water supply for a geographical area or for a significant portion of a geographical area is below seventy-five percent of normal and the water shortage is likely to create undue hardship for various water uses and users."*

Drought conditions impact many different sectors and definitions may not accurately represent all impacted areas. The state level definition guides the declaration and subsequent funding pathways to alleviate potential impacts of a declared drought. The Yakima basin has a unique setting and represents the largest portion of the state's agricultural production. The water supply in this region experiences some of the highest demand across all sectors and changes in water availability pose subsequent hardship across many sectors. This is evident as over 60 percent of the total state emergency drought permits were given to the Yakima Valley during 1994, 2001, 2005, and 2015 droughts. The lower river accounts for half of the total emergency drought actions permitted in the state.

Because the Yakima Valley experiences the highest portion of emergency drought permits, number of people impacted, and natural resources at risk; it is valuable to further streamline responses once a drought is declared. This is especially important considering the variability of impacts projected by a changing climate, increased water usage by a growing population, and the strong possibility of droughts being experienced in Southeastern Washington.

6.2 Drought Stages and Triggers

In the Yakima Basin, official water supply forecasts are not available until early March. This challenges the ability to roll out drought response measures in the Yakima Basin in time for irrigators to incorporate them into their own planning. Obtaining probabilistic water supply forecasts earlier in the season provides more lead time for response measures such as water right leasing and emergency wells, however, this is not always the case as seasons can provide surprises. Due to a high degree of regulation in the water cycle present in the Yakima River where usage rates are known for irrigation and dedicated instream flows have been established, model estimates of summer and fall water availability are improving and more reliable.

The Bureau of Reclamation (Bureau) operates the Yakima Project, consisting of five separate reservoirs in the Upper Yakima, Naches, and Tieton watersheds (Kachess, Keechelus, Cle Elum, Rimrock, and Bumping Lake reservoirs). At full capacity, these reservoirs store a combined total of 1,065,400-acre feet. They supply water to about 450,000 acres of irrigation land. Total out-of-stream water right entitlements in the Yakima Basin equal 2,406,917 acre-feet (Bureau of Reclamation 2011). Meeting these needs requires a combination of natural runoff from snowmelt and precipitation, releases from storage, and recapture of return flow from irrigated land. About 330,000 acre-feet of return flow, as measured at Parker, is used to meet total water demand in the lower Yakima River (the amount of return flow is more in wet years and less in dry years).

Monitoring and forecasting are important for managing and maintaining a water balance in the Yakima River Basin. Additionally, drought responses are critical efforts that can mitigate hardship across the many water users in the Yakima Basin. The plan revision outlined by the Washington State Drought Contingency Plan (2018) committed to a Two-State Drought Framework: Advisory and Emergency. The two stages are triggered by different criteria within a recurring process of monitoring and forecasting to determine if water supply conditions meet hydrological and hardship triggers. When the hydrologic criteria are met for a geographic area (e.g., a specific watershed, region, or the entire state), a drought advisory may be issued. When both the hydrologic criteria and the hardship criteria are met, a formal drought declaration emergency may be issued.

With the timing and release of funds, it is vital to understand the stages so that the match requirements can be met. Additionally, the rapid mobilization and funding timeline that can start any time from April-July means that appropriate planning takes place well before years of drought. The goal of this document is to ensure that rapid action can be taken if and when the drought declaration and release of funding takes place.

6.3 Timing of Emergency Drought Declaration and Funding

A drought declaration can be issued at any time of year by the state Governor, but historically, forecasts are issued in the spring months. Early in the water year (October through December), water supply forecasts for the coming April-through-September season have a wide range of possible outcomes. Because snowpack is a major component of water supply conditions over much of the state, spring brings much more clarity on water supply. Judgment must be exercised regarding the risk of acting versus not acting and choosing between an advisory and an emergency declaration. Delaying action will foreclose some options for response as the water year continues. When risks to vulnerable users in the absence of state action are high, it may be prudent to move forward with a drought advisory or declaration. Drought declarations are not open-ended, and may only be issued for up to a 1-year time period (RCW43.83B.405 (2)). The duration may be extended up to 1 additional year with written consent of the Governor.

At the Drought Advisory stage, Ecology prepares to accept applications for emergency drought permits. Historically, holders of pro-ratable irrigation rights in the Yakima Basin have filed most applications. In a drought advisory phase, Ecology may begin refreshing application templates and coordinating with local agencies. In the Yakima Basin, for example, the regional staff should begin to assess the number of water rights holders who may be interested in using emergency drought wells.

The timing of the state budget allocation occurs prior to water supply reporting of the proceeding water year, but emergency funds can be acquired for mitigation as drought conditions are advised or declared. Because the timing and release of these funds when a drought is declared is not set, preparing actions for implementation allows for the best chance to mitigate the impacts of WSG on fish passage and habitat quality. Having specific drought actions prepared to apply for drought relief funds will decrease the response time for implementation. This is pertinent as the time between drought declaration and released funds can be rapid leaving little time to mobilize and finish the relief efforts. For example, following the drought declaration in 2019, the Department of Ecology solicited proposals for $2.0 million in funds on April 4th. The Legislation then adopted a budget on April 28th of 2019 and funds were available for use by June 4, 2019. All funds had to be spent by April of the following year. This short turn-around time between funding allocation and mobilization requires adaptability and readiness to proceed by the lower Yakima Basin Partners for targeted control of Water Stargrass removal.

The award at this time was limited to $350,000 per request and required a 50 percent match of the total cost of the project. There were also three eligible elements:

1. Must be partially or completely within the area of a drought declaration order by Ecology:

(a) The public water system's service area.

(b) The geographic area where irrigated agriculture or livestock are located.

(c) The source of water, or the water body, that supplies water to the entity applying for funding.

2. The reduction in water supply caused by drought must cause, or will cause, undue hardship, as described under WAC 173-167-120.

3. Cost-share funds of at least 50 percent are required unless the applicant qualifies for an exemption from this requirement under WAC 173-167-030(3).

The drought mitigation plan outlined in this document addresses two of the qualifying project elements of Ecology's Drought Relief Funding eligibility "Fisheries and Wildlife". These include actions to ensure fish survival and health within hatcheries, which includes improvement to water quality, water supply, or other measures. With water stargrass targeting:

"Projects that eliminate migration barriers, such as temporary structures to increase flow velocity or depth".

Additionally, water stargrass treatments address drought response funding elements pertaining to "Agriculture and Irrigation". Water stargrass removal improves irrigators' abilities to divert water more efficiently supporting agriculture and livestock."

6.4 Funding for Drought Response

Funding is typically released from the state budget and can be highly variable depending on each year's available funding. Once released, funding is provided through various state agencies including Department of Ecology and Washington State Conservation Commission. Ideally, the most effective way the state can reduce hardship and stress due to drought is through a predictable and timely source of funding, however, this is rarely the case. Future planning, managing water supply imbalances, infrastructure upgrades, and integrated planning across the sectors are also effective measures to combat the impacts of droughts in the Yakima Basin by increasing resiliency. The Yakima Integrated Plan is a nationally significant watershed enhancement proposal for the Yakima Basin which, when completed, will substantially reduce drought vulnerability in the Yakima Basin. The YBIP plan includes seven elements, two of which are directly addressed by this plan (bolded) while this plan initiates discussion of a third (italicized):

- **Fish passage at existing dams**
- **Habitat protection and enhancement**
- *Structural and operational changes*
- Surface water storage
- Groundwater storage
- Enhanced water conservation
- Market-based reallocation

Contingency drought planning should not be precluded from the YBIP biennium fund allocations given the increasing frequency with which droughts are anticipated as a result of climate change alterations. As state funds typically require a high level of match funding (50%), YBIP may provide a source of matching funds that enable critical projects to move forward in water limited years. This could help continued collaboration of the basin's stakeholders, specifically decreasing the amount of WSG in the system will allow irrigation outtakes, fish ladders, and other infrastructure to be unimpeded by WSG rafting, thalweg blockages, and increase overall water transport efficiencies in years of drought. Also knowing that the scale of this problem continues well outside years of drought and cannot be remedied just in times of drought.

7.0 Drought Year Action Plan

This plan identifies key areas for WSG removal on the lower Yakima River and provides a shovel ready approach for fast mobilization in emergency drought years. Basin-wide agency coordination and adaptive management strategies will be necessary in years of drought. It should be noted that to minimize impairment of river function, yearly management of WSG will aid in preventing further reductions in water quality during normal and drought years.

The recommended actions are detailed below, providing prioritization of sites, methods of control to be implemented, plans for disposal of WSG, and overall costs. Due to the large length of river occupied by thick growth of WSG, this plan addresses the most severe locations, with expectations that long term future management is required. Previous work was used to identify targeted management areas and approaches based on metrics including fish habitat, accessibility, disposal site proximity, and river hydrology.

The scale of this issue for the lower Yakima River cannot be tackled in just drought years and other strategies for this issue are outlined in various documents including the WSG Management Techniques report (Pelly et al 2021) and the WSG Recommendations Report (BCD, 2022). However, while stakeholders and river managers are working towards longer-term reach scale solutions, it's important to be able to act swiftly in a drought with available tools to mitigate the most deleterious effects of water stargrass.

7.1. Drought Year Mitigation

In order to best mitigate WSG impacts in years of droughts, monitoring flows in February, April, and May will be a priority as low flows during these months are a strong indication of increased WSG abundance and density in the summer. Early water forecasts and drought year designations increase the chances that preventative management approaches can be taken such as early mechanical harvesting of WSG to reduce thick matting. Correctly timing early harvest is critical as spring and summer salmon runs could move through the river prior to the development of dense patches of WSG growth. Early removal is expected to open the greatest amount of habitat by improving historic redd locations and movement corridors. Additionally, previous pilot works demonstrated that hand removal of WSG from historic redd sites opens spawning habitat for subsequent years. Therefore, during drought years WSG should be removed from as many priority areas as possible in the Yakima River using all means available.

Harvests should continue through August and September to mitigate impacts to water quality and to allow for passage and spawning of fall runs. River conditions are typically more favorable to access and harvest during June, July, and August. A greater number of labor hours are expected to be required to remove WSG during these months in drought years.

Funding and staff to support large scale removal beyond these test plots has not been available to the BCD. Additional funds will allow the recruitment of paid labor and outreach efforts to identify volunteers and provide necessary accommodations for volunteers (housing, first aid supplies, drinking water, safety and equipment).

7.2 Water Stargrass Emergency Response Control Methods

The WSG Management Techniques report (Pelly et al 2021) and the WSG Recommendations Report (BCD, 2022) highlighted targeted control methods of WSG. Effective control of WSG in typical water years and especially during drought requires the integration of multiple management techniques. To effectively manage large amounts of macrophyte biomass, multiple methods across different times throughout the plant’s life cycle are needed. While the WSG management and WSG Recommendations reports outline the costs and benefits of many alternatives, this emergency response plan must rely on the methods that can be most rapidly implemented. These methods include manual removal (Hand-pulling and/or Hand-digging) and a mechanical approach (Aquatic Harvester). These methods take into account the WDFW-designated in-stream work window of June 1-Septemeber 15th to ensure minimal disturbance of spawning or incubating salmonids. The key control methods for emergency removal outlined in this document are summarized in Table 1. These include:

- Manual Removal
- Mechanical Harvesting

It should be noted that approaches such as managed flows, application of herbicides, bottom barriers, or shading are not being considered in this plan. This is because implementation is delayed due to timing requirements, permitting, and coordination of efforts from multiple agencies. This reduces the ability to rapidly implement these approaches in times of drought. Additionally, removal of water stargrass has been observed to immediately improve river flow, whereas the knowledge of the authors' other approaches have not been tested in the Yakima and effectiveness is not known. Further work to identify and evaluate additional treatment methods is needed, but is outside the scope of this plan.

Table 1. Modified table from Pelly et al. 2019.

Method	Likely Work Window	Effectiveness for Water Stargrass	Advantages	Disadvantages	Permit Required	Notes
Manual Methods						
<u>Hand-pulling and/or Hand-digging</u> Scale: Small, local Duration: Longer term if roots removed (multiple seasons)	Jun 1–Sep 15	Very effective if roots are removed	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	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						
<u>Harvesting</u> *Scale:* Large areas *Duration:* Long-term	Jun 1–Sep 15	Possibly effective long-term (pulling type); likely short-term effective (cutting type)	Can remove plants across a large area Removed plants are automatically captured and prevented from floating downstream	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

7.2.1 Manual Removal

The most action-ready, simplest, and cheapest form of removal is hand-pulling in conjunction with hand digging. This can be performed with and without tools, and requires no specialized skill, training, or equipment. However, this approach is limited to areas where water depth allows access by wading. BCD has found the combination of digging and pulling to be the most effective manual removal method. This is because when WSG is simply hand-pulled it can return rapidly, however, when root mass is removed areas remain clear for up to three years. Removal can be aided with hand rakes, hooks, and other tools to allow better disruption of root and substrate. A pilot hand-removal project observed fall Chinook redds after WSG removal and water flows cleared the gravel bed of accumulated sediment.

A major detractor of combined hand-removal methodology is the requirement for large amounts of labor. Hand-removal also requires shallow water depths for individuals to effectively and safely remove WSG. To adequately remove roots of WSG, the individual must be able to reach the river sediment without diving. Fortunately, the recommended WDFW timing window coincides with the lowest flows (USGS 2022). Additionally, water levels will be lower in years that a drought emergency is declared, increasing access to portions of the river. This will allow the labor-intensive process to have lasting impacts along traditionally deeper sections that are not typically able to be hand-harvested. As the amount of labor needed to clear an area is substantial, it is necessary to identify areas of greatest importance (Chartrand et al. 2017, Pelly et al. 2021). Therefore, historic spawning grounds should be prioritized, with factors such as access, nearby disposal location or transport, and WSG abundance impacting the determination of which site locations will yield the greatest benefits.

While hand-pulling causes minimal environmental impacts beyond short, localized disturbances; manual removal of plants can lead to WSG fragmentation and proliferation (Chartrand et al. 2017). However, the overwhelming abundance of WSG in the lower Yakima River makes this effect unlikely to impact WSG presence in lower sections of the river.

Figure 19. Photo by Rachel Little (BCD) showing hand harvest of WSG

7.2.2 Mechanical Removal

Benton Conservation District acquired an aquatic harvester in 2021. This harvester is a paddle wheel powered pontoon boat that loads vegetation onto a bunk using a conveyor. The head of the boat has two attachments for capturing vegetation; a roller head that removes aquatic vegetation by pulling the shoots, and a cutter head that shears vegetation. This harvester increases the scale at which aquatic vegetation can be removed from the river. Scaling this harvester to additional units would drastically improve efforts to remedy the WSG issue in the lower Yakima River.

The limitation to mechanical harvesting of vegetation includes specialized training to safely operate the vessel and efficiently harvest. Additionally, the harvester requires an improved boat launch into relatively slow-moving water. The harvester has limited power and can only navigate slow moving water and harvest in areas where minimal obstacles are present. While manufacturing specifications state the vessel can operate in little as a foot of water (Lake Weeders Digest LLC), BCD operators have found that two feet is an operational minimum. Finally, harvesting of vegetation rapidly fills the 10 cubic yard bunk and a nearby offloading site is crucial for efficient removal as the boats slow movement speed results in long transport times moving material from the harvest area to unloading locations. Approaches, collaboration, and permitting to allow for "pull and drift' methods would drastically improve drought response efficiencies.

Additional limitations include the indiscriminate removal of plants by harvesters, thus requiring an HPA from WDFW and Shoreline Master Program permit prior to harvesting (Chartrand et al. 2017).

Harvesting projects will be required to adhere to the WDFW timing window of June 1–September 15. Additional permit considerations may include a solid water disposal permit. However, the Shoreline Master's Program permit and Solid Waste permit may be avoided if an exception letter is authorized as the plan falls under a fish and wildlife enhancement. Because WSG is a native plant that has proliferated on a large scale within the basin and impairs river function, permitting this project is expected to proceed quickly in years of drought.

The difference in the harvester heads may allow for flexibility in the management of WSG. The two types of harvester heads differ in their efficiency at removing dense WSG. The cutting head appears more effective cutting denser areas of WSG quickly. However, this method may be less effective at reducing growth in future years. However, repeated passes in the same area could improve the level of mitigation and long-term impacts (Madsen 2000). While slower, the roller head is able to remove some root material as plants are pulled from the water. In years of drought, the cutting head may prove more efficient at rapid clearing while the roller head is expected to be more effective at reducing WSG growth in the following year.

Evidence supporting the efficiency of mechanical harvest is growing, with Chelan Public Utility District utilizing large-scale harvesting of milfoil on the Columbia River. They have implemented harvesting as treatment since 2010 during peak growing season May-September. Additionally, Columbia Irrigation District was able to contract a harvester to clear WSG biomass that was preventing flow into an irrigation intake gate. High growth rates were caused by drought conditions, but immediately following harvest flows into the irrigation intake resumed.

In 2022, BCD staff harvested 1.5 acres at Horn Rapids park and Benton City. Natural high flows delayed harvesting and impacted seasonal plant growth that year. In 2022, peak biomass occurred in the fall instead of mid-summer, so the majority of biomass growth was outside the permitted work window. However, the increased flows and delayed plant growth temporarily improved minimum dissolved oxygen levels in the early summers at the USGS gauges.

Additionally, 3 additional sites were harvested in the lower Yakima from July through September 2023. A total of 30.8 acres were cleared with an estimated 500,000 lbs of biomass removed during 2023 operations. The clearing resulted in immediate changes in river hydrology. Additional assessment of WSG harvest occurred in 2023; while the overall area of WSG harvest around Benton City was low (roughly 5 acres) it showed a substantial improvement in dissolved oxygen concentrations (+ 0.6 mg/L). The overall concentration remained well below 8.0 mg/L, however, the substantial improvement in DO post-harvest shows a meaningful impact on water quality is possible with a larger harvesting effort.

7. 2.3 Combined Methodology

To ensure emergency drought plan objectives and goals are met, this plan aims to utilize combined effort of manual and mechanical harvesting. While mechanical harvest is more efficient, many sites do not have adequate access, water depth, or low enough flow rates to allow for it. Provided adequate labor forces are available, it will be beneficial to employ both hand crews and harvester crews in conjunction to access more sites and to complete more work during the WDFW in-stream work window. Table 2 describes priorities that will be used to determine ranking in a drought. In depth site descriptions are provided in the following section, identifying current conditions and methods deemed most suitable for safe and efficient removal of WSG.

Table 2. Methods and ranking system to be used in Emergency Drought Plan

Method	Likely Work Window	Area descriptions	Locations	Priority	Permit Required	Notes
Manual Methods						
Hand-pulling **Hand-digging**	Jun 1–Sep 15	-Shallow, near shore areas -Disposal site nearby or on-shore -Site Channels or Thermal Refuge sites -Historically observed Chinook redds	● Upper Mabton reach ● Prosser reach below dam ● Benton City ● Chandler Reach ● Below Horn Rapids dam	1- Low-flow and safe wading conditions 2- Historic spawning grounds 3- Disposal site proximity 4- Density and coverage of WSG	2015 pamphlet (WDFW)	Previous work removing WSG by hand pulling and digging required a crew of approximately 30 people working for a month to clear one acre. Many factors including travel time to reach the site, physical fitness, river conditions and access will all impact labor requirements.
Mechanical Methods						
Harvesting ***Rolling Head Or Cutting Head***	Jun 1–Sep 15	-Updated boat access -Deeper, slow moving water (>3 foot depth) -Near migratory pinch points for salmonid	● Above Prosser dam ● Lower portion of Mabton Reach ● Confluence Area (additional permits may be required) ● Horn Rapids	1- Updated boat access 2- Conducive operating environment 3- Proximity to disposal site 4- Area covered by WSG	Hydraulic Project Approval (WDFW) Solid Waste Disposal Shoreline Masters USACE (in confluence area)	Previous work using the mechanical harvest required two operators working three days to clear one acre when launching and disposal access was excellent.

7.3 Permitting

Due to its status as a native plant, permitting for removal of native plants does not require a complex process and is expected to require minimal time and financial costs. For manual or mechanical methods of plant management, governed by the Washington Department of Fish and Wildlife (WDFW), water stargrass is classified as an aquatic beneficial plant. 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).

Hand removal does not require an HPA or additional permitting which reduces response time from award funding to implementation. 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. These plants have stricter permit requirements. Therefore, for management of water stargrass, the pamphlet only covers removal by hand (which includes hand-pulling, using hand-held tools or equipment, or using equipment that is carried when used). All other physical and mechanical control methods will require individual HPAs to be issued by WDFW. A solid waste permit may be required depending on accessibility of offloading locations for harvested materials.

Common questions and concerns related to permitting are the need for cultural resources correspondences and assessments. This project has zero ground disturbance, so no cultural resource assessments or permitting requirements are needed. Additionally, attached to this document is a letter for Benton Franklin Health District saying no special permit is needed for disposal of WSG (Attachment A). Also attached is the rolling Hydraulic Project Approval. As alternative strategies become available to mitigate the issue, additional permits, approvals, and correspondence may be needed.

7.4 Anticipated Impacts from Previous-Treatments

Benton Conservation District began evaluating the feasibility and efficacy of manual removal of WSG in 2007 and 2008. The first project utilized hand pulling of three small test sites where water depth allowed wading and manual removal where both roots and shoots were attempted to be completely removed. These pilot project sites yielded mixed results following the first year of treatment. The first site showed a returning monoculture stand of water stargrass, but at reduced plant density (based on dry weight). In the second site, water stargrass did not return for one year following treatment but was replaced by curly leaf pondweed *(Potamogeton crispus*), introduced from Eurasia. The third site remained clear of all aquatic macrophytes two years after treatment. It is possible that removal techniques were improved at each subsequent site, but this effect was not evaluated. This pilot study also allowed observations to be made during drying and composting harvested WSG. Like most aquatic vegetation WSG is mostly water and dries to very small nearly weightless strands. This biomass resulted in highly productive soils when landowners tilled WSG into the soil (BCD pilot harvest)

The second water stargrass removal project with Benton Conservation District investigated a larger-scale manual removal of water stargrass in 2010. Many volunteers assisted with this project and exhibited a range of diligence, skill, and speed at removing water stargrass. This project demonstrated the importance of thorough and efficient harvesting. When only the tops of the plants were removed, the plants quickly rebound, returning from the root mass and leafing again within a matter of days. When the root mass was completely removed, the area remained clear for approximately 2-3 years at which point WSG recolonized the area. In the autumn following WSG removal, staff and volunteers observed fall Chinook redds, adult fish guarding the redds, and carcasses within the 1.5-acre project boundary. It was observed qualitatively that water velocity and sedimentation rates varied with removal of a large area of water stargrass.

Figure 20. Prolific WSG abundances found on the lower Yakima River.

In 2015, removal of WSG from around an irrigation dam led to a steadier and much improved water supply. While the exact volume or improvement was not quantitatively shown, the effort annually to remove WSG from outtakes highlights the importance of the removal of this from the system to increase water delivery. In years of drought, the importance and necessity to have effective and reliable water conveyance is vital for everyone and everything. Increasing the scale of the harvest, collaborating with the irrigation districts, and the overall harvest of this plant leads to huge benefits not only in years or drought but the years following.

Late in the summer of 2021 Benton Conservation District received a large custom-built mechanical harvester for removal of WSG in the Yakima River. While only a small window for harvesting remained in the summer of 2021, mechanical testing and staff training were performed to prepare for large scale cutting. In late August of 2022 following test runs to assess boat launch and travel feasibility, a 1-acre test plot near horn rapids park was cut, and a strip of vegetation was removed near the Benton city boat launch. Observational data showed that WSG in these plots did not have significant regrowth and was free of thick vegetation for the remainder of the summer and fall. In August of 2023, Benton Conservation District scaled up the harvesting efforts at Horn Rapids Park, Benton City, and the Yakima River Delta. The harvester was operated for 26 days (145 equipment hours) with 855 cubic yards of material removed from the lower Yakima River. The total weight of water stargrass removed for the 2023 season was estimated to be 504,000 lbs. The average harvest rate for equipment is 2 loads/hour. The mechanical harvester efforts greatly scaled up the amount of biomass that can be removed from the lower Yakima River. However, this method is only confined to areas with minimal currents, deeper water, and suitable boat launch access. While one harvester is able to remove a significant amount of biomass from one location, several harvesters are likely needed for a larger scale effort in a critical drought year. During a drought year, deploying multiple mechanical harvesters with a range of sizes and capabilities would provide the maximum benefit for clearing water stargrass during the permit window.

8.0 Priority Treatment Areas and Goals

Utilizing the presence maps developed by MCF, it was determined that an emergency drought plan should focus effort exclusively from the Mabton reach to the confluence.

Combining preliminary work by MCF with observations from BCD, areas were identified where the highest biomass of WSG is present within the lower portions of the Yakima River (below Prosser). Prolific WSG growth begins in the Mabton Reach. Here the estimated macrophyte composition transitions to nearly full dominance of WSG, and occurrence of WSG across the thalweg begins to occur. In all upstream reaches there is WSG present, however, it resembles other native macrophytes and does not dominate the water column. This plan covers priority treatment areas and logistics within each reach starting at the Mabton reach where WSG becomes a nuisance species impairing river function.

8.1 Mabton

The primary goal of WSG mitigation in the Mabton area would be to diminish upstream WSG plant material. Effectively removing some of the propagation potential of the plant material by decreasing available biomass. In the upper portions of this reach, WSG is not of particular concern and occurs in natural abundances. However, as the river gradient decreases, WSG colonization increases. While harvesting of this site would be lower priority due to location within the watershed and lack of historic spawning redd observations, it should be mentioned this reach has WSG that occurs through the thalweg. An aquatic rake was deployed in areas where the bottom could not be observed, and each time WSG material was brought up with the rake. While it does not occupy the entire water column, it could be assumed it has the potential to be a fish passage issue in years of drought or as future temperature increases or sedimentation increases growth and rooting ability.

The Mabton reach does not have abundant redds located within the reach. However, it is the final leg of migration needed to reach the historic sites directly upstream in the Granger reach. The Mabton reach does have an updated boat launch for a mechanical harvester. The combination of the updated boat launch, potential coordination with Yakama Nation directly below Satus Creek for hand harvesting crews, and proximity of potential drying sites allows for effective WSG management in this reach.

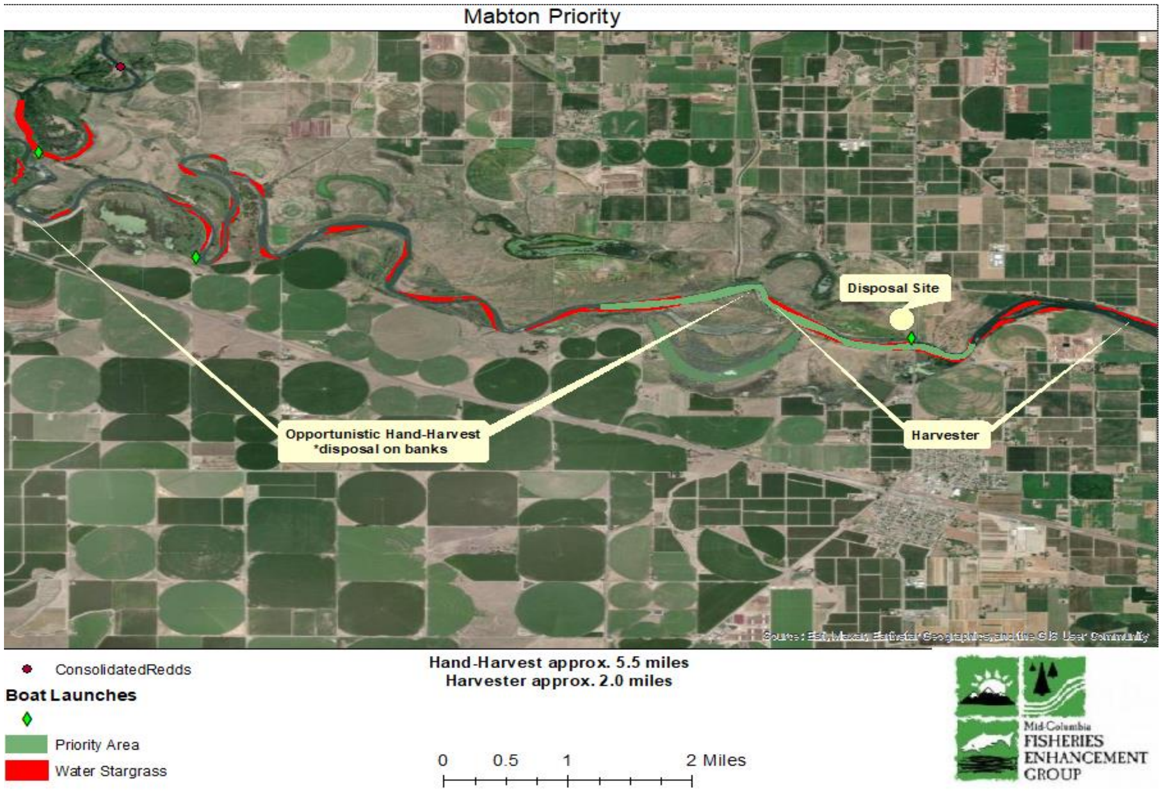

Figure 21. Mabton drought priority plan with disposal site and zones to use harvest technique.

8.2 Prosser

The Prosser reach is amongst the highest priority areas for emergency drought due to fish passage issues associated with the fish ladder and quality of habitat above Prosser Dam. With recent studies showing the presence of sockeye migration in the lower Yakima River, it is important to get fish above Prosser as quickly as possible so they do not turn back to the Columbia for refuge. It is also important to always keep fish ladders passable, so that any drop in temperatures can allow sockeye to move above the dam. Sockeye will take advantage of any cooler temperature window to leave the Columbia River refuge area, and if the dam is blocked due to WSG then this effort and energy is wasted.

Keeping the pool above the dam clear will help ensure fish passage and alleviate biomass rafts blocking the fish ladders in potential critical times of migration. This plan outlines a few disposal sites, however all opportunities for disposal will be continually investigated. The U.S Bureau of Reclamation has offered space within the lands of their ownership for staging of cut material near Prosser Dam. The potential to 'Cut and Drift' the WSG material for increased biomass harvest should be considered at this site in emergency years. This will take coordination with both the Bureau of Reclamation and WDFW.

Prosser Priority

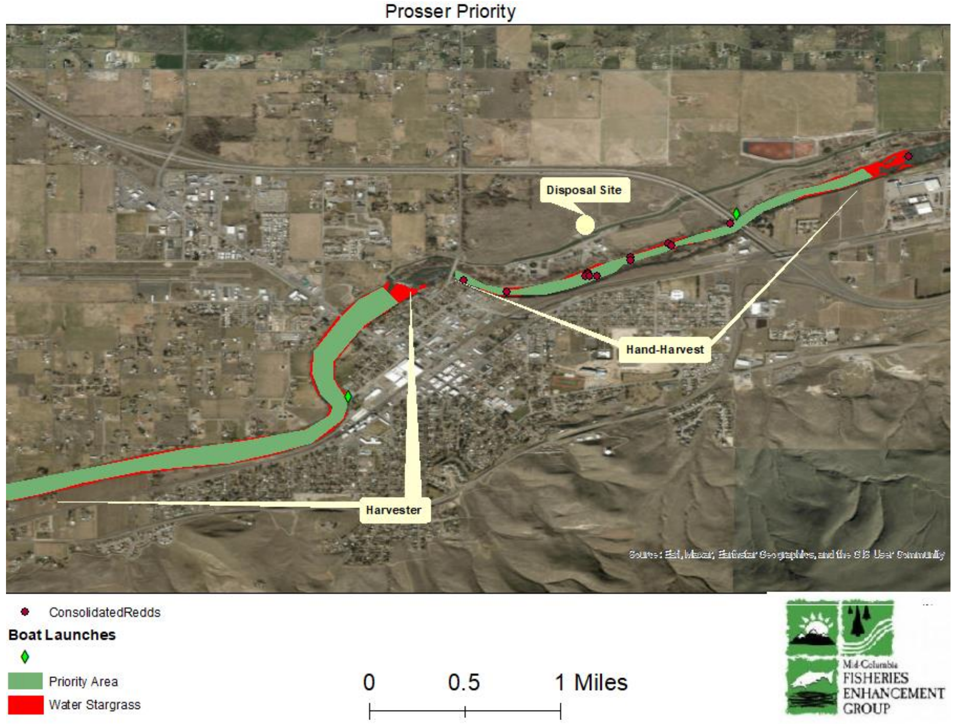

Figure 22. Prosser drought priority plan with disposal site and zones to use harvest technique.

A key component of the Prosser Reach is high fish usage of thermal refuge at the Sulphur Creek site. While site permission has not been confirmed at the time of this plan's completion, the site has good access for personnel and disposal of vegetation.

Sulpher Priority

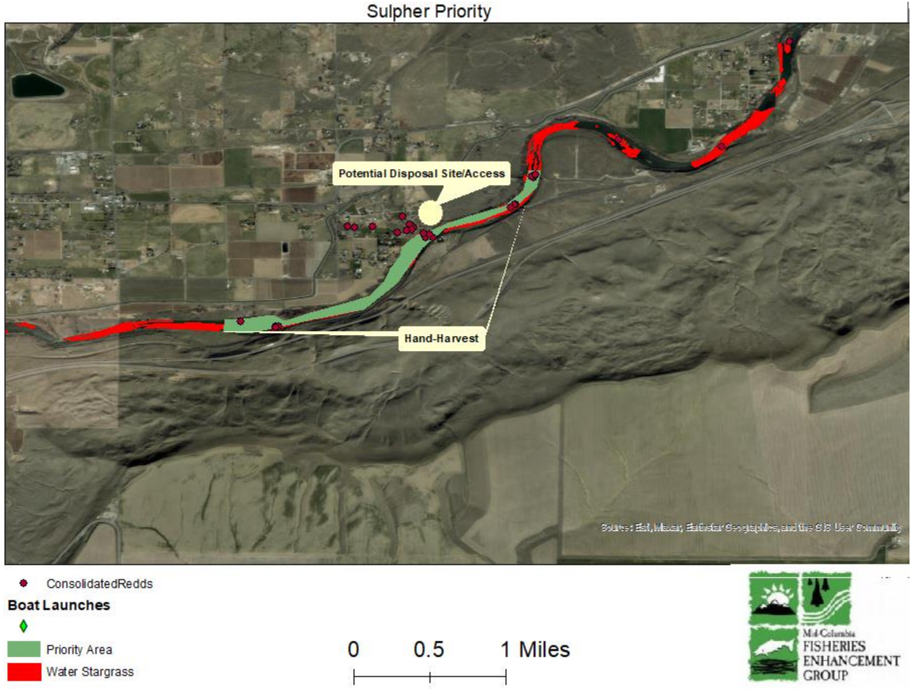

Figure 23. Sulphur drought priority plan with disposal site and zones to use harvest technique.

8.3 Chandler

The Chandler reach may have fewer sites available for harvesting WSG due to variability in flow, limited river access, river obstructions, and lack of disposal sites. However, there is an abundance of WSG in the reach that extends across the width of the channel and dominates macrophyte composition. Harvesting the lower portion priority area would require river access and disposal sites for hand-harvesting. Future coordination will need to occur with the landowners along this reach. This includes coordination with Chandler Power Plant which could provide a primitive launch point for hand-harvest crews to opportunistically harvest via canoe or other lightweight rigs. The WSG Recommendations report also cites the potential for water level drawdowns and considerations of chemical treatments, which if developed in future years would help this reach in times when mitigation is a priority.

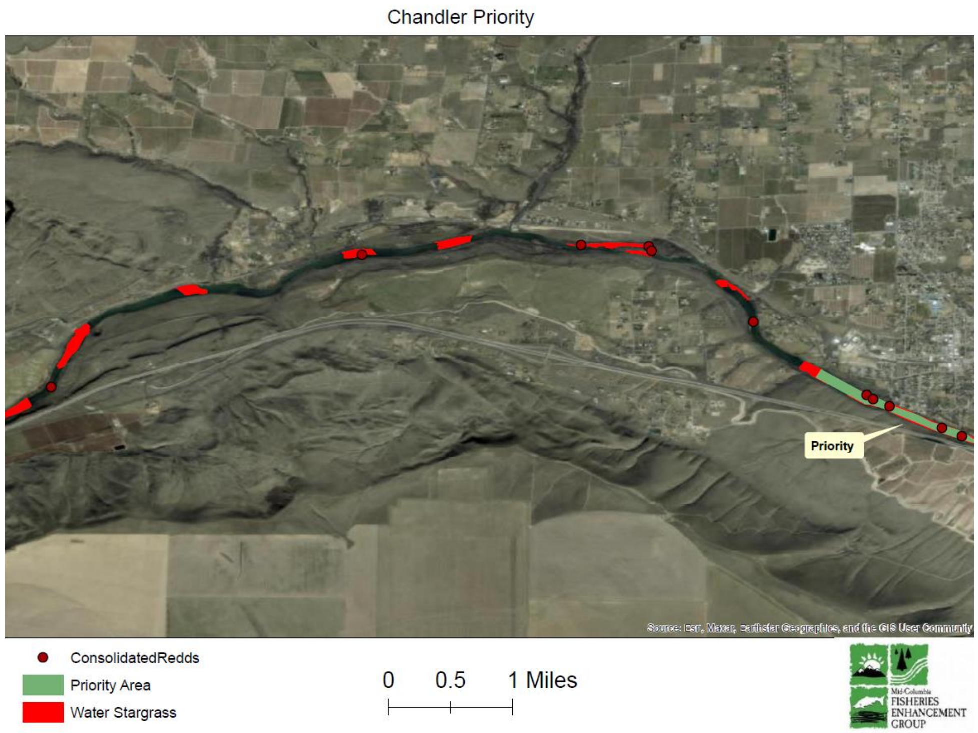

Figure 24. Chandler drought priority plan with disposal site and zones to use harvest technique.

8.4 Benton

Some of the identified areas in the Benton reach are in close proximity to Benton City Boat Launch, which could provide sites to unload harvested WSG. Private landowners, the city of Benton, and WDFW will be coordinated with for access to sites further down the reach and locations for disposal of harvested material. The shallow flows upstream of the boat launch may prohibit access for the Harvester to work in upstream areas of dense vegetation. Working with WDFW and Benton City for access locations upstream may be required to efficiently clear this reach of excessive biomass. Hand-pulling crews may be another potential option for hard to access upstream areas.

Figure 25. Benton drought priority plan with disposal site and zones to use harvest technique.

8.5 Snively

The priority areas in the Snively reach would be utilizing the Horn Rapid's Park to launch the Harvester, and the downstream launch to mobilize hand-harvest crew to target shallower spawning areas inaccessible to the harvester. Depending on crew size, the possibility would be to launch canoes, kayaks, and shallow vessels with the disposal site being nearby landowners. Otherwise, the nearest location is downstream at ~RM 3.5 on Army Corps of Engineers property (See below in confluence reach disposal areas). Similar to the Prosser Dam approach, clearing the pool above the dam will increase fish passage, and allow for more effective migration of salmonid species above the dam without fish ladder hindrances.

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Snively Reach

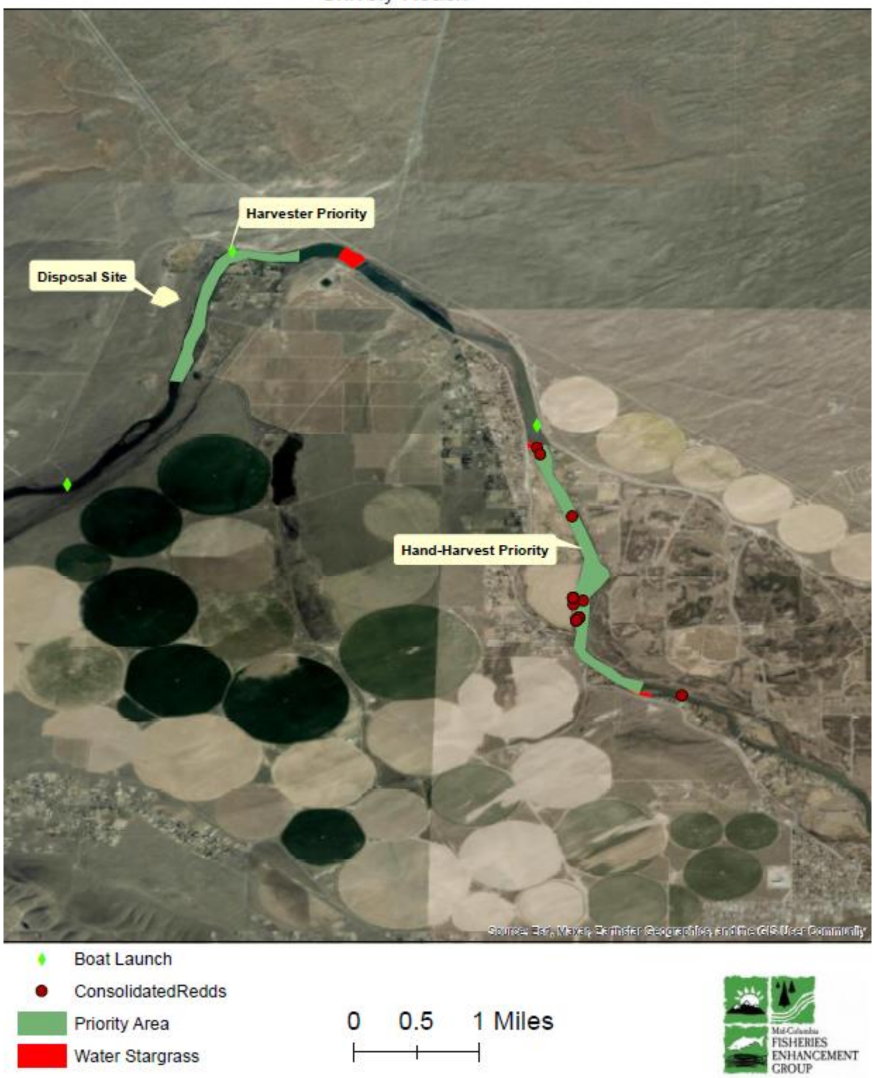

Figure 26. Snively drought priority plan with disposal site and zones to use harvest technique.

8.6 Confluence

The confluence reach could potentially be the greatest barrier to anadromous fish in the Yakima Basin. WSG blocked fish ladders in the upstream reaches confounded by the Bateman Island Causeway which leads to a large fish passage issue. WSG in this reach has effectively constrained the flow in the mouth of the Yakima River, and the many sections of this reach are dominated fully by WSG. It should be noted that this reach likely has a greater WSG abundance, as point observations and satellite digitization did not adequately address the abundance throughout the water column. While this area is still passable during low flows, it should be a priority to begin mitigating the deleterious impacts that abundant WSG causes. The impacts on stream temperature, reduced velocities, and dissolved oxygen would make the confluence area the highest priority as it relates to fish passage.

Here the harvester would harvest corridors up to RM 2.5 and dispose of the material in areas deemed appropriate by the Army Corps of Engineers. Additionally, there is the opportunity to have hand harvest crews clearing the area around Amon Creek. Amon Creek is a cool water input in the lower river; allowing fish access to the site could provide needed thermal relief in hot summer temperatures. USACE permission will be needed in the confluence area.

Figure 27. Confluence drought priority plan with disposal site and zones to use harvest technique.

8.7 Priority Ranking

Available funds will be used in the most efficient manner. Based on current access, WSG locations, and management methods, the current priority ranking for the top four sites is listed below:

1. Confluence
2. Prosser
3. Benton
4. Snively
5. Monitoring of treatments

This ranking is based upon fish passage as the priority in drought years, and the later being areas that have the highest spawning potential.

Confluence

The confluence is the first migratory barrier that fish encounter when returning to the Yakima River. Beyond the thermal barrier of this reach, the WSG chokes the river and effectively eliminates flow. With fish passage being priority, it would benefit the entire system to get fish through the confluence reach quickly and effectively. This site also benefits from boat access and disposal site on Army Corps of Engineers property.

Prosser

Prosser has been suggested to be the thermal block that limits sockeye and chinook migration through critical migration periods. Once fish reach this portion of the river it is imperative that the energy, they spent getting to this point is not wasted. If the ladders are blocked, there is minimal refuge below until the confluence reach. The established infrastructure allows for easy access, disposal, and ensuring fish passage. This section of river also is conducive for the much-needed studies on water quality, harvest impacts, and fish passage this issue needs. The monitoring needs on WSG impacts of dam operations would provide critical operational changes which this plan should address.

Benton

While fish passage ranks out the first two sites, the Benton site allows for fish usage. Chinook spawning grounds historically were prolific below Prosser and have since been abandoned due to WSG filling in gravels. Anecdotally, work done by Rachel Little showed that following hand harvest, spawning effort was observed in the harvest section as the gravels were uncovered. Harvesting in this reach will allow demonstration that spawning is directly impacted by WSG abundance while also opening the migratory corridor further. Monitoring efforts in WSG treatments of spawning habitat should be conducted to test this hypothesis, but anecdotal evidence from Benton Conservation District found a fall Chinook redd immediately after WSG harvest.

Snively

This reach includes another fish ladder and dam pool harvest strategy. Similar to the Prosser approach, this reach will harvest the pool above Horn Rapids to keep fish passage at the dam site. The ease of access and proximity of the disposal site make this an effective candidate to remove large swaths of WSG from the system. This will also allow for a more effective migration corridor and decrease avian predation of adults and overall predation of juvenile migrants.

Other considerations

It should be mentioned that increased hand-harvest in historic Chinook redd reaches is imperative to addressing the issue WSG causes in the Yakima Basin. This means, that sites will be selected opportunistically for spawning grounds, passage, and disposal site in years of drought declarations. This will not only open up critical habitat, but it will also help manage the issue into the future by decreasing biomass that the harvester cannot reach. It is also clearly evident that increased monitoring efforts on the impacts of WSG on river process and function should be addressed when dealing with an issue at this scale.

8.8 Staff and Equipment Needs for Quick Mobilization

While BCD deploys equipment and staff to support WSG management during typical water years, additional staff support and equipment will improve efforts to remove WSG. During drought years WSG will begin to alter water quality and flow rates earlier in the year and with greater severity. Additional WSG management will be needed to maintain water quality, aquatic habitat, and fish passage. Increasing the length and scale of harvesting operations will require additional resources in the form of staff requirements and equipment usage.

Additional staff hours and staff members will be needed to transport and operate equipment, harvest WSG by hand, and move harvested WSG offsite. In addition to trained and experienced BCD staff members that are able to operate the harvester, operators for trucks, trailers, and shuttle vessels to transport WSG from the harvester to shore are needed. The purchase, loan, or rental of a transport craft such as a flat-bottomed boat will be necessary as a shuttle to ferry material from the harvester onto a trailer for removal.

Support for these operations may come from Benton Mosquito Control District, Benton County Noxious Weed Control Board, Washington Department of Fish and Wildlife, and the US Army Corps of Engineers.

9.0 Adaptive Management and Future Considerations

As the abundance and biomass of WSG in the lower Yakima River is managed, there are many opportunities for adaptive management of the impairment of river function and public use. However, improving the efficiency of management practices will be critical in remedying the scale and scope of the issue of WSG. Currently, adopting a 'cut and drift' approach would allow drastic increases in the scale of harvesting.

While evidence of WSG is apparent during the late summer, there is a lack of formal research related to habitat quality, impacts on river functions, and best management approaches for controlling its spread. Thus, there are challenges in developing best management practices for limiting the growth of WSG to maintain river health. While inferences and anecdotal evidence have led to some management practices that have reduced biomass in targeted areas, there is a need for more robust studies to understand the ecological impact this plant's proliferation has on river processes and aquatic organisms. Understanding, researching, and addressing these impacts will lead to better management in the future and provide the foundation for projects addressing river vegetation concerns.

Evidence suggests that annual management and harvest of WSG is needed to remedy reductions in water velocity in the lower Yakima River. Additionally, large mats of macrophyte vegetation are associated with reduced water quality as temperature increases and nighttime dissolved oxygen is reduced. These concerns over water quality likely impair fish passage and ecological function, but currently, there are limited management options to reduce these impacts. While the priority areas of harvest in drought years were strategically selected, the issue encompasses nearly 60 miles of the Yakima River and requires larger scale management plans. Complete removal of stargrass in selected areas may not improve river conditions due to the large-scale invasion of WSG and deteriorated conditions from nearby sites. However, implementing annual management and increasing harvesting activities can reduce the scale and magnitude of WSG biomass prior to drought year designations.

This drought response plan should be updated as discussions of methods including "cut and drift" are being considered and additional control methods are discovered. A less labor-intensive approach like cut and drift would increase accessibility to many sections of the river that currently do not have offloading locations or are constrained by travel time to offload. Time spent cutting WSG with the aquatic harvester would be doubled as the conveyors would not need to be rotated and run backwards to offload material. Additionally, no management of harvested material would be necessary and would avoid equipment and labor for offloading and transport of harvested WSG. The efficiency of hand crews would also increase and would allow for larger areas to be cleared as no labor would be required to transport WSG to drying locations. These methods are of particular interest because labor is the largest limitation to the management process.

Additional updates should be made as disposal sites are identified, annual flow conditions allow for more targeted removal in areas, and more research comes out as it relates to this native species proliferation in an altered system. As focus shifts to lower river water quality, predation, and other factors impacting anadromous fish production in the Yakima Basin it is important to highlight how dynamic, widespread, and impactful this issue is. Continued efforts are being made to highlight partnerships, creative strategies, and a year-year approach to this issue.

Another approach would be bank drying on approved lands. The weight and biomass upon removal is heavy and cumbersome for transport from the river. Allowing the harvester to unload to a bank would decrease fuel cost, travel time, and overall operational efficiency which would allow for more harvesting. The same would be true of the hand harvesters, which would simply pile the harvested material on the bank for drying. Previous harvesting operations observed piles 6 feet tall drying to several inches in a four-month period. There is potential in the future that strategic flow draw down combined with chemical treatments could be used in non-migratory fish windows to quickly alleviate the issue, however this approach will need extensive study and assessment to ensure it is effective, safe, and minimizes the potential for adverse impacts.

Future approaches may not be limited to physical removal as chemical treatments may be found to be effective for WSG. Bubble barriers have been used to successfully contain chemical treatments in river systems (Sartain et al. 2022) and could be used to treat specific areas. It is unknown if surface applications of herbicides are effective when applied to the above water portions of WSG. Selection of appropriate and specific herbicides that can target WSG without wider concerns are necessary to secure permits. These treatments would need to be applied earlier in the season so that the effects could be realized during critical drought periods. While not currently planned, future work using chemical treatments remains a possibility as management approaches are evaluated for impact, efficiency, cost, and practicality.

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Appendix A

Correspondence with BOR Dam Operations

Gmail Zac Zacavish <zac@midcolumbiafisheries.org>

WSG harvest

3 messages

Zac Zacavish <zac@midcolumbiafisheries.org> Tue, Jul 18, 2023 at 8:26 AM
To: "Monk, Patrick A" <pamonk@usbr.gov>

Hi Pat,

Yesterday you mentioned the fish ladder/dam issues with WSG. As the WSG Emergency Drought report gets wrapped up, I was wondering if you could draft a letter/email about the impacts on fish ladders and potential fish passage to put as an attachment in the document. I am hoping while there is not much in terms of research on WSG impacts, this could help steer some funding toward WSG harvest. Could also highlight BOR partnership with harvest/areas to help compost

Happy Trails!
Zac Zacavish
Project Manager/Fish Biologist
Mid-Columbia Fisheries Enhancement Group
1200 Chesterly Dr. Ste. 270
Yakima, WA 98902
681-208-2850 (mobile)
zac@midcolumbiafisheries.org

Note: No trees were killed in the sending of this message, however a large number of electrons were inconvenienced

Monk, Patrick A <pamonk@usbr.gov> Wed, Jul 26, 2023 at 7:07 AM
To: zac zacavish <zac@midcolumbiafisheries.org>
Cc: "McDaniel, James M" <jmmcdaniel@usbr.gov>

Sorry for delayed response Zack. I attached a few photos of the fishways on Wanawish Dam on the lower Yakima River at Horn Rapids showing water stargrass build up on the fishway exit trash rack and the dam forebay in front of the rack showing dense growth. During the height of the water stargrass growth in the summer fishway exits can become blocked frequently. The racks were designed to keep larger woody debris out of the fishways, which is removed by hand, but even daily removal of water stargrass can't prevent blockage of the trash rack. When water quality is suitable adult salmon migrate upstream from the Columbia River during any month of the summer. USGS has some monitoring data suggesting adult Sockeye salmon, which migrate primarily in summer, were delayed at the dam during their upstream migration, although the causes of delays weren't identified. Harvest of the material in front of the fishways might decrease the build up of the stargrass in the ladder exit and help keep the ladders cleaner for longer time periods. Reclamation could provide some support in-kind labor or equipment such as a backhoe and dump truck to remove material that is harvested for composting. Over the long term the fishways may require modification but that will take some engineering design and planning.

Patrick Monk

Fish Biologist

HYDRAULIC PROJECT APPROVAL

Washington Department of
Fish & Wildlife
PO Box 43234
Olympia, WA 98504-3234
(360) 902-2200

Issued Date: May 17, 2021
Project End Date: September 15, 2025

Permit Number: 2021-3-15+01
FPA/Public Notice Number: N/A
Application ID: 24642

PERMITTEE	AUTHORIZED AGENT OR CONTRACTOR
Benton Conservation District ATTENTION: Mark Nielson 10121 W. Clearwater Avenue, Suite 101 Kennewick, WA 99336	

Project Name: Lower Yakima River Stargrass Harvesting

Project Description: Project Need - The purpose of this project is to monitor how mechanical harvest can relieve fish passage barriers created by excessive stargrass growth. Water stargrass can present both physical and chemical barriers to salmonid spawning habitat. The physical barrier occurs because stargrass covers gravel in historic spawning areas, preventing the fish from accessing the gravel to build nests. The chemical barrier occurs when overnight respiration by the plants consumes dissolved oxygen down to levels that will stop chinook spawner upstream migration. It is anticipated that the removal of water stargrass in key locations at baseflow conditions will improve water quality, enhance and provide access to spawning habitat, improve migratory habitat, and improve water quality. Mowing during baseflow conditions will improve habitat conditions for migrant steelhead, sockeye, summer chinook and Pacific lamprey in the Lower Yakima River.

Timing – Project implementation is planned for July and August of 2021 and will be implemented during the authorized Washington Department of Fish & Wildlife in-water work window for the Lower Yakima River and per the WDFW Aquatic Plants and Fish pamphlet. Funding for additional water stargrass removal in subsequent years is expected but not yet guaranteed. If possible, it is hoped that relevant permits be issued for a five year period.

Staging and Access — The aquatic plant harvesting vessel will be launched from a boat trailer at developed public boat launches that are owned and maintained by Washington Department of Fish and Wildlife, Benton County, and City of Richland. These boat launches are the Benton City Boat Launch, Horn Rapids Park, and the Columbia Park Marina. Project vehicles and trailers will remain within the boundaries of paved boat launches and parking areas so no ground disturbance will be required for project staging. A wheeled conveyor trailer will be used to receive harvested aquatic plant material from the harvesting vessel. The conveyor trailer will be used to transport the freshly harvested aquatic plant material to an area at least 25 feet above the ordinary high water mark for further drying in a temporary location. Harvesting aquatic plants and their safe, temporary storage will be the top priority during the limited in-water work window of July and August. Dried aquatic plant piles will be removed after the end of the summer in-water work window, during fall and not later than December. Size and location of temporary drying piles will be in accordance with a plan (in process of development) to be approved by Benton-Franklin Health District. Project budget includes fees for disposal of this green waste in the City of Richland sanitary landfill.

Project Monitoring - Data collection before and after stargrass harvest will include macroinvertebrates, fish use, and water quality (parameters: temperature, dissolved oxygen, turbidity).

HYDRAULIC PROJECT APPROVAL

Washington Department of
Fish & Wildlife
PO Box 43234
Olympia, WA 98504-3234
(360) 902-2200

Issued Date: May 17, 2021
Project End Date: September 15, 2025

Permit Number: 2021-3-15+01
FPA/Public Notice Number: N/A
Application ID: 24642

PROVISIONS

1. Work shall be accomplished per plans and specifications approved by the Washington Department of Fish and Wildlife entitled Lower Yakima River Stargrass Harvesting dated 3/24/2021 and Stargrass Work Areas (Project Drawings) date 3/23/2021, except as modified by this Hydraulic Project Approval. A copy of these plans shall be available on site during construction.

2. TIMING LIMITATIONS
This Hydraulic Project Approval is effective July 1, 2021 and all in-water work of aquatic plant harvesting is limited to July 1 through August 31.

3. When using mechanical harvesters or cutters to remove or control aquatic noxious weeds, completely remove detached plants and plant parts from the water body. Dispose of detached plants and plant parts at an upland site so they will not reenter waters of the state.

4. Prevent contaminants from the project, such as petroleum products, hydraulic fluid, or any other toxic or harmful materials, from entering or leaching into waters of the state. Keep equipment well-maintained and use food-grade oil in the hydraulic system

5. If at any time, as a result of project activities, you observe a fish kill or fish life in distress, you must immediately cease operations and notify the department. You may not resume work until the department gives approval. The department will require additional measures to mitigate the project impacts.

6. Existing fish habitat components such as logs, stumps, and large boulders may be relocated within the water body if needed to operate the equipment. Do not remove these habitat components from the water body.

7. Always operate mechanical harvesters and cutters so that they cause the least adverse impact to fish life.

8. Immediately and safely return to the water body all fish life that becomes entrained in the cut vegetation while operating a mechanical harvester.

9. Do not use contaminated equipment which can spread plant parts. Thoroughly remove and properly dispose of all viable plants and plant parts from the equipment before using the equipment in waters of the state.

10. Limit alteration or disturbance of the bank and bank vegetation to that required to conduct the project. Protect all disturbed areas from erosion using vegetation or other means. Replant the banks within one year with native or other approved woody species.

LOCATION #1:	Site Name: Horn Rapids near Horn Rapids Park & Boat Launch, Benton City, WA 99320					
WORK START:	July 1, 2021			WORK END:	September 15, 2026	
WRIA		Waterbody:			Tributary to:	
37 - Yakima (Below Naches R)		Yakima River (rb)			Columbia River	
1/4 SEC:	Section:	Township:	Range:	Latitude:	Longitude:	County:
	04	10 N	27 E	46.379028	-119.432108	Benton
Location #1 Driving Directions						

HYDRAULIC PROJECT APPROVAL

Washington Department of
Fish & Wildlife
PO Box 43234
Olympia, WA 98504-3234
(360) 902-2200

Issued Date: May 17, 2021
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FPA/Public Notice Number: N/A
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From I-82, take the Benton City exit #96 to WA-225. Turn north towards City Center onto 1st St/Webber Canyon Road. Proceed north through Benton City. Horn Rapids Park, Campground and Boat Launch located on right and is well marked with signs.						
LOCATION #2:	Site Name: Benton City near Benton City Recreation Area & Boat Launch, Benton City, WA 99320					
WORK START:	July 1, 2021			WORK END:	September 15, 2021	
WRIA		Waterbody:			Tributary to:	
37 - Yakima (Below Naches R)		Yakima River (rb)			Columbia River	
1/4 SEC:	Section:	Township:	Range:	Latitude:	Longitude:	County:
	19	09 N	27 E	46.254714	-119.473739	Benton
Location #2 Driving Directions						
The Benton City work area can be reached by taking the Benton City exit #96 from I-82. Turn northbound onto Webber Canyon/1st Street towards Benton City city center. Cross the bridge over the Yakima River. Immediately after crossing the bridge, turn right into the Benton City Recreation Area and Boat Launch, which will serve as the access point for the Benton City work area.						
LOCATION #3:	Site Name: Amon near Yakima Delta Habitat Management Unit, Richland, WA 99352					
WORK START:	July 1, 2021			WORK END:	September 15, 2021	
WRIA		Waterbody:			Tributary to:	
37 - Yakima (Below Naches R)		Yakima River (rb)			Columbia River	
1/4 SEC:	Section:	Township:	Range:	Latitude:	Longitude:	County:
	24	09 N	28 E	46.248881	-119.260858	Benton
Location #3 Driving Directions						
The Amon Creek work area can be reached from eastbound I-82. Take exit #102 for I-182 towards Richland. Take exit #3 to Queensgate Drive. At the roundabout, exit southbound onto Queensgate Drive. At the next roundabout, exit eastbound to Columbia Park Trail. Continue to the USACE Yakima Delta Habitat Management Unit on the left side of the road, turn left into the parking lot marked with a sign.						

APPLY TO ALL HYDRAULIC PROJECT APPROVALS

This Hydraulic Project Approval pertains only to those requirements of the Washington State Hydraulic Code, specifically Chapter 77.55 RCW. Additional authorization from other public agencies may be necessary for this project. The person(s) to whom this Hydraulic Project Approval is issued is responsible for applying for and obtaining any additional authorization from other public agencies (local, state and/or federal) that may be necessary for this project.

This Hydraulic Project Approval shall be available on the job site at all times and all its provisions followed by the person(s) to whom this Hydraulic Project Approval is issued and operator(s) performing the work.

This Hydraulic Project Approval does not authorize trespass.

The person(s) to whom this Hydraulic Project Approval is issued and operator(s) performing the work may be held liable for any loss or damage to fish life or fish habitat that results from failure to comply with the provisions of this Hydraulic Project Approval.

Failure to comply with the provisions of this Hydraulic Project Approval could result in civil action against you, including, but not limited to, a stop work order or notice to comply, and/or a gross misdemeanor criminal charge, possibly punishable by fine and/or imprisonment.

All Hydraulic Project Approvals issued under RCW 77.55.021 are subject to additional restrictions, conditions, or revocation if the Department of Fish and Wildlife determines that changed conditions require such action. The person(s) to whom this Hydraulic Project Approval is issued has the right to appeal those decisions. Procedures for filing appeals are listed below.

MINOR MODIFICATIONS TO THIS HPA: You may request approval of minor modifications to the required work timing or to the plans and specifications approved in this HPA unless this is a General HPA. If this is a General HPA you must use the Major Modification process described below. Any approved minor modification will require issuance of a letter documenting the approval. A minor modification to the required work timing means any change to the work start or end dates of the current work season to enable project or work phase completion. Minor modifications will be approved only if spawning or incubating fish are not present within the vicinity of the project. You may request subsequent minor modifications to the required work timing. A minor modification of the plans and specifications means any changes in the materials, characteristics or construction of your project that does not alter the project's impact to fish life or habitat and does not require a change in the provisions of the HPA to mitigate the impacts of the modification. If you originally applied for your HPA through the online Aquatic Protection Permitting System (APPS), you may request a minor modification through APPS. A link to APPS is at http://wdfw.wa.gov/licensing/hpa/. If you did not use APPS you must submit a written request that clearly indicates you are seeking a minor modification to an existing HPA. Written requests must include the name of the applicant, the name of the authorized agent if one is acting for the applicant, the APP ID number of the HPA, the date issued, the permitting biologist, the requested changes to the HPA, the reason for the requested change, the date of the request, and the requestor's signature. Send by mail to: Washington Department of Fish and Wildlife, PO Box 43234, Olympia, Washington 98504-3234, or by email to HPAapplications@dfw.wa.gov. You should allow up to 45 days for the department to process your request.

MAJOR MODIFICATIONS TO THIS HPA: You may request approval of major modifications to any aspect of your HPA. Any approved change other than a minor modification to your HPA will require issuance of a new HPA. If you originally applied for your HPA through the online Aquatic Protection Permitting System (APPS), you may request a major modification through APPS. A link to APPS is at http://wdfw.wa.gov/licensing/hpa/. If you did not use APPS you must submit a written request that clearly indicates you are requesting a major modification to an existing HPA. Written requests must include the name of the applicant, the name of the authorized agent if one is acting for the applicant, the APP ID number of the HPA, the date issued, the permitting biologist, the requested changes to the HPA, the reason for the requested change, the date of the request, and the requestor's signature. Send your written request by mail to: Washington Department of Fish and Wildlife, PO Box 43234, Olympia, Washington 98504-3234. You may email your request for a major modification to HPAapplications@dfw.wa.gov. You should allow up to 45 days for the department to process your request.

APPEALS INFORMATION

If you wish to appeal the issuance, denial, conditioning, or modification of a Hydraulic Project Approval (HPA), Washington Department of Fish and Wildlife (WDFW) recommends that you first contact the department employee who issued or denied the HPA to discuss your concerns. Such a discussion may resolve your concerns without the need for further appeal action. If you proceed with an appeal, you may request an informal or formal appeal. WDFW encourages you to take advantage of the informal appeal process before initiating a formal appeal. The informal appeal process includes a review by department management of the HPA or denial and often resolves issues faster and with less legal complexity than the formal appeal process. If the informal appeal process does not resolve your concerns, you may advance your appeal to the formal process. You may contact the HPA Appeals Coordinator at (360) 902-2534 for more information.

A. INFORMAL APPEALS: WAC 220-660-460 is the rule describing how to request an informal appeal of WDFW actions taken under Chapter 77.55 RCW. Please refer to that rule for complete informal appeal procedures. The following information summarizes that rule.

A person who is aggrieved by the issuance, denial, conditioning, or modification of an HPA may request an informal appeal of that action. You must send your request to WDFW by mail to the HPA Appeals Coordinator, Department of Fish and Wildlife, Habitat Program, PO Box 43234, Olympia, Washington 98504-3234; e-mail to HPAapplications@dfw.wa.gov; fax to (360) 902-2946; or hand-delivery to the Natural Resources Building, 1111 Washington St SE, Habitat Program, Fifth floor. WDFW must receive your request within 30 days from the date you receive notice of the decision. If you agree, and you applied for the HPA, resolution of the appeal may be facilitated through an informal conference with the WDFW employee responsible for the decision and a supervisor. If a resolution is not reached through the informal conference, or you are not the person who applied for the HPA, the HPA Appeals Coordinator or designee may conduct an informal hearing or review and recommend a decision to the Director or designee. If you are not satisfied with the results of the informal appeal, you may file a request for a formal appeal.

B. FORMAL APPEALS: WAC 220-660-470 is the rule describing how to request a formal appeal of WDFW actions taken under Chapter 77.55 RCW. Please refer to that rule for complete formal appeal procedures. The following information summarizes that rule.

A person who is aggrieved by the issuance, denial, conditioning, or modification of an HPA may request a formal appeal of that action. You must send your request for a formal appeal to the clerk of the Pollution Control Hearings Boards and serve a copy on WDFW within 30 days from the date you receive notice of the decision. You may serve WDFW by mail to the HPA Appeals Coordinator, Department of Fish and Wildlife, Habitat Program, PO Box 43234, Olympia, Washington 98504-3234; e-mail to HPAapplications@dfw.wa.gov; fax to (360) 902-2946; or hand-delivery to the Natural Resources Building, 1111 Washington St SE, Habitat Program, Fifth floor. The time period for requesting a formal appeal is suspended during consideration of a timely informal appeal. If there has been an informal appeal, you may request a formal appeal within 30 days from the date you receive the Director's or designee's written decision in response to the informal appeal.

C. FAILURE TO APPEAL WITHIN THE REQUIRED TIME PERIODS: If there is no timely request for an appeal, the WDFW action shall be final and unappealable.

Habitat Biologist	Michael.Ritter@dfw.wa.gov	Michael Ritter	for Director
Michael Ritter	509-543-3319		WDFW

State of Washington
Department of Fish and Wildlife
Mailing Address: PO Box 43234, Olympia, WA 98504-3234, (360) 902-2200, TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia, WA

August 28, 2023

Benton Conservation District
Mark Nielson
10121 W. Clearwater Ave., Suite 101
Kennewick, WA 99336

Dear Mark Nielson:

SUBJECT: YOUR APPLICATION FOR LOWER YAKIMA RIVER STARGRASS HARVESTING, WDFW APPLICATION ID: 24642

On March 24, 2021, Washington Department of Fish and Wildlife (WDFW) first received your application materials for a Hydraulic Project Approval (HPA) for the project referenced above.

Your request for a minor modification of your existing HPA has been approved. You are authorized to conduct work through September 15, 2023. Work window extensions for 2024 and 2025 will require a separate minor modification to be approved once water conditions for those years have been assessed.

If any impacts to salmonids or other fish life are observed, contact me immediately to determine any additional modifications that may be necessary.

Please attach this letter to your HPA on-site.

If you have any questions, please call me at 509-312-8117.

Sincerely,

Troy Maikis
Habitat Biologist

PUBLIC HEALTH
Prevent • Promote • Protect
BENTON-FRANKLIN HEALTH DISTRICT

August 31, 2021

Mark Nielson, District Manager
Benton Conservation District
10121 W Clearwater Avenue
Suite 101
Kennewick, WA 99336

The purpose of this letter is to document the development of a solid waste disposal plan for the Benton Conservation District's Aquatic Plant Removal Program. Benton-Franklin Health District has jurisdiction over solid waste permitting in Benton County, WA. Benton Conservation District (BCD) staff have developed this plan in consultation with Benton-Franklin Health District (BFHD) Environmental Health and Washington Department of Ecology (Ecology) staff. BFHD will not require BCD to obtain a solid waste permit for the Aquatic Plant Removal Program, conditioned upon the following criteria:

- The overgrowth of aquatic plants, primarily the native plant known as water stargrass (*Heteranthera dubia*), has reached proportions that impair multiple beneficial uses of the Yakima River in Benton County, as defined by the Washington Administration Code (WAC) 173-201A updated 12/30/2019. These impairments are negatively affecting the following beneficial uses:
    - aquatic life, specifically salmonid spawning, rearing, and migration;
    - primary contact recreation;
    - water supply use for irrigation; and
    - miscellaneous uses including wildlife habitat, boating, and aesthetics.
- Excessive emergent stands of water stargrass are creating new, stagnant-water habitat for disease-carrying mosquito species as documented by Benton County Mosquito Control Board. Captured specimens have tested positive for West Nile Virus, which constitutes a public health threat.
- BCD and its agency partners will operate an aquatic plant harvesting vessel to reduce stargrass biomass as an effort to restore multiple beneficial uses of the river. This harvest operation will be conducted during the Washington Department of Fish and Wildlife in-water work window of June 15 to September 1. Harvested material will be captured in the water column, collected onboard the harvester vessel, then transported to shore. Aquatic plant material will be dewatered as it is pulled onboard.

7102 W. Okanogan Place
Kennewick, WA 99336
Office: (509) 460-4200

412 W. Clark
Pasco, WA 99301
Office: (509) 547-9737

- BCD staff will off-load harvested aquatic plant material from the harvesting vessel and onto a mechanized conveyor. The mechanized conveyor will be used to load the aquatic plant material into a transport vehicle. The transport vehicle will move the harvested aquatic plant material landward, beyond the ordinary high water mark to a temporary drying bed. The properties where the drying will take place are described in Attachment A. Permission to use the properties has been granted by the landowners.
- The harvested aquatic plant material will dry in temporary drying beds until October 1. The harvested aquatic plant material is organic-origin. Pacific Northwest National Laboratory testing failed to document any heavy metals in harvested stargrass. After seasonal air drying, the remaining biomass will be transported to a sanitary landfill or composting facility.
- Drying piles will be monitored for internal temperature with a composting temperature probe once a week. If internal pile temperatures reach 160°F then monitoring frequency will be increased to twice a week. If internal pile temperatures reach 170°F then piles will be turned and/or dispersed to reduce fire risk. This plan will be jointly reviewed by Benton-Franklin Health District and Benton Conservation District staff before spring 2022 for extension and possible modification.

Attachment A: Temporary Drying Locations

Benton County - Horn Rapids Park

Parcel #: 104074000001000

Legal Description: Government lots 2 and 3 and the east half of the SW quarter of Section 4, Township 10, Range 27

Taxing District: 1412

Columbia Irrigation District

Parcel #: 103073000002002

Legal Description: That portion of the south half of Section 3, Township 10 N, Range 27 defined as follows: commencing at the SE corner of said Section 3. Thence N 00° 24′ 51″ east along the east line thereof, for 1,439.27 feet. Thence N 89° 35′ 09″ west for 2,522.83 feet to the true point of beginning. Thence N 72° 12′ 27″ W for 85.52 feet. Thence S 71° 01′ 08″ for 33.37 feet. Thence N 72° 12′ 27″ west for 313.27 feet. Thence N 45° 00′ 03″ W for 756.79 feet. Thence N 00° 29′ 11″ E for 275 feet, more or less, to a point on the line of ordinary high water on the south bank of the Yakima River. Thence southeasterly, along said line of ordinary high water for 1,500 feet, more or less to a point which lies N 71° 01' 08" W for 89 feet, more or less, to the

true point of beginning: except the existing Columbia Irrigation District canal right-of-way and except any portion lying within Harrington Road right-of-way.

Taxing District: 1424

The Benton Conservation District Aquatic Plant Removal Program shall be exempt from a solid waste permit in accordance with the conditions described above.

James R. Coleman
Environmental Health Specialist II
Benton-Franklin Health District