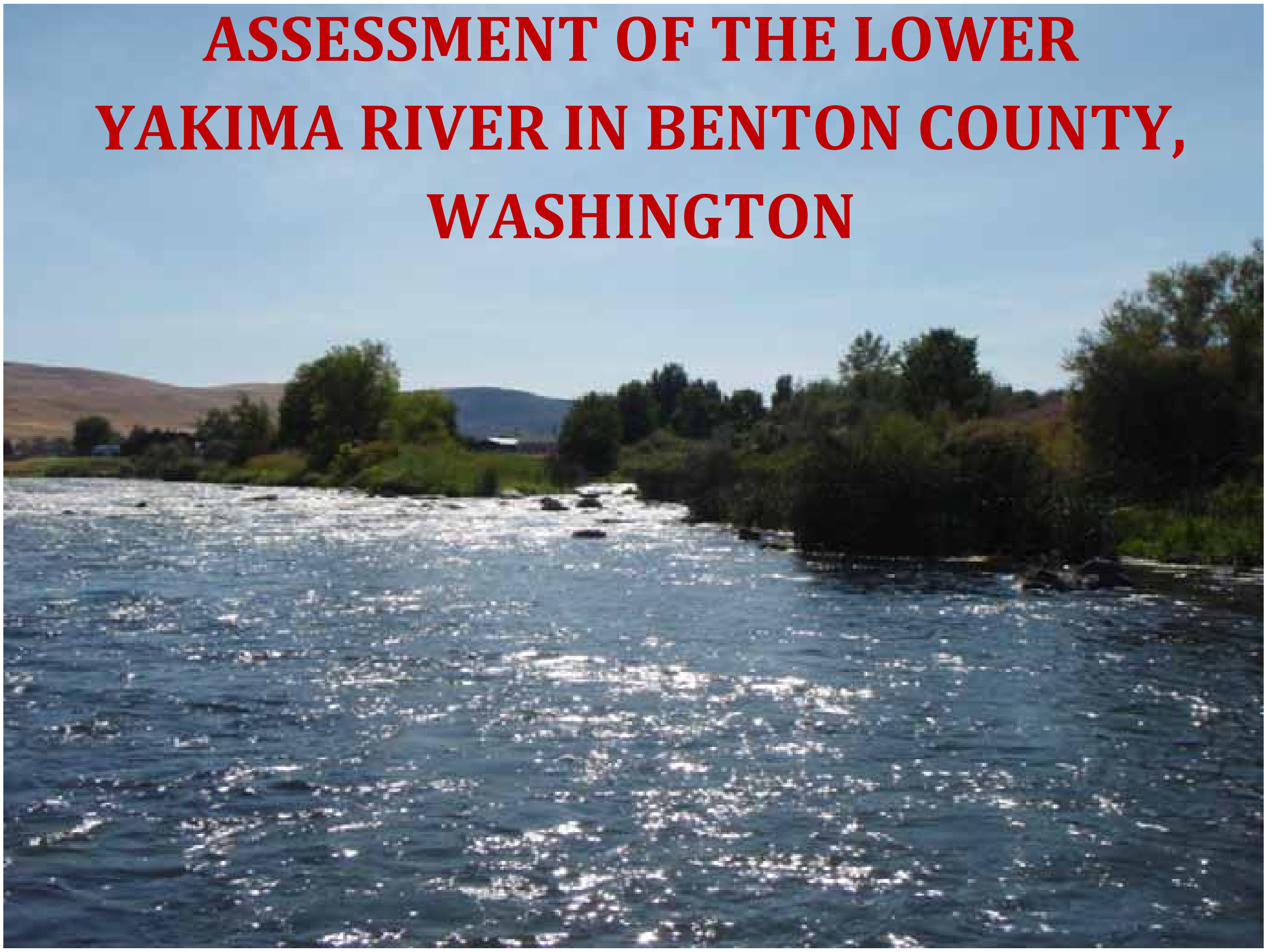
ASSESSMENT OF THE LOWER YAKIMA RIVER IN BENTON COUNTY, WASHINGTON



Prepared by:
M. Appel, R. Little, H. Wendt, M. Nielson
Benton Conservation District

In cooperation with:
The Yakima Basin Fish and Wildlife Recovery Board

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EXECUTIVE SUMMARY

Benton Conservation District (BCD) investigated the lower Yakima River from Prosser, WA to Richland, WA with the purpose of identifying and assessing high priority actions for the benefit of local and basin-wide salmon recovery efforts. This assessment, funded by the Salmon Recovery Funding Board (SRFB), was conducted from 2008 to 2010 and included thermal profiling of the lower Yakima River, investigation of the thermal dynamics of the Yakima River delta, river depth measurements at baseflow conditions, identification of local fish screening needs, and inventory of riverbank, island, and floodplain conditions.

Based on this assessment, the following have been identified as high priority restoration actions and/or areas requiring further assessment. Listed items were chosen based on feasibility by local community and/or governmental agencies, ability for near-future completion, and have a high degree of certainty for improving lower Yakima River conditions.

1. **Yakima River Delta and Bateman Island Causeway**. Elevated temperatures at the Yakima Delta confluence with the Columbia River are likely causing adult salmonids to delay migration. Further investigation is needed to determine if removal of the Bateman Island Causeway will result in increased mixing with the Columbia River, decreased sedimentation, and decreased temperatures within the Yakima Delta, thereby improving delta function and minimizing water temperature issues.

2. **Fish Screening and Irrigation Water Conservation**. Over 60 privately owned irrigation intakes were identified during this assessment. River floats indicated that at least half of these intakes were not compliant with current fish screening standards and need to be updated. Outdated irrigation systems should be converted for irrigation efficiency and water savings as well as protecting salmon from uptake and impingement.

3. **Restoration of Riparian Buffers**. Shoreline residential development, grazing, and non-native riparian vegetation are common on the lower Yakima River. Working with private landowners to restore native riparian buffers and to manage streamside grazing is imperative.

4. **Side Channel Restoration and Protection (Prosser to Richland)**. Side channel degradation is apparent by many of the islands, especially between Benton City and Richland. Degradation appears to be due to extensive water stargrass, sedimentation, low flows, and non-native vegetation. Projects aimed at restoring side channels either through water stargrass removal or scouring with large woody debris (LWD) should be considered. Priority should be given to islands near identified thermal refugia pockets and/or historical spawning grounds. Projects will need to be implemented with community support, as the islands and neighboring lands are primarily privately owned.

5. **Off-channel Restoration and Re-connectivity (Benton City to Richland)**. Previous research found off-channel habitat has been lost as a function of lower flows (Stanford et al. 2001). Managing higher summertime flow is outside of the scope of this assessment, however, projects aimed at enhancing current flow scenarios (especially spring-time flows) to off-channel habits and promoting scour are recommended. Much of this land is privately owned and located between Benton City (e.g., Benton City oxbow, floodplain adjacent to Songbird Island) and West Richland/Richland (e.g., Fox Island channel, island habitat under I-182 bridge).

6. **Island and Floodplain Protection (Benton City and West Richland)**. Investigations to lease or purchase floodplain habitats in Benton City and West Richland and islands (e.g., Fox Island, Twin Bridges Island) from willing participants should be further explored. Partnerships with other entities such as Benton County and Tapteal Greenway may foster management of riparian areas for both conservation and recreation.

7. **Protection, Enhancement, and Further Analysis of Thermal Refugia Potential**. Although predominantly a losing reach, this study determined that thermal heterogeneity is present along the lower Yakima River and may provide critical temperature differentials for migratory species at the tail end of out-migration and the front-end of in-migration. Additional studies should be performed to determine dissolved oxygen levels and temperature differentials between the identified "cooler" areas and the average river temperature at the end of spring run-off and the beginning of fall migration to determine the suitability of existing cool pockets as migratory thermal refugia.

   Pockets of cooler water were mainly associated with interstitial groundwater flow along riverbanks and point-and non-point source irrigation returns. A few "holes" were identified that also coincided with localized decreased temperatures. Segments of the river within West Richland had thermal suppression; this may be in part due to West Richland's extensive floodplains and irrigation. The sources of water for these cool pockets (i.e., percentage of river recharge vs. irrigation recharge) should be investigated to help with future decisions of river management. Projects coupled with these identified "cooler" areas are likely to provide the greatest benefit.

8. **Water Stargrass Management**. Removal of water stargrass and development of removal techniques in critical salmonid spawning habitat areas should continue as water stargrass represents both a direct physical threat to habitat and a threat to water quality and temperature. It is recommended that removal efforts be targeted at historical fall Chinook spawning grounds and threatened side-channel habitats.

9. **Large Woody Debris (LWD).** Historical documentation indicates that the lower Yakima River and delta primarily obtained its large woody debris from upstream

sources with only minor contribution from growth along the lower riverbanks. Capture of wood at the Prosser Dam needs to be managed so as to promote the continuation of wood downstream within the lower Yakima River. Large woody debris is captured by island heads and floodplains within the lower Yakima River and along the banks during high flow events. Placement of LWD may help with island side channel scour, habitat complexity, and enhance areas of thermal refugia.

10. **Levees and Flooding**. Options should be investigated for converting the existing levees (e.g., Yakima Delta) to more fish friendly levees that provide both flood control protection and ecological benefit. In addition to improving the levees, other programs to reduce fecal coliform contamination should be developed to help reduce the impact of flooded areas contiguous to the river that contain pasture and old septic systems.

Although not presented as part of this action list, predation, water quality, and altered flow regimes are recognized as important factors to consider for salmon recovery efforts in the lower Yakima River. Solutions to these problems require basin-wide support with the involvement of many stakeholders and multiple government agencies and, as such, are outside of the intent of the proposed action list above. It should be noted that predation and water quality and flow are discussed within the report document. Furthermore, results of the temperature profiling performed as part of this assessment raise interesting questions regarding temperature and the lower Yakima. Shifting the current view of the lower Yakima River as one continuous slug of warm water to a model that incorporates thermal heterogeneity could have implications for future flow management discussions (e.g., managing to enhance and maintain thermal refugia for migration versus managing flows to lower entire main-channel summer temperatures).

As a result of this assessment, the first three identified inventory actions along with water stargrass management (#8) have already procured additional grant funding. BCD was awarded three grants from the Community Salmon Fund (CSF) in 2009 and 2011 to help private landowners with riparian restoration/fencing activities and implementation of water stargrass removal from island-side channels. Additionally, BCD procured two SRFB grants to screen 23 privately owned irrigation intakes so that they are compliant with current screening criteria. To date, 15 screens have been replaced with fish friendly screens. Lastly, a collaborative study with Mid-Columbia Fisheries Habitat Enhancement Group, BCD, and the Yakama Nation has been funded by SRFB in order to assess the fish dynamics and hydrodynamic properties of the Yakima River delta in order to ascertain if removal of the Bateman Island Causeway will lead to improved passage within the Yakima Delta. The results of this study will be available by 2013.

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ACKNOWLEDGEMENTS

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CHAPTER 1 INTRODUCTION

Benton Conservation District (BCD) was awarded a $36,000 grant with a match of $45,000 through the Salmon Recovery Funding Board in 2007. The grant was awarded to perform an assessment of the Yakima River in Benton County. The end goal of the assessment was to identify high priority actions for the benefit of salmon and people. Fisheries advocates generally focus on anadromous fish habitats higher up in the Yakima Basin. The many tributaries draining the mountains and the complex floodplains of the middle and upper mainstems attract the majority of attention and funding. When the lower Yakima is noted, it is as a migration corridor that, despite many challenges, generally delivers adults and smolts to the upstream and downstream habitats on which they depend.

Discussions on the lower Yakima River typically involve two basic perceptions. One perception views the lower Yakima as a fundamentally altered and irrecoverable habitat, where there is little opportunity for significant fish returns from restoration efforts and as such the only goal should be moving fish through to better habitats as quickly as possible. A second perception assumes that the fundamental issue in the lower Yakima is a lack of water, and that a more natural flow regime is a requirement for significant improvement in fish survival and production in the lower Yakima. The goal of this assessment is to understand and identify the value of the lower Yakima River for anadromous fish, investigate the aforementioned perceptions of the lower Yakima River and identify concrete restoration projects linked to specific fish benefits.

As part of this assessment, BCD convened a technical advisory group (Lower Yakima River TAG) to provide input and feedback for the assessment. The lower Yakima River, as used in this study, includes the portion of the river that flows through Benton County and runs from Prosser, WA to its confluence with the Columbia River at Richland, WA (Figure 1). BCD and the Lower Yakima River TAG identified knowledge gaps and prioritized assessment efforts for the lower Yakima River. The primary areas of focus determined by BCD and the Lower Yakima River TAG were:

1. Data collection on the historical conditions of the lower Yakima River and delta
2. Determination of temperature heterogeneity of lower Yakima River and thermal refugia potential
3. Salmonid utilization of the lower Yakima River (historical and current spawning)
4. Riparian vegetation and riparian bank conditions (both historical and current)
5. Assessment of irrigation intakes and potential fish screening needs
6. Presence and importance of large woody debris in the Lower Yakima River
7. Assessment of river islands, channels and floodplains

The primary data gathering for this assessment was a two year thermal profiling effort in which data were collected to assess river temperature heterogeneity (e.g., cooler pockets of water resulting from groundwater or pools) and identify thermal refugia potential of the lower river. Thermal profiling was conducted during base flow conditions in July and August of 2008 and 2009 in the lower Yakima River. During the thermal profiling floats, data were also gathered pertaining to riparian vegetation and riverbank condition, riverside livestock grazing, island and side channel habitat condition, presence/absence of large woody debris, and irrigation intakes. Depth data on the lower Yakima River were also collected. The results of the assessment are discussed herein and a list of high priority actions and projects are presented.

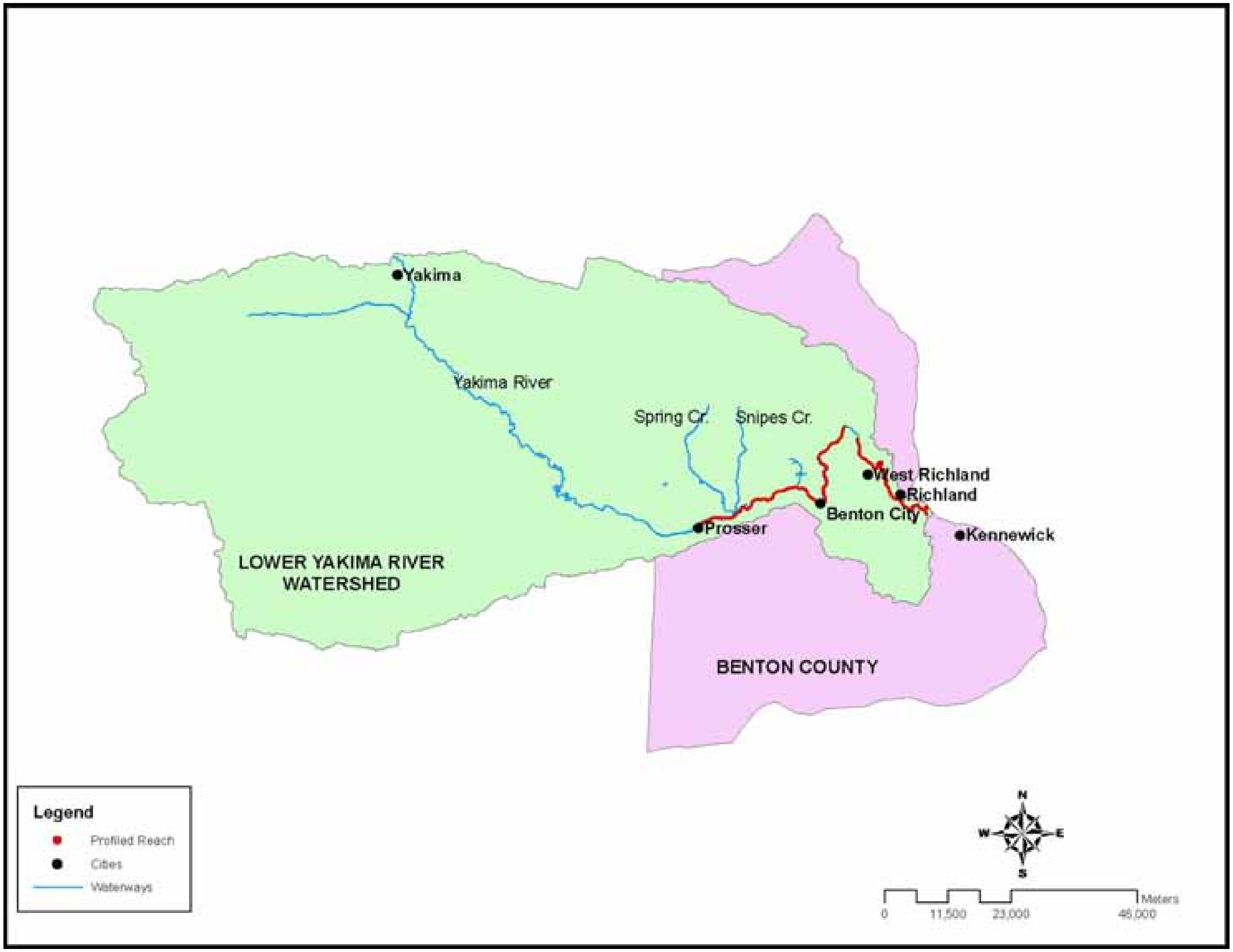

Figure 1. Lower Yakima River Study Reach (Prosser, WA to Richland, WA)

CHAPTER 2 HISTORICAL OVERVIEW

When talking about ecological restoration, we often fall prey to a simplified vision of history, in which an idealized past is compared to a degraded present. This quickly leads to cognitive dissonance, as the impression that everything needs fixing bashes against the sense that all is hopelessly lost. But if we step back and take a more nuanced view of history, we may find ourselves on a middle ground, looking at a modern river that faces fundamental constraints, but where there are also real opportunities to make significant changes that have tangible benefits.

Looking at the history of the lower Yakima in some detail allows us to see how some problems have already solved themselves (e.g. the extremely low flows of the early 20th century in the lower Yakima), even as unexpected new issues arise (the now-clear regulated flows of the modern lower Yakima fostering the recent expansion of water star grass). Understanding specific issues and their drivers allows us to formulate specific actions to address them, or to think about how we can accommodate the changes that we cannot reverse. To foster this kind of thinking, the following section gives an overview of how the Yakima River has changed over the last 160 years.

2.1 Geological History

The lower Yakima River is located within the Columbia Plateau, which is consists of a series of basalt lava flows. A majority of the basalt flows is interspersed with sedimentary layers and are known as the Columbia River Basalt Group (Kinnison and Sceva 1963). The basalt plateau of the eastern basin was folded and faulted into a series of northwest-southeast trending anticlinal ridges and synclinal valleys known as the Yakima Fold Belt and extend from the Cascades to the Columbia River (Kinnison and Sceva 1963). Columbia River basalts dominate between Prosser and Benton City, and as such the river channel is generally confined throughout this reach with minimal area for braiding and meander. Alluvial deposits are present Between Horn Rapids and West Richland. Alluvial islands formed by Quaternary floods are dispersed throughout this reach and mediate changes in channel morphology.

2.2 The Pre-European River

Though dwarfed by the Snake, the Yakima River is one of the largest tributaries to the Columbia River in both area and flow. It is estimated to have produced anywhere from 400,000 to 2 million adult salmon each year prior to the 19th century collapse of salmon populations. It sustained a large population of humans made up of many of the bands now brought together as the Yakama Nation, and fish returning to the Yakima also supported the salmon-based cultures along the Columbia River.

The lower Yakima carries the snowmelt of the Cascades to the Columbia, with pre-settlement flows typically climbing through the spring, to peak in June and then drop rapidly in July to reach annual low flows in August and September. The upper curve in

Figure 2 shows the estimated average unregulated hydrograph used by the Bureau of Reclamation (while this does not exactly match the presumed pre-settlement hydrograph, it gives a solid approximation of its general shape, magnitude and divergence from approximate modern flows as represented by the lower line) (Bureau of Reclamation 2008).

Figure 2. Hydrograph of unregulated versus regulated flow for the lower Yakima River, BOR (2008)

The lower Yakima presumably offered resumed unimpeded physical passage for adult and juvenile fish, though rapids in the river at Horn Rapids/Wanawish and Prosser funneled fish past native fisheries where the level of fishing pressure unknown. While outmigration timing for smolts in this period is unknown, the June freshet would have delivered smolts to the July high flows in unregulated Columbia, and the greatest extension of the estuary's freshwater plume into the Pacific. [1]

Water quality is generally presumed to have been good, although there is still much debate regarding historical temperatures at baseflow in the lower Yakima River (see discussion in CHAPTER 9). Whether or not the river was historically warmer or cooler at baseflow conditions, there was likely to be a greater amount of thermal heterogeneity (temperature variation) in the lower Yakima than exists today. Historically, floodplain recharge may have greatly influenced and benefited thermal heterogeneity and thermal refugia along the riverbanks and off-channel habitat. A study by Stanford et al. (2001) indicates that under higher flows there is greater amount of floodplain connectivity, interstitial flow, deeper water, and more riffles below Prosser Dam. This may lead to

[1] Whether pre-1850 smolts left the basin at the height of the freshet or whether they had similar run timings to the present when yearling and older smolts typically leave the basin from March through May is unknown. Selective pressures since 1850 have clearly favored earlier outmigration over the May through early July outmigration that may have been present earlier.

greater thermal heterogeneity in the lower river, even if baseflow summer temperatures in July and August remain too warm for salmonids:

> *Although this is based on a conceptual framework (sensu Ring and Watson 1999), it is supported by underlying fundamental principles of hydrology; namely that the infusion of cooler water, earlier in the season (e.g., during historic spring runoff) over the active floodplain would provide relatively more thermal refugia below Prosser than exists under the current regulation scenario and with the significant alteration and disconnection of the floodplain.* (Snyder and Stanford 2001)

If river temperatures did rise to inhospitable levels from mid July through some point in August, upstream migration of adults and downstream migration of smolts through the lower Yakima is likely to have been unimpeded the remainder of the year. Whether or not temperature conditions allowed for rearing of juvenile salmonids in the lower Yakima through the summer is a topic of much debate.

The records of early surveyors (see section 2.3) tell of banks with extensive willows and scattered cottonwoods, with larger groves of riparian trees on limited areas of bottomland. However, even under pre-settlement conditions, shade was likely limited when compared to width and orientation of river. While riparian vegetation in the reach may have contributed some wood to the river, local inputs are likely to have been less significant than the import of large woody debris from higher in the watershed. As surveyors noted in 1863:

> *Yearly, the Yakama River disgorges from its mountain sources [an] abundance of driftwood, composed of the finest quality of timber, whole trees from 20 to 70 in diam. And from 100 to 250 feet in length of fir and cedar lumber are often seen winding their way down its current, into the broad waters of the Columbia.*

This significant influx of large wood from upstream can be hypothesized to have caused wood accumulations that scoured pools and encouraged island formation. Periodic large floods would have moved the river's cobble bedload on regular basis, likely creating excellent spawning habitats for fall Chinook.

There is no evidence that any of the tributaries to the lower Yakima flowed perennially; early surveys note springs higher in the foothills, but current perennial flows are generally acknowledged to be a function of modern irrigation in the surrounding uplands (Child and Courter 2010). The first significant unambiguously perennial tributary (Satus Creek) enters the Yakima River well above the study reach.

While this description of the pre-European river is inherently speculative, descriptions of the Yakima at the time of initial settlement give it some credence.

2.3 Historical Records Prior to 1865

The earliest written records of the Yakima River come from Lewis and Clark's expedition. Their journals note the abundant salmon and tribal fisheries on the Columbia at the mouth of the Yakima, and note, from their highest upriver point on Bateman Island, that "... there is no timber of any Sort except Small willow bushes in Sight in any direction."[2] Ross briefly stopped at the mouth of the Yakima on August 16, 1811, again noting the Columbia River fisheries, but saying little about the Yakima.

The McClellan railway survey of 1853 noted, "The lower part of the Yakima Valley is less fit for cultivation than higher up, but contains much good grass land. It is wide, open, and destitute of timber except in the bottom lands, and even there few trees are found for fourty [sic] miles up" (p. 141). And later, "You pass up the Yakima seventy miles before you reach the building pine, though cottonwood is found along its banks sufficient for camping purposes." (p. 257).[3]

The most detailed early records come from the General Land Office surveys that laid out the township/section grids. The surveyors' detailed notes provide an excellent sense of the country just prior to widespread settlement by Europeans.[4] According to the Prosser Historical Museum, the earliest recorded white settlers in Prosser were in the 1870's. Richland had its first settlers in 1864. Surveyors note a few settlers on Bateman Island, and the presence of half-wild cattle in some areas. Notes regarding the lower Yakima River from the general overview sections of the 1863-1864 surveys are provided in Appendix C.

2.4 Comparison of Mapped Channel Locations

Overlaying General Land Office survey maps allow us to look at whether and how channel and island locations have changed over the last 145 years. The following images show these overlays from Prosser to the Confluence. The general picture they give is of a river whose channel and islands have moved very little. The confluence of the Yakima and the Columbia Rivers highlight the increased amount of inundation on the delta floodplains as a result of backwater from McNary Dam.

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[2] http://columbiariverimages.com/Regions/Places/yakima_river.html

[3] http://quod.lib.umich.edu/cgi/t/text/text-idx?c=moa&idno=AFK4383.0012.001

[4] Survey notes viewable at http://www.blm.gov/or/landrecords/survey/ySrvy1.php

Figure 3. Overlay of 1864 GLO survey (Yakima River Confluence) over current 2009 aerial image

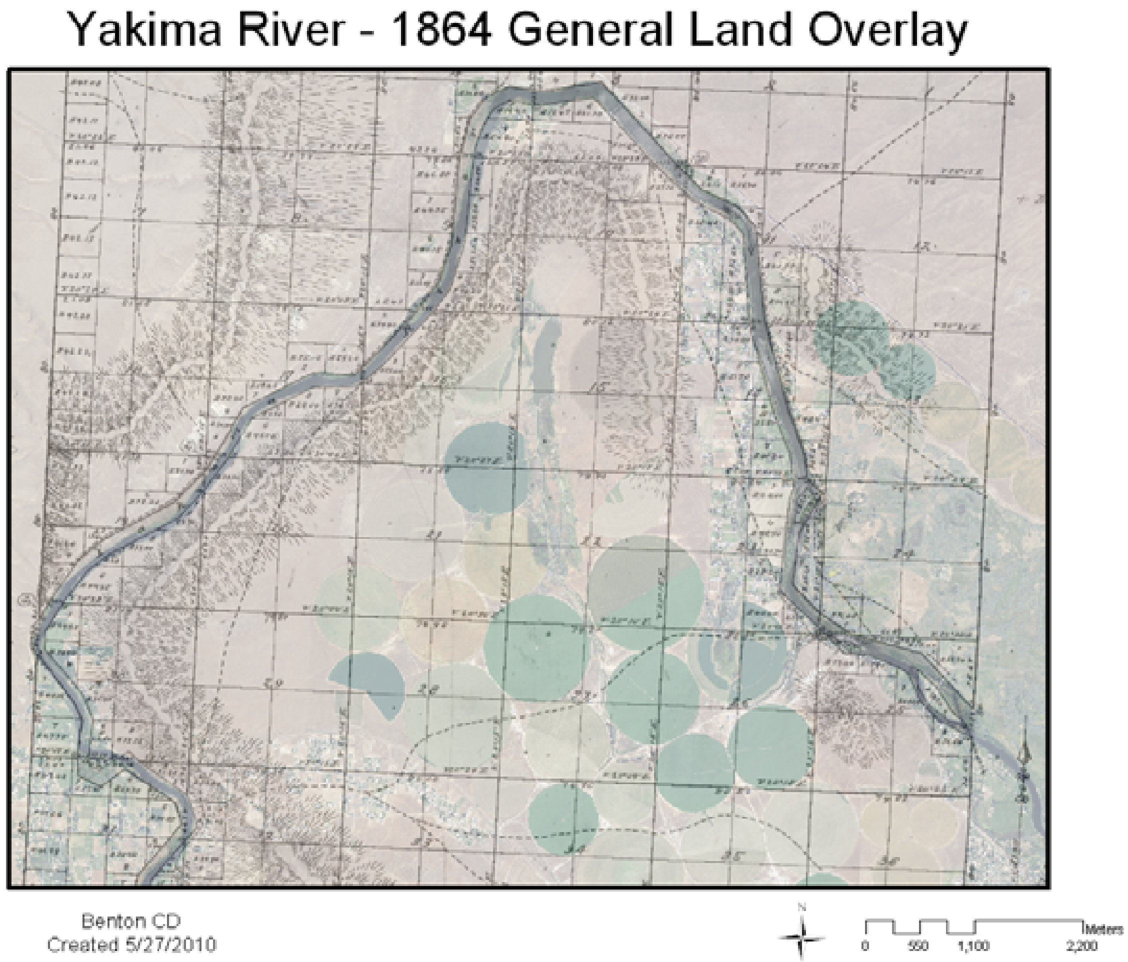

Figure 4. Overlay of 1864 GLO survey (T10N27E, Benton City, Horn Rapids and West Richland) on current 2009 aerial image

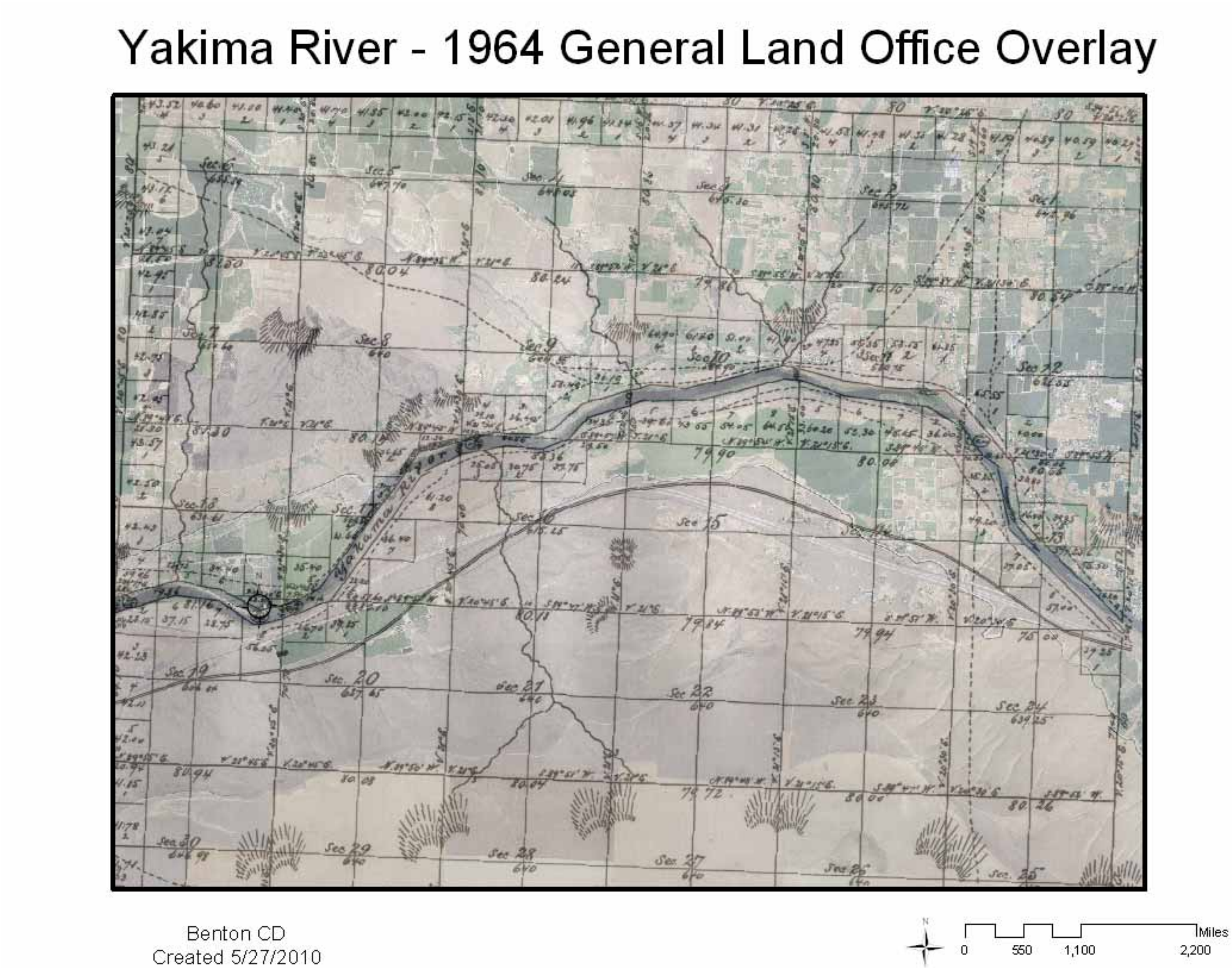

Figure 5. Overlay of 1864 GLO survey (29N26E, east of Chandler to east of Benton City) on current 2009 aerial image

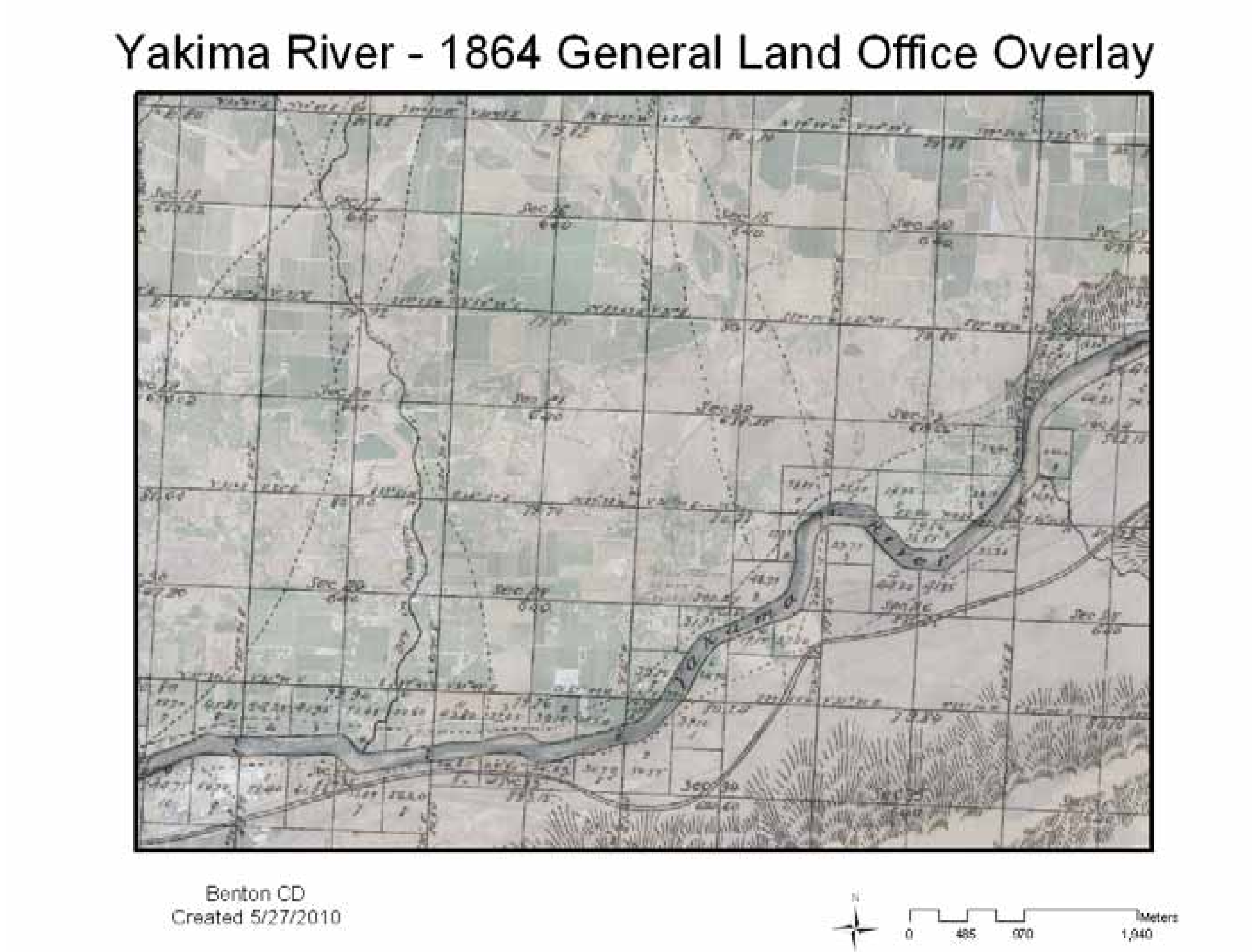

Figure 6. Overlay of 1864 GLO survey (T9N25E, east of Prosser to east of Chandler) on current 2009 aerial image
Note: The drainage marked “dry in summer” is west of Spring Creek and Snipes Creek wasteways and is a separate drainage system. This drainage outlet is still present today and was located during thermal profiling (see Section 9).

2.5 1850 to 1890: The Early Years

Prior to 1850, European presence in the Yakima Basin was largely limited to the fur trapping expeditions of 1811-1830, which reduced beaver abundance but made few other changes to the landscape. The 1850s saw the establishment of the first missions, the Yakama Wars, and the first cattle drives into the Yakima Valley. As noted in the Bureau of Reclamation's history of the Yakima Project:

> *The first settlers came to the Yakima Valley in about 1860. They were cattlemen attracted by the abundance of bunch grass and wild game, and the fertile bottom lands. The first irrigation ditch of record was constructed in 1864. The ditch conveyed water from Ahtanum Creek for irrigation of a small garden above the Catholic mission. Hops were first raised in 1872, and alfalfa was successfully grown in 1881. Construction of the Northern Pacific Railway into the valley in 1886 gave greater impetus to irrigation development.*[5]

During this period, irrigation development significantly affected tributaries of the Yakima above the study area. Extensive grazing and wood gathering for firewood, fences, lumber and hop kilns presumably lead to heavy impacts on riparian vegetation and wood floated down from the mountains by the river. However successful irrigation development on the mainstem was quite limited until the 1890s, resulting in only minor changes to mainstem flows and flood frequencies.

Anadromous fish were heavily impacted by harvest—both local, and more heavily, in mainstem Columbia fisheries—and by the changing conditions in tributaries, but while riparian and floodplain cover was changing rapidly, the hydrology of the lower Yakima and the Columbia largely resembled that of pre-settlement times.

2.6 1890 to 1920: The Diverted River

From 1890 on, more extensive irrigation systems were developed in Kittitas and Yakima Counties, greatly increasing diversions above the study area. Within the lower Yakima, a number of gravity fed ditches were developed to water accessible bottomlands. The Columbia Irrigation District system began with the construction of Horn Rapids Dam in 1892, while the Benton Irrigation District was delivered water from the Sunnyside system in 1912, and the Kiona District organized in 1917. Smaller ditches watered portions of

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[5] http://www.usbr.gov/projects/Project.jsp?proj_Name=Yakima+Project

the limited bottomlands in the lower Yakima. The combined upstream diversions greatly reduced flows into the lower Yakima during the July to August base flow periods, and resulted in slight to moderate reduction in the spring freshet. However, only the last part of this period saw reduced spring flows and flood frequencies as the federal dams higher in the basin were completed (Bumping in 1910, Kachess in 1911, and Keechelus in 1917).

Records from the long defunct Richland gage were used to quantify the "wastage" left to flow from the Yakima into the Columbia. As shown in Table 1, August flows in 1909 ranged from 64 cfs to 660 cfs; September flows from 38 cfs to 400 cfs; and October flows from 375 cfs to 660 cfs. Irrigation developments had indeed nearly eliminated "wastage" in the summer and fall, essentially drying out the lower Yakima (Stevens, Rue and Henshaw 1911).

Table 1. Daily discharge for Yakima River 1909 (from Stevens, Rue and Henshaw 1911)

Daily discharge, in second-feet, of Yakima River near Richland, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	......	64	375	11	387	38	465	21	133	167	562
2	......	64	387	12	368	64	400	22	96	215	562
3	614	64	400	13	337	64	465	23	96	268	530
4	614	51	400	14	337	59	660	24	96	257	595
5	725	64	498	15	279	80	595	25	80	279	562
6	465	64	562	16	279	64	595	26	64	325	562
7	387	59	465	17	225	59	595	27	80	337	595
8	387	51	465	18	225	80	582	28	133	337	595
9	375	51	465	19	133	103	582	29	133	350	595
10	356	38	498	20	133	96	582	30	133	400	595
								31	96	......	628

NOTE.—These discharges are based on a fairly well-defined rating curve.

Looking at flows at Kiona from 1906 to 1915 (Figure 7) the river consistently reached 10,000 to 20,000 cfs in late spring early summer and then rapidly dropped to lows of 100 to 300 cfs in average to poor years. The average flow at Kiona in august of 1906 was 171 cfs. These flows are much lower than typical modern low flows of 750-2000 cfs at Kiona, especially as the later development of the Kennewick Irrigation District means that diversions upstream of Kiona run 100-200 cfs higher in the modern period.

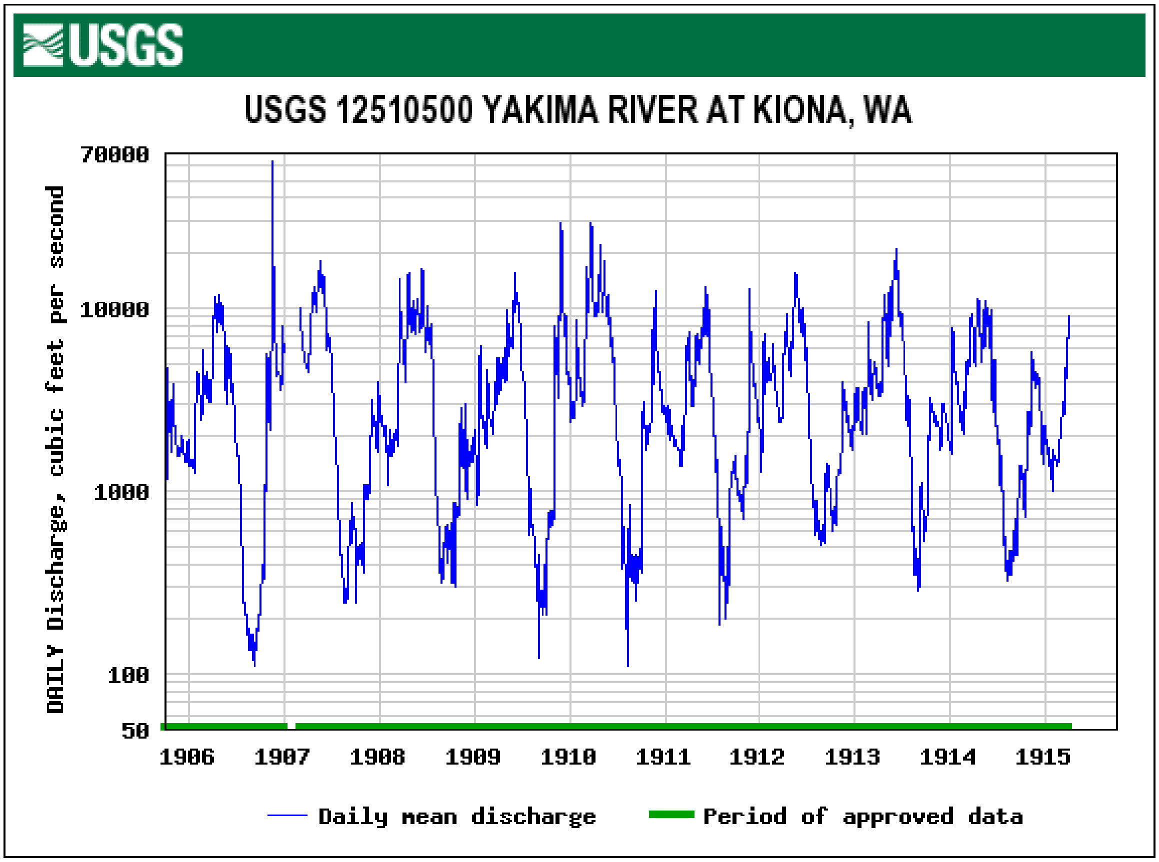


Figure 7. Historical daily discharge for lower Yakima River from http://waterdata.usgs.gov/nwis

Looking at monthly means for Kiona (Table 1 and Table 2) tells a similar story, with 1906-14 flows averaging 3,000 to 5,000 cfs higher than 1998-2008 flows in April through June, and then dropping rapidly in July to end up averaging ~1000 cfs less in August through October.

Table 2. Kiona gage, monthly average flow (in cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1906-1914 Average	2,900	3,160	5,650	7,640	9,320	7,540	2,300	467	634	1,150	4,670	3,580
1998-2008 Average	3,900	5,020	4,810	4,590	4,690	3,690	1,590	1,490	1,710	2,030	3,010	3,650
Difference*	-1,000	-1,860	840	3,050	4,630	3,850	710	-1,023	-1,076	-880	1,660	-70
	*1906-14 Average minus 1998-2008 Average)											

Two full spanning dams were constructed in the lower Yakima in this period; Horn Rapids in 1892, and the low head dam at Prosser that powered the Prosser Flour Mills starting in 1887 and served irrigation by the Prosser Falls Land Company and Irrigation Company (see photo; this initial low head dam was significantly modified by Reclamation in 1932-1933 and 1956).

http://www.yakimamemory.org/cdm4/item_viewer.php?CISOROOT=/memory&CISOPTR=7942&REC=7

The degree to which these two barriers constrained adult upstream migrations is unknown, but the combination of physical barriers and low flows and associated high river temperatures must have severely limited passage opportunities through the lower Yakima from late July through September. This is hypothesized to have placed significant constraints on summer migrant adults (lamprey, summer Chinook, sockeye and the earliest part of the steelhead run), by placing selective pressure to move migrations either earlier (when conditions in the Yakima were more hospitable, but when migration conditions in the Columbia were tougher (due to the height of flows in the Columbia at Celilo and other rapids) or into the fall. Indeed it is during this period that the summer Chinook was greatly reduced and sockeye were extirpated (both runs were also heavily impacted by conditions above the study reach, with the river sometime dry at Parker, and sockeye blocked from their natal lakes by new dams).

Fall through spring migrants (steelhead, spring Chinook and coho) presumably fared better in the Lower Yakima through this period, though severe impacts in their upstream habitats and in Columbia River fisheries drove populations downwards.

During this period, all of the major ditches were insufficiently screened. High smolt mortality in ditches was regularly documented upstream of this reach and is presumed to have occurred at diversions in the study reach (Tuck 1995). While the limited extent of diversions in this reach during this period and high April through June flows mean that early season entrainment likely had a minor impact on smolts in this reach, high rates of entrainment would be presumed for any smolts migrating out from July on. Combined with low flow and high temperatures, this would presumably have driven strong selection against late outmigrating smolts, even as the flow regime of the Columbia River had not yet changed.

2.7 1920 to 1980: The Regulated River

After 1920, the regulation of flows that became possible as federal storage facilities were built in 1911 through 1917 became more dramatic with the completion of Tieton Dam in 1925 and the significant expansions of Cle Elum's storage capacity in 1932 and 1936. Irrigated acreage continued to expand with the growth of existing districts and the creation of the Roza and Kennewick Irrigation Districts (provided water starting in 1941 and 1957, respectively). The lift pumps and hydropower diversion installed as part of the Kennewick Irrigation System in 1956 increased the amount of water diverted at Chandler Dam significantly, as in addition to the 150 to 250 cfs diverted for KID, diversions of up to 1500 cfs are made to drive the turbines and lift pumps. These diversions significantly reduce instream flows in the approximately 13-mile bypass reach between Prosser Dam and the Chandler Powerhouse. This period also saw a shift from ditches to small pump diversions to serve bottomlands along the lower Yakima and the expansion of groundwater pumping to irrigate lands around the lower Yakima.

By the 1940s, the modern regulated flow regime was largely in place (see the lower curve in Figure 8 for a generic representation). The historic spring freshet is greatly reduced and shifted earlier (as lower elevation snowmelt enters the Yakima below storage facilities, while the higher elevation snowmelt that fueled the latter part of the freshet is retained in the storage reservoirs), winter flows are significantly reduced higher in the basin, though year round return flows reduce that difference lower in the Yakima, and the low flow/high temperature baseflow period, which historically generally began in July now began anywhere from late April (in a drought year) to early July, with a drop to baseflow levels occurring around storage control. Fall cooling of the river still occurs anywhere from mid August to mid-September, when the cooling climate typically leads to a relatively rapid drop in river temperatures.

At the same time that the spring freshet of the Yakima declined and shifted earlier due to increased in-basin storage capacity, the flow regime of the Columbia River was transformed. The construction of Columbia River dams with significant storage, starting with Grand Coulee's completion in 1941 and ending with Mica Dam's completion in 1973 dramatically changed the hydrograph of the Columbia River by spreading the water from its early summer peak flows across a broader season, while the construction of the Columbia dams below the Yakima affected adult and smolt survival and changed the nature of the mainstem Columbia. Under modern conditions, outmigrating smolts face increasingly harsh conditions from late May through July. Higher survival rates for earlier fish mean that later outmigration, which may have once been adaptive, has been heavily selected against since the 1940s.

Figure 8. Lower Yakima River hydrograph

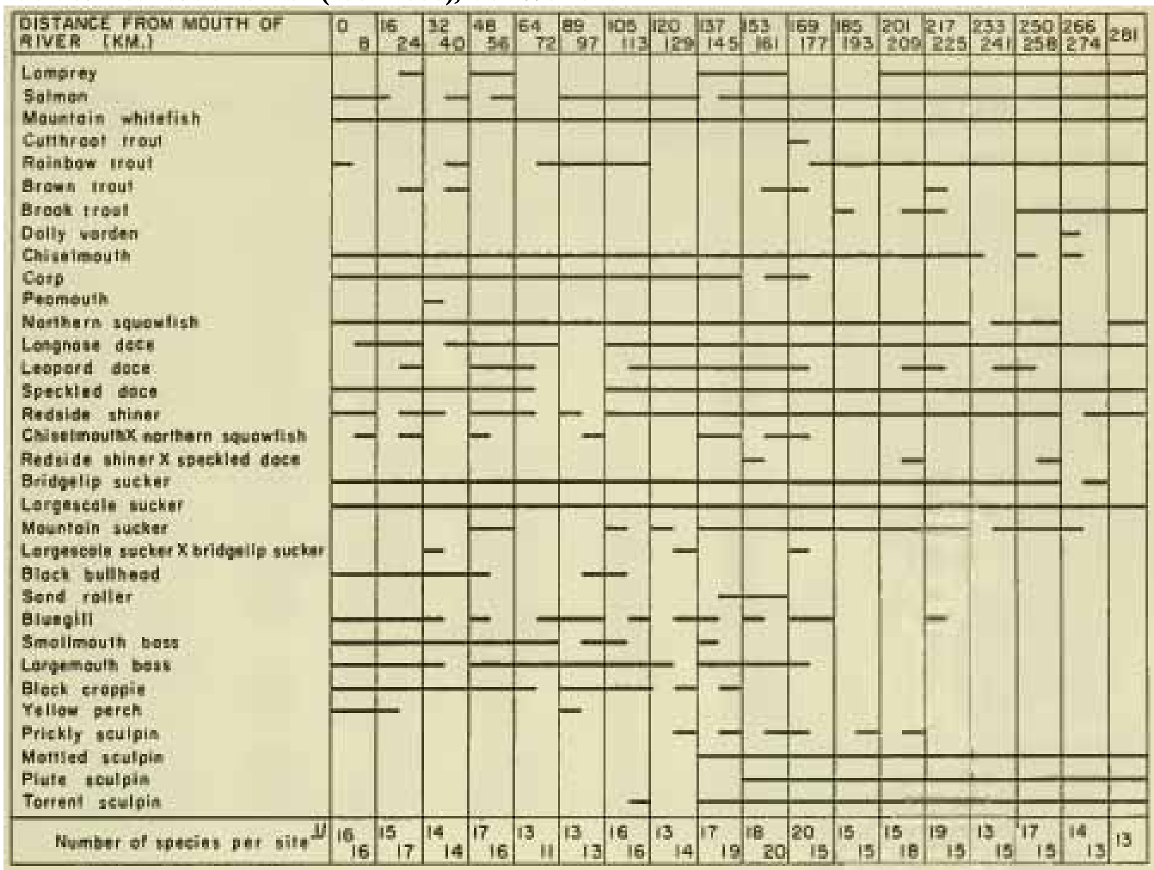
During this period, saturation of shallow aquifers lead to increased irrigation return flows to the lower Yakima, with many of the tributaries developing perennial flows that increase over the course of the irrigations season, and significant subsurface returns reaching the river. The combined effects of regulation and increased return flows mean that August and September flows in the lower Yakima ran as much as 10 fold higher than during the previous period.

The completion of McNary Dam in 1957 resulted in backwatering of the Yakima delta and 2 miles of the Yakima Mainstem River. This combined with the causeway to Bateman Island turned the south side of Yakima delta into a backwater area and prevented the Columbia River from flowing around the west side of Bateman Island. The impact of this change on anadromous fish are addressed in Section 9.5.6

High levels of fine sediment, nutrients and agricultural chemicals in runoff and agricultural return flows led to severely degraded water quality. Temperature conditions were presumably similar to modern conditions.

The changes in both the Yakima and the Columbia created favorable conditions for exotic fish species. The report of a USFWS survey of fish distribution in the Yakima Basin conducted from April of 1957 to May of 1958 makes clear that the makeup and distribution of fish species in the lower Yakima resembled that of today (Table 3) with non-native smallmouth bass, carp and catfish all widespread and perch, bluegill, largemouth bass and brown trout present in the lower river (US Fish and Wildlife Service 1970). The effects of these species are discussed in more detail in Section 3.7.

Table 3. Distribution of fish (1957-1958), USFWS 1970



The period from 1920 to 1980 saw the ongoing decline of the remaining runs of anadromous fish, as conditions in the Columbia River, intense ocean and Columbia River fisheries and degraded habitat conditions in the Yakima Basin took their combined toll. Coho were extirpated and steelhead and spring Chinook dropped to their lowest levels (~500 fish each) by the early 1980s. By the 1970s, the demise of anadromous fish in the Yakima Basin was widely predicted.

2.8 1980 to 2010: The Multi-purpose River

The irrigation infrastructure and basic flow regime of the modern Yakima was in place by the 1950s, as noted above, but by 1980, an increased emphasis on the need to rebuilt dwindling runs of anadromous fish began forcing significant changes in how the Yakima Project was run. Adjudication of water rights for the Yakima Basin in 1977 began the long process of allocating water among agricultural users, and between agriculture as a whole and the Yakama Nation's treaty right to flows to protect and maintain fisheries. In 1980, legal action by the Yakama Nation led to changes in management of the Upper Yakima and Tieton Rivers to avoid dewatering of spring Chinook redds. In 1984, Phase I of the Yakima River Basin Water Enhancement Project authorized the construction of fish ladders and fish screens at major diversion dams and diversion canals. This funded major improvements to fish screening at Chandler Dam and other Bureau facilities upstream of the study reach.

Phase II of the Yakima River Basin Water Enhancement Project was authorized by Title XII in 1994 (108 Stat. 4550, Public Law 103-434). Phase II created the Yakima River Basin Water Conservation Program, which uses federal and state funds to acquire water for fish and wildlife and fund water delivery efficiency projects that allow conserved water to be used to improve in-stream flows for fish. Phase II also provided for installing and upgrading screens at many mid-sized irrigation districts, including several in the lower Yakima.

Phase II also specified in-stream target flows over Sunnyside and Prosser Diversion Dams during April through October of each year in relation to the total water supply available. This new operating regime was initiated in 1995, and has resulted in the maintenance of at least 500 cfs in-stream flow in the Prosser to Chandler bypass reach. Subsequent commitments by Reclamation call for subordination of power generation at Chandler during the spring migration season in order to maintain at least 1000 cfs in the bypass reach.

The original legislatively mandated purpose of the Yakima Project was irrigation. The Kennewick Division was authorized for irrigation, hydroelectric generation, and the preservation and propagation of fish and wildlife, and Title XII authorized fish, wildlife, and recreation as additional purposes of the Yakima Project as a whole. These purposes however, are mandated to not impair the operation of the Yakima Project to provide water for irrigation purposes nor impact existing contracts.

Thanks to the changes associated with YRBWEP and Title XII, significant investments in habitat improvements higher in the Yakima Basin, changes in management of the Columbia river, restrictions on fisheries, new hatchery programs for coho and Chinook in the Yakima, and improved ocean conditions, resulted in significantly improved anadromous fish runs from their lows in the late 1970s and early 1980s (Figure 9).

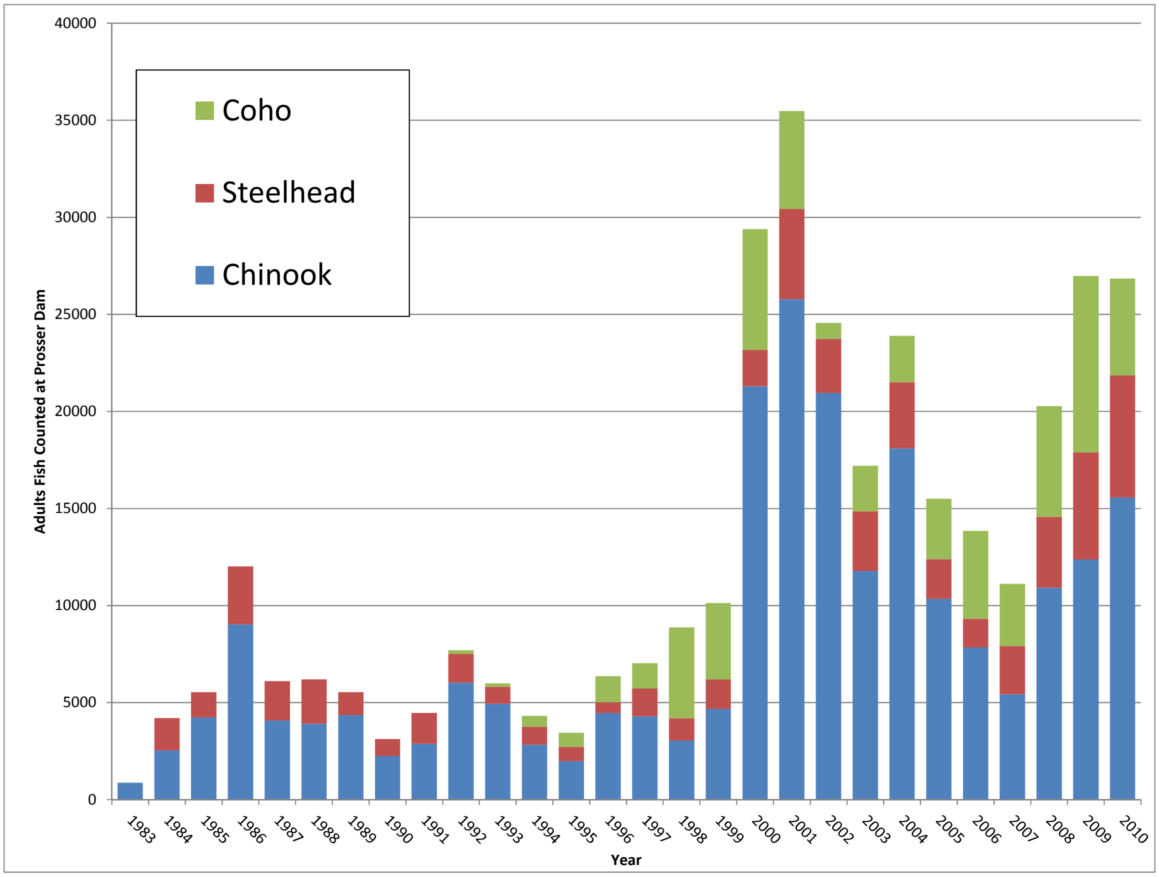


Figure 9. Graph of anadromous fish abundance in Yakima River adapted from YBFWRB

By 2009, conditions in the Yakima had improved enough for the Yakama Nation and partners to begin reintroducing sockeye and summer Chinook to the Yakima Basin. The success of these reintroduction efforts will be highly dependent on the ability of adult salmon to pass through the lower Yakima from June through September.

Where steelhead, coho and spring Chinook runs improved significantly, fall Chinook- the run most dependent on conditions in the lower Yakima- have not done as well. Together, these trends have increased the level of attention being paid to habitat conditions in the lower Yakima.

2.9 Water Quality

Water quality on the lower Yakima River had been severely degraded by sediment and legacy pesticide loading (DDT) from local agricultural practices. The lower Yakima River also suffers from many of the problems associated with urban streams, including leaking septic systems and storm sewer pollution (WDFW 1998). Summer in-stream temperatures make the lower Yakima River inhospitable to salmon and low dissolved oxygen levels threaten all aquatic life.

In 1997, the Department of Ecology (Ecology) implemented a Total Maximum Daily Load (TMDL) study and as a result targets were set for sediments and pesticides (DDT) allowed in the Yakima River (Johnson et al.1997). In response to the TMDLs, the Roza-Sunnyside Board of Joint Control, landowners and state and federal partners worked together to achieve dramatic reductions in the delivery of fine sediment and associated pesticides to the Yakima River.

As a result of these concentrated efforts, sediment loading and consequently pesticide loading decreased dramatically to the lower river improving river clarity and fish health. The Yakima Toxics Project was established by Ecology to investigate improvements in Yakima River Water Quality and update the fish consumption advisory for the river (Johnson et. al. 2007). It has been determined that soil sediment, DDT and associated chemicals were much improved in the mainstem river but still exceeded state criteria (Johnson et. al. 2007 and Johnson et. al. 2010). In 2009, state health officials determined that advisories on certain Yakima River fish species could be dropped as a result of improved agricultural practices, but that recent data (Johnson et. al. 2010) indicate eating common carp from the Yakima is still not advised due to poly-chlorinated biphenyl (PCB) levels.

Despite recent improvements in the water quality of the lower Yakima River, there still remains much work to be done. Legacy pesticides and chemicals in the water column and river sediments still pose a risk to human and fish health. Continued improvements in agriculture, irrigation, stormwater returns, and wastewater and processor plant discharges within the entire Yakima Basin will need to be made in order to improve lower Yakima River water quality.

Although not part of the TMDL, the lower Yakima River also suffers during the summer months from high in stream temperatures (over 21°C during the summer months), low dissolved oxygen levels, and at times high pH levels. These conditions have led to a very inhospitable river for more sensitive aquatic species. High in-stream temperatures in the lower Yakima River are primarily a result of the large expanse of slow-moving, shallow water exposed to full sunlight (see: Snyder and Stanford 2001; Haring 2001; and Lilga 1998). Solutions to the thermal problem in the lower Yakima River are under much debate. Increasing summer flow is likely to provide only “slight” improvements in temperature (Harring 2001). Prolonging increased spring streamflow into the early summer may provide a few extra weeks of lower in-stream temperatures thus aiding spring migration.

Improved water clarity has led to a dramatic increase in water stargrass expansion, changing the nature of much of the lower Yakima (see CHAPTER 7). Coinciding with its expansion was the change in geographic distribution of fall Chinook spawning; spawning has shifted from the majority of spawning occurring below Prosser dam to the majority of spawning occurring upstream of the study reach in the vicinity of the town of Granger. Dense mats of water stargrass are influencing dissolved oxygen levels and pH in the lower Yakima River. As a response to water stargrass proliferation, a recent study was conducted by the United States Geological Service (USGS) and South Yakima

Conservation District (SYCD). Wise et al. (2009) investigated several parameters within the Kiona reach including nutrient loading, gross primary productivity, pH, dissolved oxygen, and temperature. They found that large amounts of plant growth caused large 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. 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 spring 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). This is something that may help future predictive models of dissolved oxygen in the lower Yakima River. Wise et al. (2009) found that pH levels were above the Washington State standard of 8.5 during almost all of the irrigation season in low flow years, and following spring runoff in high flow years.

2.10 The River of the Future

Discussing the upcoming river of the future is as important as looking at the past. There are several trends worth noting that are likely to result in changes in fish habitats in the lower Yakima River in future years. These include:

1. Climate change increasing water temperatures in the lower Yakima during summer and changing how flows in the Yakima River are regulated;
2. Continuing change in agricultural cropping patterns;
3. Increased suburbanization throughout the area and continued growth of the Tri-Cities urban area;
4. Increasing efficiencies in irrigation water delivery (e.g., canal lining) thereby decreasing return flows to the lower Yakima; and
5. Possible changes to the flow regime of the lower Yakima River, through:
    a. The use of conservation water being acquired through the Yakima River Basin Water Enhancement Project (YRBWEP) (currently 20 kaf, but projected to increase to 70-100 kaf of water over the next 5 to 10 years).
    b. Major changes to the water supply infrastructure of the Yakima River, such as the construction or expansion of in-basin reservoirs or the transfer of Columbia River water to serve irrigation needs in the Yakima Basin (all of which are under consideration as part of the Yakima Basin Integrated Water Resource Management Plan under development by the Bureau of Reclamation and Washington Department of Ecology) [6]
    c. The proposed reconfiguration of the Kennewick Irrigation District to move a portion of its diversions from the Yakima River at Prosser to the Columbia River below the confluence of the Yakima and/or electrify the pump system at Chandler.

[6] See http://www.usbr.gov/pn/programs/yrbwep/2011integratedplan/index.html for more details

2.10.1 Climate Change and the Yakima River Basin

The Climate Impacts Group (CIG), which is part of the Center for Science in the Earth System at the University of Washington, is currently investigating the impacts of climate change on the future of the Yakima River Basin and salmon habitat. Climate change is already impacting the Yakima River Basin by altering the amount and timing of snowpack. A recent publication by Vano et al. (2010) on climate change and the Yakima River Basin states:

> *Climate change is expected to cause continued decline in snowpack and earlier snowmelt resulting in reduced water supplies. Analysis of past observations suggests that this process is already underway (Mote et al. 2005). Previous studies have shown that the Washington Cascade Mountains, from which the Yakima River drains, are likely to lose about 20% of their April 1st snowpack with 1◦C (1.8◦F) of warming (Casola et al. 2009), and an accompanying study (Elsner et al. 2010) suggests that for the Yakima basin, a similar temperature-snowpack sensitivity can be expected. Using +1◦C and +2◦C warming scenarios, Mastin (2008) showed a 12% and 27% decrease, respectively, in snowmelt within the basin over a base period of 1981–2005. Because the reservoir system is relatively small (total reservoir storage is about 30% of the mean annual flow of the river), and because the snowpack is highly sensitive to even modest warming, water deliveries from the reservoir system have been sensitive to even small departures from average historical conditions.*

Alterations in the amount of snowpack and snowmelt timing and their consequences on salmon habitat are predicted to become increasingly more problematic within the 21st century for the Yakima (Mantua et al. 2010). Impacts of climate change are predicted to result in reduced summer/fall flows and increased water temperatures for the Yakima Basin. Historically warm reaches are predicted to have greater increased summer water temperatures thereby resulting in increased thermal stress for migratory salmonids (Mantua et al. 2010). Mantua et al. (2010) suggests that it is possible to develop management options for mitigating the projected impacts of climate change on northwest salmon habitat, however, these options will require trade-offs with other land and water uses in the watershed. Hydrologic processes that influence streamflow timing, volume, and stream temperature are highly sensitive to projected changes in future climate scenarios. These are the same hydrologic processes that are highly sensitive to changes in land and water use impacts. Vano et al. (2010) concludes that the current approach to managing water supply in the Yakima Basin by using a regression-based forecast of total water supply available (TWSA) above Parker for the period of April through September is no longer tenable as this approach implicitly assumes that the historical conditions on which the forecasts and management strategies are based will persist into the future.

Vano et al.(2010) modeled the influence of climate change on the irrigated agriculture within the Yakima River Basin. Their study found that historically the Yakima Basin had substantial water shortages 14% of the time. For the Intergovernmental Panel on Climate

Change (IPCC) A1B emission scenarios, water shortages increased to 27% by the 2020s and 23% in the 2040s (Vano et al. 2010). Modeled future scenarios of climate change impacts on Yakima Basin water availability found that even senior water right holders will suffer curtailments with increasing frequency and that economic losses include expected annual production declines of 5%-16%, with greater possible operating losses for junior water rights holders (Vano et al. 2010).

Competition and water demand between ecosystem protection and water utilization will continue to rise as climate change continues, as such, sound management of water utilization should be developed now to help alleviate future costly conflicts (Mantua et al. 2010). Mantua et al. (2010) states that “Restoring, protecting, and enhancing instream flows in summer are key management options for mitigating effects of projected trends toward warmer, lower streamflows as a consequence of climate change.” Identifying and protecting thermal refugia provided by groundwater and tributary inflows may also help mitigate future warming impacts within the Yakima Basin (Mantua et al. 2010).

CHAPTER 3 LOWER YAKIMA FOCAL SPECIES

Several fish species populate the lower Yakima River. Historically, the Yakima River was a significant producer of important salmonid species, including Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and steelhead (*O. mykiss*). Each of these fishes utilizes the lower Yakima habitat to some degree. Although bull trout (*Salvelinus confluentus*) were historically found in the Yakima River, they are no longer considered a focal species in this reach. Other fishes of interest include lamprey, piscine predators on salmonids and other resident fishes, both native and non-native.

3.1 Steelhead (*Oncorhynchus mykiss*)

Steelhead represent one of two life history manifestations exhibited by the *Oncorhynchus mykiss* species. The anadromous *O. mykiss* spends one to three years in the ocean before returning to freshwater to spawn and is referred to as steelhead. Steelhead are iteroparous, so post-spawning adults called kelts, although weakened and often in poor condition, do not necessarily die. The resident form of *O. mykiss* is considered a rainbow trout. Progeny from both steelhead and rainbow trout may exhibit either the anadromous or resident life history, making restoration planning more difficult.

In 1999, NOAA listed as threatened the naturally spawning steelhead in the Yakima River as part of the larger Middle Columbia Evolutionarily Significant Unit. Steelhead are primarily tributary spawners, and most spawning activity takes place in the upper Yakima system. The Steelhead Recovery Plan emphasizes that improving migration conditions in the lower mainstem Yakima River is a critical recovery strategy for all threatened upstream populations of steelhead. Anadromous steelhead must migrate through the lower Yakima River during two vulnerable stages: as juveniles and kelts.

The returning adults begin passing Prosser Dam in September, later than other major Columbia River tributaries, probably because of elevated water temperatures and low flow in the lower river. Tagging data has shown that some Yakima steelhead over-shoot the Yakima and are captured at Priest Rapids Dam (Keefer et al. 2008). Perhaps they are avoiding seasonal warm water in the lower Yakima, as the McNary Pool of the Columbia is cooler in summer. Historically, a portion of the steelhead run would likely have traveled rapidly from the ocean into the Yakima system during the summer, but modern high temperatures in the lower Yakima River now limit that run timing. The extent to which adult migrants hold in the Columbia to avoid warm Yakima water is not known.

Steelhead over-winter in the cold water of December and January then move upstream again February through April. Most spawning occurs in April. Steelhead fry emerge from redds between early May and early August. Juveniles spend from one to three years in fresh water before migrating to the ocean during April through June. On average, a female steelhead in the Yakima subbasin produces 5,100 eggs. The Yakama Nation maintains an active steelhead kelt reconditioning program at their Prosser facility. Naturally spawning kelts are captured, medicated and fed for several months, improving survival rates and condition factors. Upon release the following year, many adults ascend upstream directly to spawning areas, able to forgo the treacherous migration to the Pacific.

A possible cause for the drift from anadromy to residency may be the lower survival rate for anadromous juveniles and adults, due to changed river conditions such as low flow, elevated water temperatures, passage issues and predation by non-native fishes. Causes of steelhead decline relevant to the lower Yakima include fragmentation and loss of rearing habitat; migration delays; degradation of water quality; decline of habitat complexity; alteration of stream flows, banks and channel morphology; alteration of ambient water temperatures; sedimentation; and loss of pool habitat and large woody debris. The Yakima River and its tributaries have been detached from their historical floodplains, impairing floodplain function, reducing access to off-channel habitats, reducing flow and elevating temperatures.

Predation in the lower Yakima River also has contributed to the decline of steelhead. Non-native smallmouth bass, and to a lesser extent channel catfish, take a heavy toll on juvenile steelhead. Gulls and white pelicans prey aggressively on juvenile steelhead, especially at in-stream structures like Wanawish Dam (Fritts and Pearsons 2006). Increases in water temperature in the lower river are thought to lengthen the outmigration for juvenile steelhead, causing them to spend more time in lower river areas where non-native predators are most effective. Non-native predators may be more efficient in warm water conditions. Poor water quality conditions in the lower Yakima River can lead to increased mortality rates in steelhead and other native anadromous smolts from water-borne pathogens.

3.2 Coho (*Oncorhynchus kisutch*)

Native coho salmon were extirpated from the Yakima River by the early 1980’s as a result of overexploitation of fishery, water and habitat resources. Recently, the Yakima Nation and the Yakima Klickitat Fisheries Project have reestablished coho populations in the Yakima Basin. The lower Yakima River mainstem is utilized as a migration corridor for this species. Impaired lower Yakima River mainstem conditions limit productivity. Predation, mortality/injury from diversions (e.g., Chandler), altered flow regimes, floodplain/side-channel disconnection, and water quality are important migration barriers for juveniles. Projects to enhance and maintain the lower Yakima River migration conditions from September through June may help improve juvenile coho production. Adult coho are not significantly constrained by lower Yakima River temperature conditions based on their migration timing.

3.3 Chinook Salmon (*Oncorhynchus tshawytscha*)

Chinook salmon display a continuum of run timing, labeled as spring, summer and fall varieties. Beckman et al. (2000) described 0-year juvenile Chinook distribution in spring and summer as largely above Roza Dam. Fritts and Pearson (2006) describe two life histories manifested in Yakima River Chinook salmon: spring Chinook, which return in the spring and spawn in upstream portions of the basin; and fall Chinook, which return in the fall and spawn in the lower elevation portions of the basin. Spring Chinook rear for a full year before migrating downstream to the Pacific as yearling smolts. Fall Chinook migrate to the ocean as subyearlings by late June. Fall Chinook salmon populations in modern times have supported tribal and sport fisheries.

Spring Chinook

Spring Chinook are primarily considered limited by the available juvenile rearing habitat in the Yakima River (Harring 2001). As spring Chinook spawn above Prosser Dam, restoring spring Chinook juvenile rearing habitat is outside of the lower Yakima River assessment. In general, adult spring Chinook are not significantly constrained by warm summer temperatures as their run timing is predominantly before temperatures become inhospitable in the lower mainstem river. Spring Chinook, however, are constrained by other migration factors in the lower river and maintaining the lower corridor for juveniles from September through June is critical. Reducing diversion related mortality and injury at Chandler, reducing predation, improving flow conditions, and improving Yakima delta conditions are all primary goals related to improving juvenile spring Chinook production in the lower river (Haring 2001).

Fall Chinook

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. In contrast, during 2004 to 2008 about 80% of the estimated escapement was 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). Water quality and warm temperatures are also a concern. Projects to reconnect floodplain habitats and disconnected side-channels may improve fall Chinook production. Predation is also a primary concern.

The recent proliferation of water stargrass and sedimentation of spawning gravels has been attributed to decreased spawning habitat in the lower Yakima River. In 2002, the WDFW counted more than 1,000 redds in the lower Yakima but by 2008, the count had dropped to 42 (Hoffarth 2009). This upstream shift in spawning is most attributed to increased water stargrass abundance in the lower Yakima River (Hoffarth 2009). Water stargrass forms a thick mat over spawning gravel, preventing redd building. Spawning further upstream lengthens migration time and distance for both adults and juveniles, and potentially reducing survival rates. Water stargrass in the lower Yakima River is further discussed in CHAPTER 7.

As part of this assessment, fall Chinook spawning grounds in the lower river were examined. Recent historical spawning grounds were identified by WDFW (personal comm. with Paul Hoffarth) for the lower Yakima River and are shown in Figure 10 and Figure 11. These figures show locations that fall Chinook have been known to spawn prior to recent degradation of fall Chinook habitat.

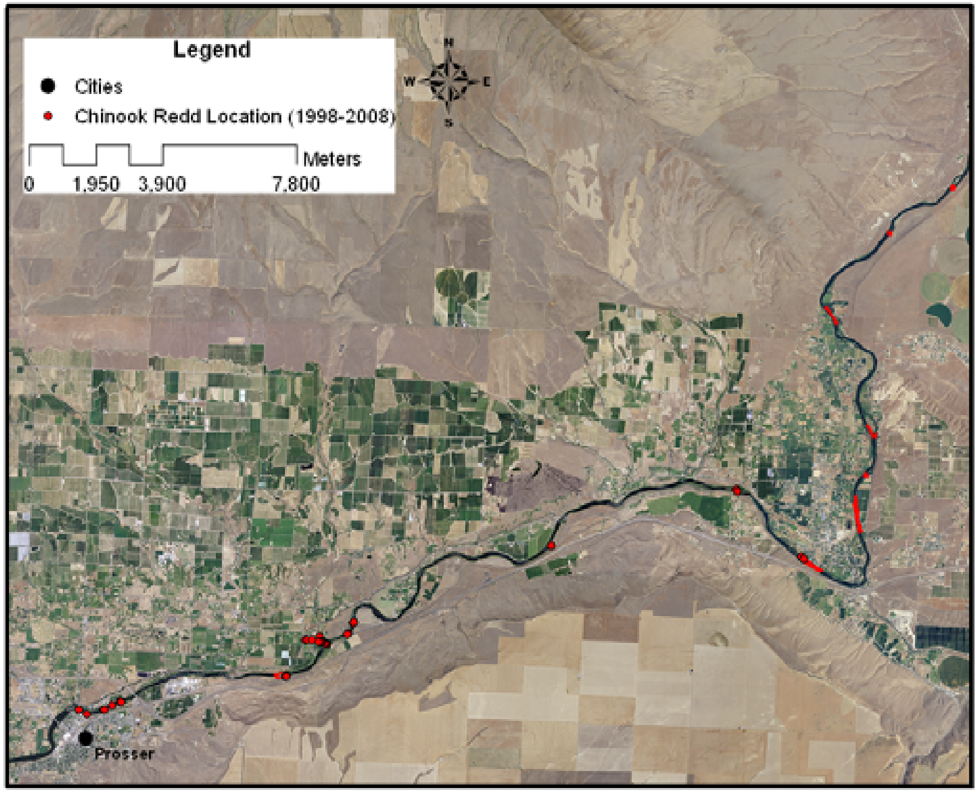


Figure 10. Identified fall Chinook redd locations (recent history), Prosser to Benton City

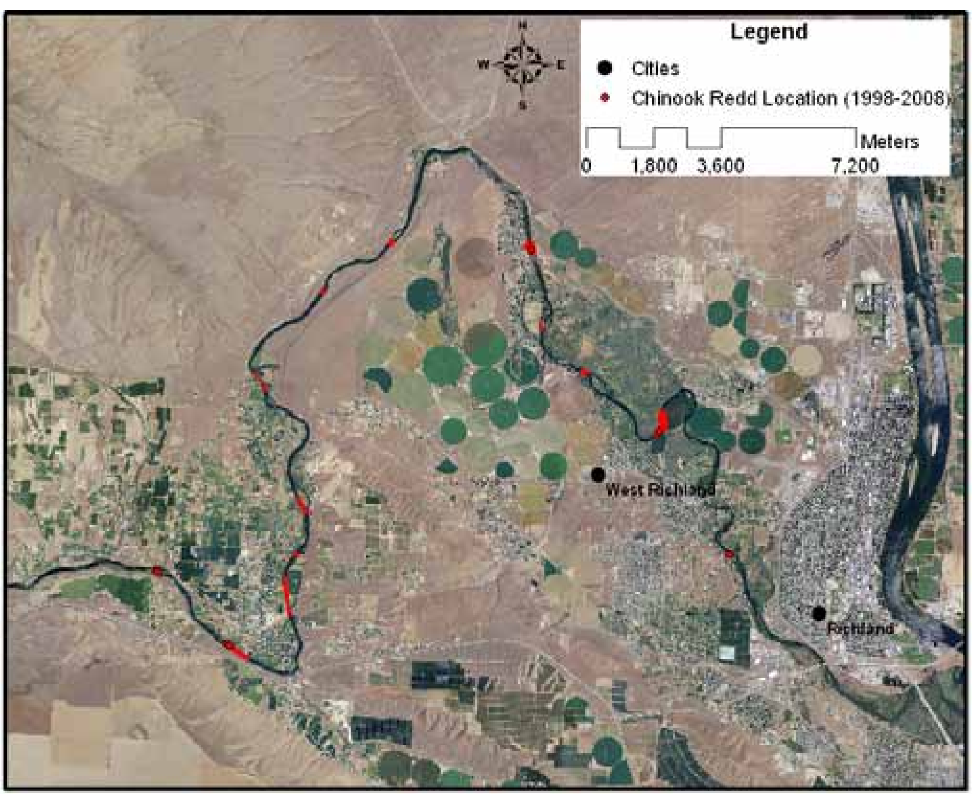


Figure 11. Identified fall Chinook redd locations (recent history), Benton City to Delta

In 2009-2010, aerial redd surveys were conducted by Pacific Northwest Laboratory in conjunction with DC Consulting, LLC to document redd spawning in the lower Yakima River. The aerial redd surveys were conducted over the lower Yakima River in fall of 2009 and 2010. The results of these aerial surveys are presented in Mueller (2010) and Mueller and Child (2011). Previously, only limited aerial surveys could be performed for the lower Yakima River due to limitations resulting from high turbidity and poor water clarity. With recent improvements in irrigation practices and wasteway drainages it is now possible to conduct aerial redd surveys within the lower Yakima River. These results can be used in tandem with ongoing boat surveys performed by the WDFW and the Yakama Nation to quantify redd presence in the lower Yakima River. Knowledge of salmonid utilization within the lower river is imperative for identifying appropriate restoration priorities. Results of these studies are beneficial for federal and state agencies and support ongoing research in the basin (Mueller 2010).

PNNL flights conducted in 2002 counted a total of 176 redds between Wanawish Dam and Highway 240 (PNNL unpublished data as cited in Mueller 2010). This is in stark contrast to the redd counts within this stretch during the 2009 and 2010 aerial flights; no redds were detected in 2009 and only 7 redds were detected in 2010 (Mueller 2010 and Mueller and Child 2011). In both years, redds were primarily located within the stretch of river between Prosser and Wanawish Dam for the lower Yakima River in Benton County. There were 24 redds identified in 2009 (Mueller 2010) and 18 redds identified in 2010 (Mueller and Child 2011). The number of fall Chinook redds counted within this portion of the river pales in comparison, however, to the redd counts above Prosser Dam. In 2009, 449 redds were counted above Prosser Dam (Mueller 2010) and in 2010, 175 redds were located above the dam (Mueller and Child 2011). Note: the lower counts in 2010 are most likely the result of fewer survey flights in 2010 as compared to 2009 because of weather conditions. The aerial flight data highlights the fact that fall Chinook spawning grounds have been greatly diminished in the lower Yakima River within Benton County over the last decade. The final PNNL reports and locations of the identified redds are provided in Appendix A (2009 data) and Appendix B (2010 data).

Summer Chinook

Summer Chinook, as with sockeye, have been eliminated from the Yakima Basin. Reintroduction programs for the return of summer Chinook to the Yakima are underway by the Yakima Nation and Yakima Klickitat Fisheries Program. Extreme thermal temperatures in the lower Yakima River are a primary limitation to the success of summer Chinook returns as warm summer temperatures coincide with their migration timing. Projects to enhance cool water refugia in the mainstem Yakima along with projects to improve temperatures at the delta may increase the success of migration runs for adult summer Chinook.

3.4 Sockeye (*Oncorhynchus nerka*)

The Yakima River watershed historically supported sockeye, but they have been eliminated from the basin as the result of damming lake outlets in the upper watershed for water storage during the early 1900's. Studies are ongoing to determine sockeye reintroduction in the Yakima Basin. Although it may be possible to reintroduce sockeye spawning in the Yakima, the thermal block created by the lower Yakima River during the return of the adult sockeye run would limit success of reintroduction efforts (Haring 2001). Enhancing adult migration in the lower Yakima River from June through September is critical for sockeye returns. Enhancing cool water refugia, removing summer thermal barriers at the mouth, exploring optimal flow parameters and continuing water quality improvement efforts may help with future reintroduction efforts.

3.5 Lamprey (*Lampetra tridentata*)

Pacific lamprey is a cartilaginous, primitive, anadromous fish resembling an eel. Historically three species of lamprey, including anadromous and resident varieties inhabited the middle Columbia Basin. In recent decades, their populations have crashed. Pacific lamprey is a federal species of concern with monitoring status in Washington State. The U.S. Fish & Wildlife Service determined that not enough was known about the Pacific lamprey to warrant an official listing. Currently there is growing interest in documenting and protecting lamprey throughout the Columbia Basin and in the Yakima River. Adult lamprey spawn in freshwater gravel areas similar to salmon spawning habitat. Restoration efforts to enhance spawning gravel for salmonids will likely afford benefits to lamprey as well and vice versa.

Lamprey fulfill several ecological roles, including filtering nutrients, transporting marine nutrients into freshwater, and serving as slow-swimming prey with high fat content. As lamprey numbers have dropped, predators may switch prey choice and exhibit more predatory pressure on juvenile salmonids. Lamprey are fundamentally important to local native cultures as a traditional food source and part of the ecosystem. More information is needed on lamprey distribution, abundance, life history, habitat use and limiting factors in the lower Yakima River.

3.6 Bull Trout (*Salvelinus confluentus*)

The 2010 bull trout critical habitat final rule lists the Yakima River mainstem, including the lower Yakima River, as designated critical habitat for possible migrations of bull trout to the Columbia River.

3.7 Piscine Predators

One of the earliest introductions of smallmouth bass (*Micropterus dolomieu*) in Washington State occurred in 1925 when state game protector N. E. Palmer planted 5,000 juvenile fish in the Yakima River. WDFW has estimated smallmouth predation on salmonids in the lower 68 km of the Yakima River at 202,722 juveniles in the spring, primarily on fall Chinook (WDFW 2000). Fritts and Pearson (2006) also found that Chinook salmon (*O. tshawytscha*) were the most abundant food item in smallmouth bass stomachs in spring and summer, but coho (*O. kisutch*) and steelhead (*O. mykiss*) were also present. Smallmouth bass prefer to eat the smallest fish available, which in the spring and summer are naturally produced fall Chinook juveniles. Although native northern pikeminnow (*Ptychocheilus oregonensis*) were the dominant piscivorous predator on juvenile salmon in the lower Yakima, they have been displaced by non-native smallmouth bass. The average smallmouth bass predator is smaller than the pikeminnow, but the bass are so numerous that they have a larger detrimental effect on juvenile salmonids. Smallmouth bass are capable of consuming salmonids that are up to 56.6% of predator fork length (Fritts and Pearsons 2006). WDFW has removed the individual catch limit on smallmouth bass 12 inches or smaller in an economical attempt to reduce predation on juvenile salmonids. Since approximately 50% of bass anglers practice catch-and-release, this effort is not highly likely to have the desired result. Many people remain cautious about eating Yakima River fish due to past Health Department warnings about residual pesticide levels in fish.

CHAPTER 4 IMPACTS OF THE YAKIMA PROJECT

The Yakima Project has influenced salmonids in the lower Yakima River through altered flow regimes, passage and entrapment issues with diversion dams, while increasing predation issues at diversion facilities. Two diversion dams are present on the lower Yakima River in Benton County. These are the Wamawish (Horn Rapids) Diversion Dam and the Prosser Diversion Dam. The impacts of these diversion dams on salmonid populations are cited in Habitat Limiting Factors (Haring 2001) and are summarized as follows: adult passage delay due to bedload ladder clogging and/or large woody debris at ladder exits, entrainment within Chandler Canal during dewatering for screen maintenance, and dewatering of fall Chinook redds with the onset of fall Chandler power generation in the area known as the “bypass reach.” Prosser Dam diverts up to 1500 cfs into the Chandler Canal removing this flow from the stretch of river downstream of the Prosser Dam. Over half of this flow is routed to the Chandler Power Plant for energy generation prior to its return to the river. The Kennewick Irrigation District uses the remainder of the diverted flow for Tri-Cities irrigation. This diversion of water at Prosser leaves a “hole” in the river between Prosser and Chandler resulting in even lower mainstem flows within this reach. This can negatively impact smolt out-migration and lead to higher than normal water temperatures during times when the river is already under drought conditions (Haring 2001). The diversion dams do have fish passage and screening for juveniles to help mitigate salmonid mortality.

Smolt survival at the Chandler Enumeration Facility has been studied and mortality was found to be higher at warmer water temperatures (Haring 2001). As a result, the Yakama Nation Fisheries Department implements a trap-and-haul operation when water temperatures exceed 70°F and daily air temperatures exceed 90°F. Salmonids are captured and trucked past the lower Yakima River. By implementing trap-and-haul operations, out-migrating salmonids are able to bypass the harsh thermal conditions of the lower Yakima River and delta.

Predation is also problematic with the bypass systems at the diversion dams. At Prosser Dam, northern pikeminnow assemble at the bypass outfall and smallmouth bass congregate at Horn Rapids Dam (McMichaels 1999) (all as cited in Haring 2001). Piscivorous fish also congregate inside the Chandler Canal. This is further exasperated by bird predation on migratory fish by gulls, terns, cormorants and pelicans. California gulls feed at the Prosser Dam and Horn Rapids Dam as the salmonids are discharged back into the river. Phinney (1999, as cited in Haring 2001) found a relationship between higher flows and the decline of gull predation on salmonids. At Chandler, gull feeding declined around 4,000 cfs and at Horn Rapids, gull feeding declined around 3,000 cfs. The decline is likely due to increased turbidity, which decreases the predators’ ability to see the fish.

CHAPTER 5 FLOODPLAINS AND FLOOD CONTROL

5.1 Floodplain and Habitat in the Lower Yakima River

A thorough analysis of flow and habitat relations in the lower Yakima River from Prosser, WA to the delta (Richland, WA) was completed from 1999-2001 by Stanford, Kimball and Whited (2001). This analysis investigated and quantified the change in aquatic habitat associated with low summer flow (~500 cfs) and high summer flow (~1,000 cfs). The study investigated channel complexity, number and size of identified habitat, water depth and velocity for in-stream habitats, biological aspects (benthic invertebrates) and geomorphological characteristics.

Regional mapping of the Yakima River from Prosser dam to the confluence with the Columbia River showed a total wetted area of 600 ha with 70% of the surface water area classified as deep-slow (Stanford et al. 2001). Horn Rapids to the delta had the greatest amount of backwater/off-channel habitats (6.12 ha) with Prosser to Chandler having the least amount of backwater/off-channel habitat (1.23 ha). The total surface water area was greatest for the reach between Chandler to Horn Rapids (250 ha) with Prosser to Chandler having the least amount of total surface water area (134 ha). The study results indicate that the lower Yakima system reflects a recent history of reduced volume and altered seasonal flow regime that severs the more complex flow pathways within an alluvial, dynamic river/floodplain system (Stanford et al. 2001).

Under measured low flow conditions Stanford et al. (2001) found that off-channel habitats were less abundant, more isolated and had shallower depths relative to high flow conditions. This is significant in the context of the lower Yakima River where off-channel habitats are naturally scarce even at high flow due to its confined river geomorphology. Off-channel habitats decreased by 38% under low flow conditions, with the largest losses occurring within connected habitats (decrease of 2.6 ha) (Stanford et al. 2001). These off-channel habitats such as backwater channels, spring brooks, and floodplain pools are critical to juvenile salmonids. Deep off-channel habitats had the greatest amount of loss under low flow conditions (62%) thereby removing deeper water pools that are likely to provide thermal refugia during mid-summer extremes (Stanford et al. 2001).

For high flow conditions, 12% of the main-channel was classified as riffle habitat whereas only 8% was classified as riffle habitat during low flow analysis (Stanford et al. 2001). Exposed rocks within the main-channel increased significantly at lower flows creating an additional source of in-stream warming.

The number of islands and size of islands fluctuated with high and low flow regimes. At high flow, 140 islands were measured in comparison to 85 at low flow (Stanford et al. 2001); the average island size increased by 11% at low flow. These results reflect aggregation of several small islands into larger islands and smaller near shore islands being absorbed by the shoreline under low flow conditions. As such, channel complexity, channel habitat heterogeneity, and lateral and vertical floodplain connectivity were decreased under low flow conditions (Stanford et al. 2001).

Groundwater seeps within backwater habitats were identified during the study and found to maintain consistently cooler temperatures than the main-stem channel (Stanford et al. 2001). These areas are likely to provide critical thermal refugia for benthic organisms and associated fish populations. Flow of river water through interstitial pathways in floodplains and gravel bars is important for regulating river temperature and salmonid ecology (Giber et al.1994).

The work by Stanford et al. (2001) highlights, that with only moderate changes in flow, substantial gains can be made in regards to floodplain connectivity and off-channel habitats that are important for salmonid rearing in the lower Yakima River below Prosser, WA. This discussion is independent of increased flow for regulating temperature in the lower Yakima River. Even at high flow, floodplain habitat is minimal within the lower Yakima River and as such any degradation to this habitat as a result of decreased flow is likely to have a significant impact on the off-channel habitats, complexity of the reach, and thermal refugia.

5.1.1 Examples of Floodplain Projects on Lower Yakima River

Higher, faster flows would arguably benefit the following examples in terms of habitat and scouring, however, managing flow is outside of the scope of work for this project. Despite flow management issues, there are projects that would benefit disconnected side-channels and prevent further sedimentation and loss of habitat. Projects would need to be developed to capture current flow dynamics and aid in scour. The following are a few aerial photos of side-channels on the lower Yakima River that are experiencing sedimentation.

Figure 12. Disconnected oxbow, Benton City

Figure 13. Dry side channel, West Richland

Figure 14. Side channel, Richland (west bank)

Figure 15. Fox Island side-channel, West Richland. Dry channel in summer (left). 2011 May flood event (right) (photo by Tom Seim, all rights reserved)

Figure 16. Side channel, I-182 bridge, Richland. Dry side channel (left). 2011 May flood event (right) (photo by Bill Evans and Wendy Shaw, all rights reserved)

5.2 Flooding and Flood Control in Benton County

Floodways and Floodplains along the Yakima River are shown on Figure 17. The flood areas on the Federal Emergency Management Act (FEMA) FEMA map indicate the magnitude of floods. The most damaging floods in Benton County are associated with the Yakima River (Benton Comprehensive Plan 2006). Areas along the lower Yakima River extending from Benton City downstream through West Richland to the delta are especially vulnerable to flooding (Benton Comprehensive Plan 2006). This area is characterized by low-lying river bottomlands and ancient river channels that are the river's natural floodway and flood plain.

The greatest known flood of the Yakima River in occurred in December of 1933 with a depth of approximately 9.5 feet above the top of the riverbank at Benton City (Benton Comprehensive Plan 2006). Other notable floods occurred in 1948, 1974, and 1996. The flood of

At present, there is limited flood control on the lower Yakima. Levees exist on both banks of the Yakima River at its mouth. A levee also exists on the south bank of the Yakima River in West Richland across from Van Giesen Rd (HWY 224). Removal of the levees is not feasible, as it would result in partial flooding of the cities of West Richland and Richland. Hardened levees should be made more ecologically friendly providing both flood protection and habitat for the river.

Yakima River flooding in agricultural and rural areas threatens water quality with the potential for capturing livestock and agricultural pollutants including manure and pesticides, and petroleum products from road surfaces. West Richland and Benton City are especially susceptible to flooding of agricultural and rural areas. Outreach programs targeting these landowners should be developed with the dual purpose of protecting private property and water quality.

Yakima River flooding in rural residential areas threatens water quality due to the potential for floodwater to overwhelm domestic septic systems, January 2011

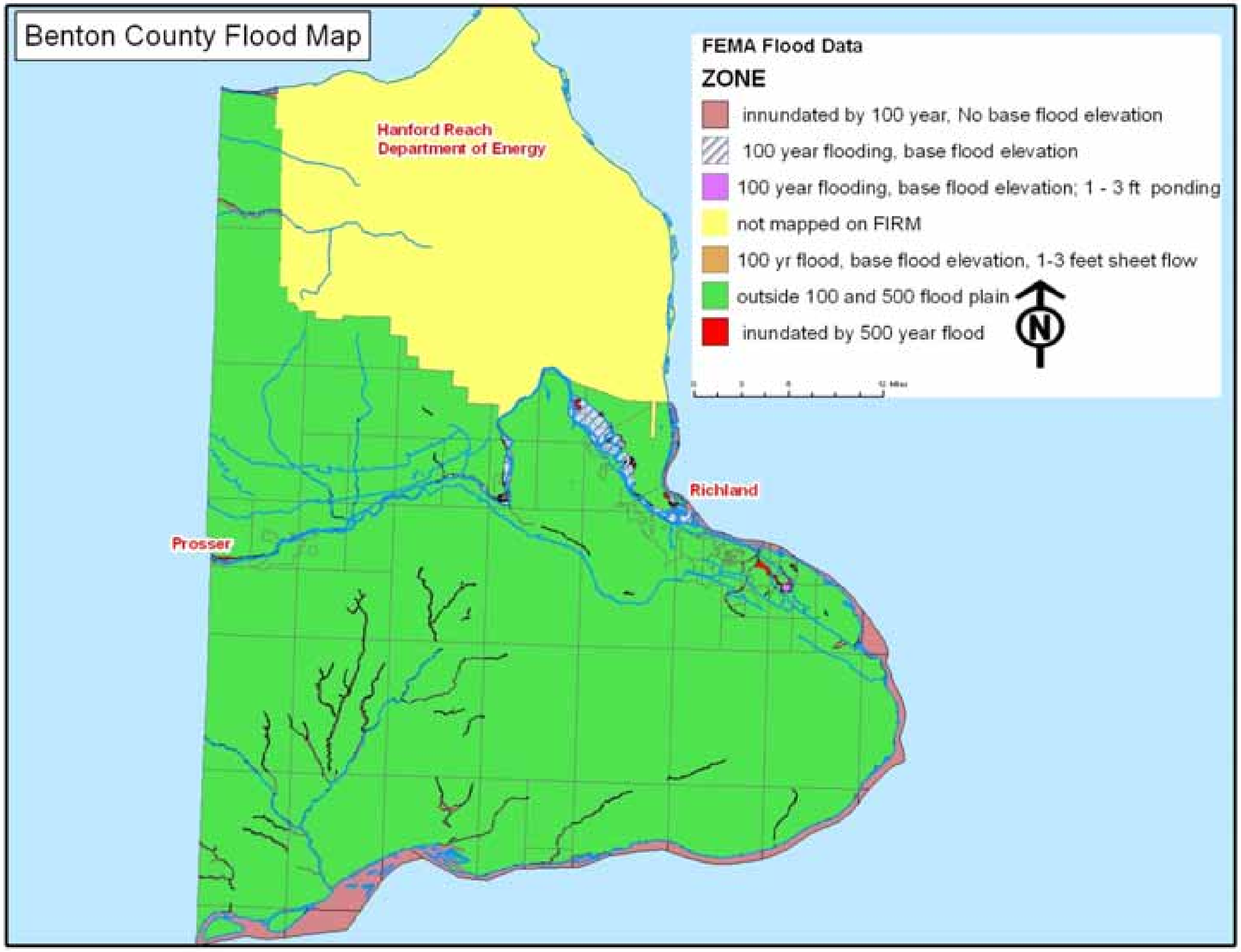


Figure 17. Benton County flood map

CHAPTER 6 MANAGEMENT OF WASTEWAYS

The Yakima River from Prosser to the delta contains four wasteways maintained by local irrigation districts. These irrigation wasteways are:

- Snipes Creek Wasteway and Spring Creek Wasteway - Roza and Sunnyside Irrigation Districts
- Corral Creek Wasteway - Roza Irrigation District and Benton Irrigation District
- Amon Creek Wasteway - Kennewick Irrigation District

As wasteways, they are operated to carry irrigation return flows directly back to the Yakima River and provide a water bypass route in times when there is temporary excess of water arriving down the irrigation district's main canal. All four of these irrigation wasteways utilize natural depressions such as draws and ravines that may have historically captured rainfall and runoff but did not seemingly maintain year round flow. With the onset of irrigation in the Yakima Basin, flow within these ravines and draws has increased and is maintained year round through irrigation groundwater recharge and overland return flow. With continued year round flow, salmonids are utilizing these wasteways as spawning and rearing habitat; sparking much debate regarding the best management practices and utilization of these wasteways.

Several recent studies have investigated the various properties of these wasteways to determine fish usage (Monk 2001), natural stream flow estimates (Smith et al. 2002), fish habitat quality (Romey and Cramer 2001, Child and Courter 2010), water quality (BCD 1998, Wagner 2000, Zuroske 2006, Zuroske 2009), and potential for salmon restoration projects within the wasteways (Romey and Cramer 2001 and Child and Courter 2010). Stream habitat was determined by S.P. Cramer and Associates (Romey and Cramer 2001) to be fair to good for natural production of salmonids in Snipes Creek, Spring Creek, and Corral Creek Wasteways but that migration barriers and low flows limit their potential for salmonid production. Monk (2001) confirmed through his findings that salmonids appear to have some success spawning and rearing in Spring Creek, Snipes Creek and Corral Creek Wasteways.

Over the last decade significant improvements have been made in the Spring Creek and Snipes Creek Wasteways regarding water quality. Previously, these wasteways were major contributors of total suspended solids to the Yakima River during the summer months. They additionally provided a source of nutrient loading. Water quality analysis between the years of 1997 and 2008 showed a significant decrease in discharge and concentrations of total suspended solids and nutrients (Zuroske 2009). The improvement of water quality within several irrigation wasteways in the Yakima Basin has led to improved water clarity within the lower Yakima River.

Fewer habitat and fish studies have been completed for Amon Creek Wasteway than its counterparts of Spring Creek, Snipes Creek, and Corral Creek Wasteways. Child and Courter (2010) studied Amon Creek Wasteway's suitability for salmonid rearing and determined that Amon does seasonally support a limited number of salmonids, but that carrying capacity is limited. From their results it appears that at this time the mainstem and East Fork of Amon Creek do not appear to be well suited for the rearing of salmonid during summer and early fall when temperatures are well above 21°C.

Habitat projects and targeted salmon restoration efforts within the wasteways are a complex issue. On a basin wide scale, salmon recovery efforts in the wasteways are not a high priority as the population returns are likely to be minor compared to other salmon recovery efforts within the basin. Locally, interest is high to see wasteways with improved salmon habitat for both social and economic reasons; however, restoration efforts must meet the functionality of the wasteways and managing desires of the involved irrigation districts. Given the difficulty of marrying wasteway management with salmon recovery efforts is a problem not likely to be solved in the near term; however, there are interim actions that can be undertaken regarding the wasteways.

1. Implementing projects targeted at improving best management practices (BMPs) on land bordering wasteways for the goal of water quality enhancement and water conservation. BMPs should include livestock fencing and bank management.
2. Improve understanding of the complexity of hydrological flowpaths and nutrient transport process affecting the wasteways during both the irrigation and non-irrigation seasons to develop BMPs targeted at improving water quality (Zuroske 2009)
3. Improved knowledge of the tradeoffs of irrigation canal lining on the influence of removing groundwater recharge and cool water inputs to the Yakima River vs. supplying a greater amount of flow within the river
4. Investigation of wasteways for potential thermal refugia possibilities

CHAPTER 7 WATER STARGRASS (*Heterantera dubia*)

The lower 43 miles of Yakima River below Prosser Dam are dominated by an aquatic macrophyte called water stargrass (*Heterantera dubia*) (Figure 18). In 2008 and 2009, Water stargrass was found to be prolific in the lower Yakima River starting above Whitstran, WA. Water star grass was not as prevalent in the swift boulder sections of the river below Prosser, WA.

Water stargrass is a rooted perennial plant, easily distinguished from terrestrial grasses by the lack of distinct medial vein on the leaf. It is named for the bright yellow, six-petal star-shape flower that blooms just above the water surface in June and July (Figure 19). The thin stem bears alternating short branches, each with a single elongate leaf. The running stems have been observed as long as 3 m, but distinguishing individual plants is difficult because of its tendency to form dense colonies. At intervals, the running stem produces root nodules so that long running stems become anchored to the substrate at multiple points. Water stargrass propagates via running shoots and seeds. The plant is brittle and stem sections with leaves often break off and drift downstream. If broken stem sections contain root nodules, the broken section can develop roots and attach at a new location. Water stargrass is such an aggressive and successful pioneering species that the Army Corps of Engineers uses it to quickly establish lakeshore restoration projects in the Midwest.

Figure 18. Water stargrass in Kiona reach (July)

Figure 19. Yellow blossoms on water stargrass (Yakima River)

7.1 Problems Associated with Water Stargrass

Residents and scientists became increasingly concerned about aggressive plant growth in the lower Yakima River in the late 1990s. The Eutrophication Study (Wise et al. 2009) was implemented in large part due to these concerns about aquatic plants. Water stargrass has been observed thriving in the lower Yakima in a variety of habitats, ranging from finely silted slackwater areas to cobble substrate with high water velocity, even atop boulders in bedrock reaches. Sections detached from the main plant will grow and flourish without the benefit of attachment to the sediment, such as hanging on large woody debris. A contract diver collecting reference plant samples traversed the entire river width near Benton City, just downstream of the decommissioned railroad bridge, and found no limit with depth to the water stargrass distribution. Water stargrass forms a bank-to-bank monoculture in the majority of the lower Yakima, with magnified effect in low water years. In shallow areas, water stargrass plants easily reach the water surface, then continue growing, laying horizontal and forming a canopy at the water surface. In deeper areas, water stargrass plants form straight columns to the surface.

Despite its classification as native, water stargrass in the lower Yakima acts like a non-native invasive species. Water stargrass is exploiting river conditions to the exclusion of other plants. The dominant land use in the Yakima River watershed is agriculture. Decades of intensive agriculture have led to increased nutrients in the Yakima, now coupled with expanding urban development and associated water treatment demands. Wise et al. (2009) theorized that the relatively recent expansion of water stargrass is due to a combination of effects. The excessive nutrient load to support the plant community may have existed for decades, but dramatic recent improvements in water clarity now allow sunlight to penetrate the water column at greater depths. Washington Department of Ecology developed a TMDL for sediment load in the Yakima River. Several simultaneous improvements to agricultural practices significantly reduced the sediment load, including conversion from flood to sprinkler irrigation, scientific irrigation water management and conservation and application of polyacrylomide (PAM) to stabilize soil particles on fields. Although praised nationally as a conservation success story[7], this great improvement in water quality unintentionally opened the door proliferation of water stargrass.

Figure 20. Return flow discharging into the Yakima River before (left) and after (right) irrigation improvements (photos courtesy of SYCD)

Water stargrass causes a host of problems in the lower Yakima River, including physical threats to habitat, chemical threats to water quality and management issues. US Geological Survey has maintained a gauging station at Kiona, Washington measuring both flow and gauge height. As a result of the high amount of plant biomass, USGS measured a change in flow:depth ratio. The large amount of water stargrass was physically displacing the river.

Water stargrass also physically threatens habitat. Beaver, carp and other fishes have been regularly observed traveling along the same narrow confines within dense water stargrass stands, much like terrestrial animals navigate along game trails in a thick jungle. Water stargrass forms dense vegetative mats, approximately 3-4 inches thick over the substrate including cobble. Fall Chinook salmon avoid the ‘carpet’ of stargrass and push past traditional spawning grounds in the lower river to find redd-building gravel further upstream. Historical fall Chinook spawning prior to water stargrass was almost entirely below Prosser Dam (Mueller 2009). Now that lower Yakima spawning gravels are covered with water stargrass, almost all fall Chinook spawning occurs above Prosser. This upstream shift in spawning increases migration effort for both adults and juveniles and forces fish to utilize areas other than those the population may be adapted to. Water stargrass’ effects on water velocity and suspended particles is also contributing to the covering of spawning gravels.

Large amounts of water stargrass slows stream flow causing fine sediments to settle. Water stargrass was removed in a side channel of the lower Yakima River as part of a BCD spawning habitat restoration project (completed in 2010). The downstream edge of the project area showed a sandy bottom where underneath the root mat of water stargrass was approximately three inches of sand. Underneath this sand layer was a decomposing

[7] http://www.nacdnet.org/policy/environment/water/tmdl/casestudies/washington.phtml

mat of water stargrass that had become covered with sand. The decomposing mat layer was also removed, revealing more sand underneath. Upon returning to the site the next day, staff found cleared cobble in the downstream edge area. The increase in water velocity from removing water stargrass had uncovered and restored the hidden cobble within one night. Water stargrass, by slowing water velocities, is causing significant sedimentation of spawning gravel and critical side channels in the lower Yakima River.

Water stargrass also impacts dissolved oxygen 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). Given the large mass of water stargrass, during daylight hours, oxygen production from photosynthesis is greater than the oxygen demand of respiration. During night, however, oxygen consumption is greater leading to low dissolved oxygen levels in the morning. The eutrophication study (Wise et al. 2009) determined that the strongest factor impacting gross primary productivity (GPP) in the Kiona reach was streamflow. Wise et al. (2009) found a negative correlation between streamflow and GPP, with a lower amount of spring GPP occurring at higher streamflows. The high flows are likely to result in increased turbidity and water depth, thereby decreasing light availability to the plants. Water stargrass also affects pH through plant respiration and photosynthesis, causing daily fluctuations in pH that may stress local aquatic organisms. Wise et al. (2009) found that in low flow years, the maximum pH was almost always greater than the Washington State standard of 8.5, whereas in spring of high flow years, there were extended periods when the maximum daily pH levels were less than 8.5.

Water stargrass causes problems for people who rely upon the Yakima River for their livelihood and recreation. The thick vegetation can plug intake screens, forcing irrigators to clean intake areas daily, just to keep their pumps operational or fabricate “homemade” modifications to existing screens. Washington Department of Fish and Wildlife (WDFW) creel surveys reveal reduced fishing success and reduced fishing effort in both pole-days and fishing hours, as stargrass becomes more abundant. Unsolicited phone calls to Benton Conservation District and personal interviews have detailed the public’s frustration with water stargrass. Boating and intertubing are difficult in the thick, stringy jungle of plants. Some residents no longer feel safe wading when the long strands of water stargrass wrap around their legs.

Diver emerges covered in water stargrass in Benton City area near decommissioned railroad bridge. Water stargrass makes navigation and recreation difficult in the lower Yakima

7.2 Recent Removal Efforts

Benton Conservation District has worked on projects to remove water stargrass. Removal methods were considered, including biological, chemical and mechanical techniques. Biological options are limited because the lower Yakima is a free-flowing open system. Biological agents cannot be responsibly introduced because reasonable containment cannot be assured. Chemical applications are also inappropriate because some treatment areas have high water velocities, making it difficult to impossible to ensure adequate plant-chemical contact time. The mechanical techniques that were considered included hand cutting, hand pulling and tilling. Hand cutting was quickly abandoned as ineffective, partly because the brittle stems break away before a person can gather a handful to cut. Therefore pulling on the stems achieved the same effect as cutting, but more quickly. Instream work is most appropriately done in July and August, to avoid disturbing salmonid migrations, when flow is low and biomass is high.

7.2.1 Pilot Scale

This first water small grass project investigated smaller pilot scale plots in 2007-2008. Early water stargrass pilot project sites yielded mixed results a year following treatment. The first treatment site showed a returning monoculture stand of water stargrass, but at reduced plant density (based on dry weight). In the second treatment site, water stargrass did not return one year following treatment but was replaced by curly leaf pondweed (*Potamogeton crispus*), introduced from Eurasia. The third treatment 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 provided qualitative information about composted harvested water stargrass. Like most aquatic plants, water stargrass is largely water by volume and weight. In the dry summer weather, stargrass desiccates quickly, drastically reducing its volume. A local cherry orchardist was willing to experiment with using composted water stargrass as mulch at the base of his trees. When he decided he was ready to mulch the trees, he was surprised to find that the pile of harvested material had dried and reduced to such a small volume of material that he didn’t bother moving it.

Volunteer tractor operator making a pile of harvested water stargrass

7.2.2 Large Scale Removal

The second water stargrass removal project investigated large-scale removal of water stargrass in 2010. This project demonstrated the importance of harvest efficiency. Many individual volunteers assisted with this project. Volunteers exhibited a range of diligence, skill and speed at removing water stargrass. If the tops of the plants are removed but the root mass remains, the plants quickly rebound, leafing again within a matter of days. When the root mass was more completely removed, the area remained clear. The most effective technique was to use a cultivator. The cultivator is needed to start pulling the root mass away from the substrate. Once a section of mat is partially lifted, the root mass can be rolled onto itself, much like rolling grass sod. Harvested material was placed on floats to prevent escapement downstream and later towed to shore.

AmeriCorps member towing a raft of harvested water stargrass to unloading area

Treatment area showing exposed cobble substrate in the foreground and the edge of the water stargrass stand in background. Juvenile fish appeared in open water after water stargrass removal

In autumn, following the most recent stargrass removal, staff and volunteers observed fall Chinook redds and 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. Additional studies need to be performed to qualitatively determine the amount these variables changed with water stargrass removal. Water stargrass removal projects to restore salmonid spawning sites should continue in the absence of more effective management techniques. Continued monitoring and maintenance of these projects is necessary as it contributes to the knowledge basis about water stargrass management.

CHAPTER 8 LOWER YAKIMA RIVER DEPTH

Mainstem lower Yakima River depth was measured at base flow conditions during the last week of July in 2009. Continuous depth data were collected from Prosser to the Confluence using a Lowrance HDS-5 Depthfinder/GPS Chartplotter unit. The unit was attached to a pontoon boat and a rig was assembled with a mounting bracket to allow the transducer to be raised in extremely shallow waters. All depth data were analyzed and charted using ArcGIS Desktop 9.3. Data between Benton City and Horn Rapids were not charted because of mechanical problems with the GPS battery unit.

Lower Yakima River depths typically ranged from 2.5 ft-5.5 ft from Prosser through West Richland (Figure 21, Figure 22, Figure 23). Depth increased to >7 feet west of the HWY 240 Bridge in Richland and continued to the confluence. Depths quickly decreased to 2.5 ft or less within the delta of the Yakima River.

Deeper areas within the lower Yakima River were typically either glide areas or “holes”. Several of the holes identified within the lower Yakima River coincided with the location of incoming seeps and irrigation returns. For example, holes were located at both Knox Creek and Corral Creek Wasteway (Figure 22). “Holes” were also located at the east and west ends of the relic oxbow on Barker Ranch (Figure 21) an area identified by temperature data as having localized cooling. Given that the incoming irrigation returns provide a source of cool water to the Yakima River, these deeper holes need to be further investigated for their potential as thermal refuge areas.

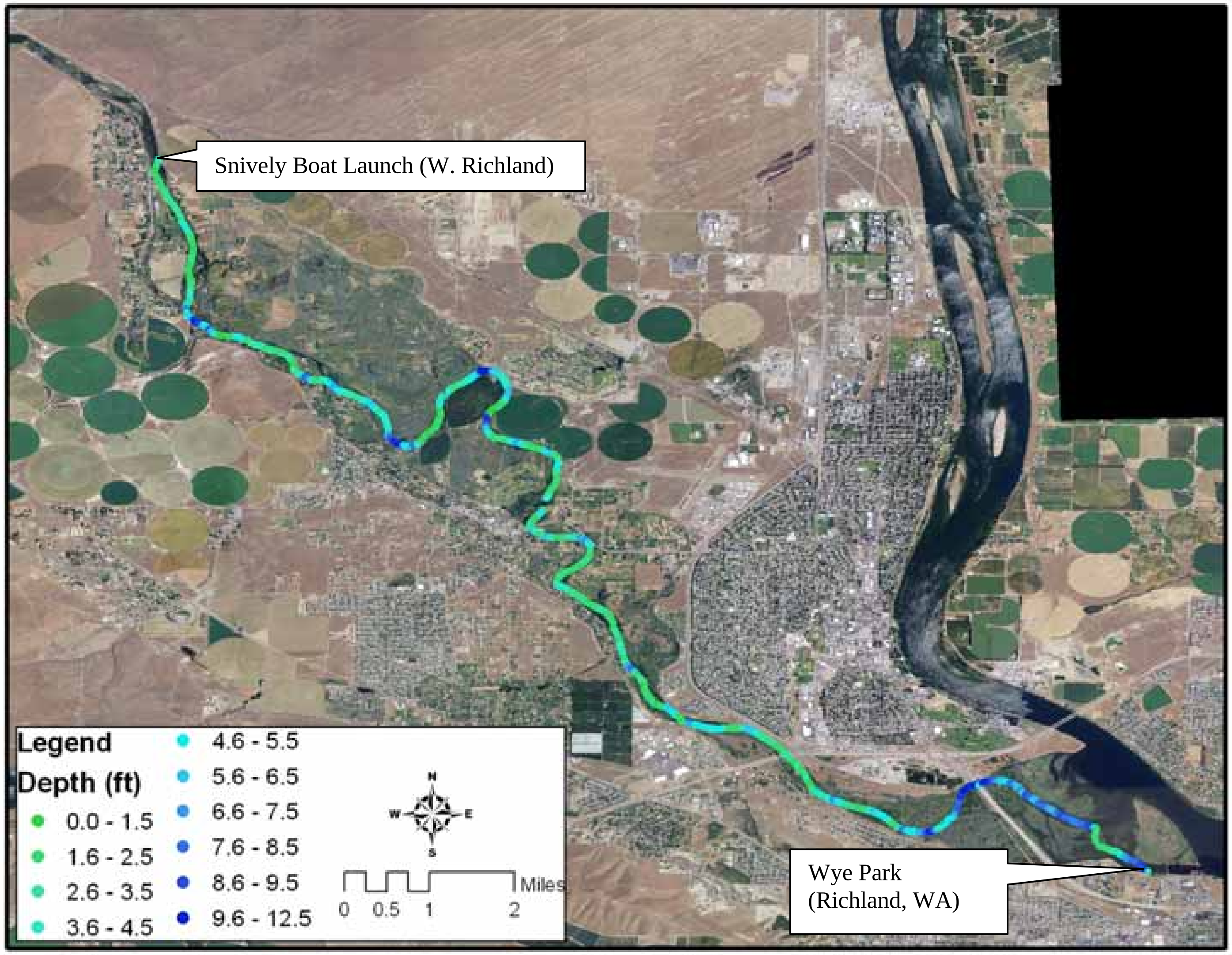


Figure 21. Depth map for lower Yakima River, West Richland to the confluence

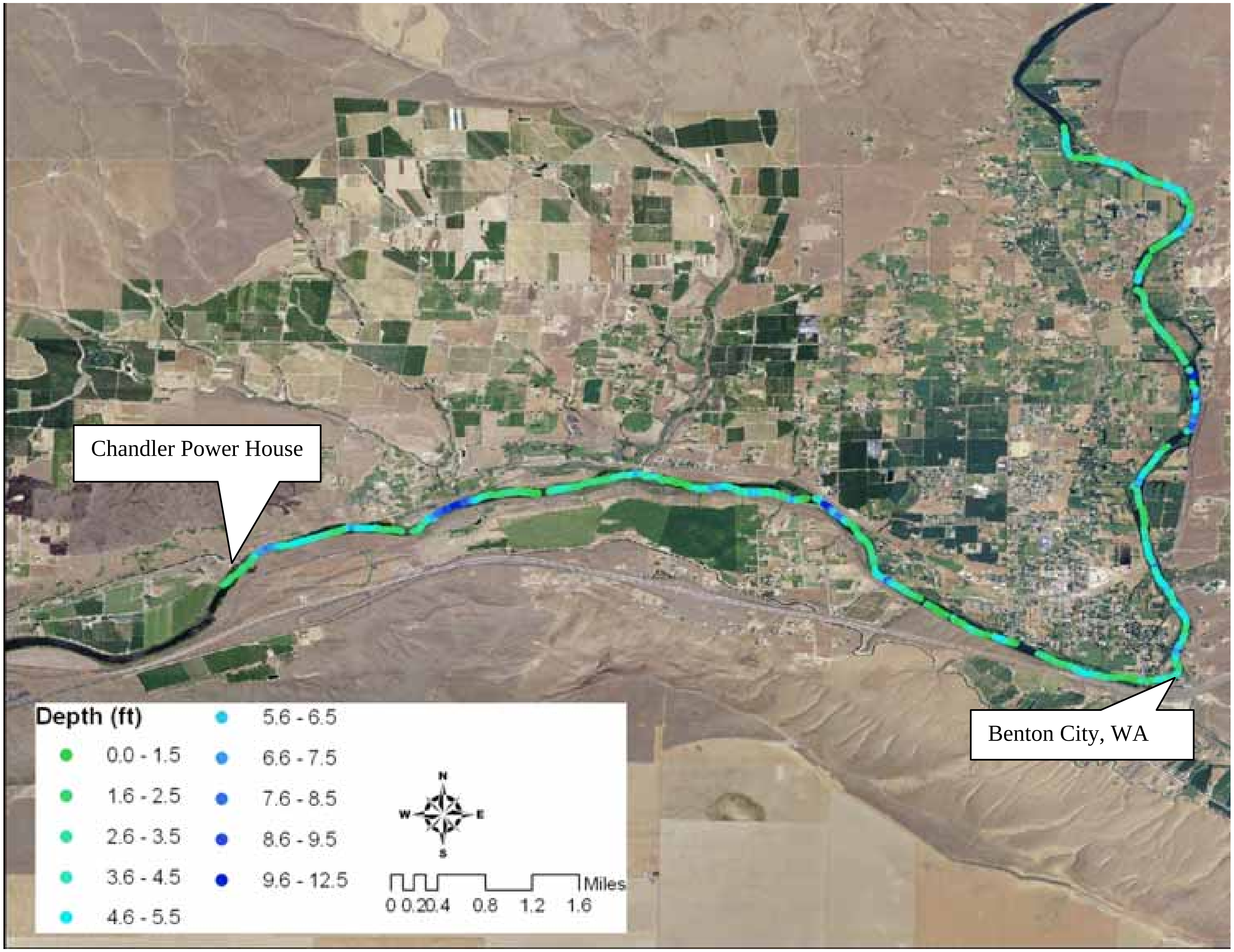


Figure 22. Depth map for the lower Yakima River, Chandler to Benton City

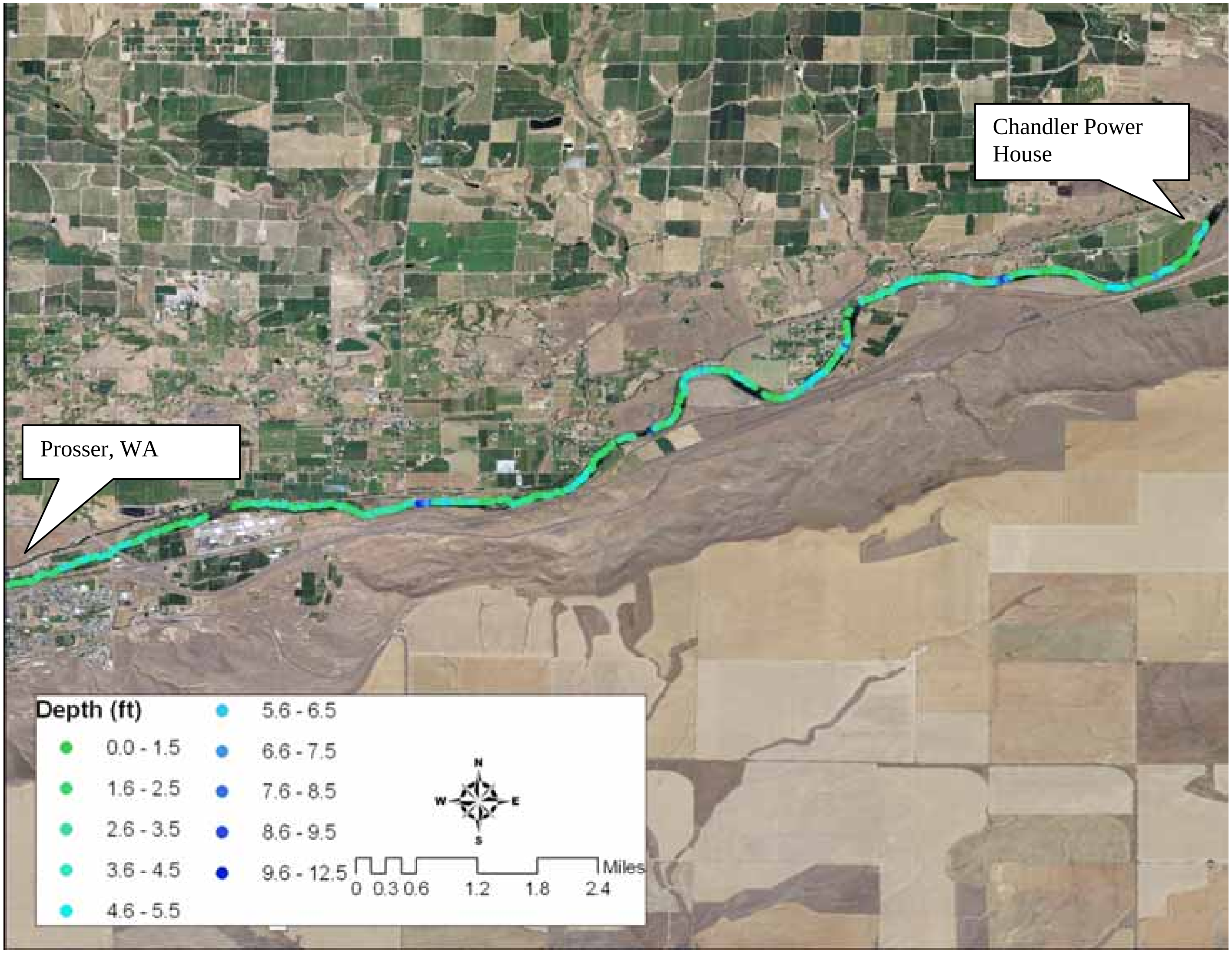


Figure 23. Depth map for the lower Yakima River, Prosser to Chandler

CHAPTER 9 THERMAL PROFILING

Numerous studies have reported extreme temperatures in the lower Yakima River as a limitation to salmon productivity (Lilga 1998; Vaccaro 1986; Wise et al. 2009). In July and August, daily maximum river temperatures often exceed the Washington State Standard of 21°C (Wise et. al. 2009). The lower Yakima River is a migration corridor for most salmonid species (e.g., spring Chinook, steelhead, and coho) and fall Chinook utilize the lower Yakima River for spawning. Spring and autumn are critical migration seasons for salmon entering and exiting the lower Yakima River. Lower river temperatures typically begin to rise towards the end of spring migration (mid June) and remain inhospitable for salmon until early fall.

There has been much discussion on how to manage lethal summer temperatures in the lower Yakima River. The lower Yakima River is a highly regulated system with a landscape dominated by irrigated agriculture, irrigated pasture, and residential areas. The current flow regime is designed to meet competing needs within the river (e.g., irrigation, fish survival, and flood management). As such, the hydrograph is quite different than what would have occurred historically within the basin. Several studies have investigated the impact of altering flow management as a way to lower summer river temperatures. Vaccaro (1986) modeled several different flow regimes and analyzed their impact on river temperatures. Vaccaro found that mean temperatures throughout the irrigation season would be lower at Prosser and Kiona with natural flows except in August when temperatures would be higher than current temperatures. While lower flows and slow moving water aid in the lower river temperature problem, Lilga (1998) estimated that approximately 70% of the variation in water temperature could be explained by ambient air temperature. Because of the width of the lower Yakima River, riparian shading does not inhibit full sun exposure and is not likely to decrease in stream temperatures. Ring and Watson (1999) argue that reduced river-floodplain interactions may be part of the problem for increased river temperatures. They argue that removal of the frequency and timing of alluvial aquifer recharge by cutting off natural river-floodplain interactions may result in higher summer temperatures and decreased areas of thermal refugia (1999). While important, alterations in timing and flow of river management for temperature alteration are a complex issue that is beyond the scope of work of this project.

This assessment investigated current temperature dynamics of the lower Yakima River and the presence of temperature heterogeneity (i.e., the presence of localized cool and warm areas) for the possibility of thermal refugia (cool pockets for refuge). While there is a vast amount of literature on the extreme summer temperatures in the lower Yakima River most of the data are collected from a few discrete locations. Typically temperature data are cited from the USGS monitoring station at Kiona. While there is great value in these studies, there is heterogeneity within rivers that cannot be captured by synoptic sampling. This project utilizes methods developed by Vaccaro (2006) to capture a thermal profile of the lower Yakima River (Prosser to the delta) and investigate the potential for refuge areas to help migrating salmon potentially navigate through inhospitable waters. Vaccaro (2006) developed a thermal profile method designed to locate cool water pockets from ground water discharge. Vaccaro argued that the profile method displays diversity and structure within the river that cannot be captured by fixed station data. This method was created to locate patches of cool water that may provide salmonid habitat and refuge (Vaccaro 2006).

Few studies have investigated this possibility of thermal heterogeneity (i.e., the presence of cool and warm areas) and thermal refugia (i.e., cool pockets for salmonid refuge) in the lower Yakima River. In August of 1997, the Bureau of Reclamation collected aerial thermal images of the lower Yakima River. These data looked at the general trends in surface temperature and provided insight into river temperature heterogeneity. The thermal imaging results suggested that there was a slight cooling of the Yakima River from the delta to Prosser and that a local warm anomaly is present at Prosser downstream of the Prosser Dam (Holroyd 1998). Additionally, this study detected a 3°C difference between the mouth of the Yakima River and the Columbia River with warmer water pooling in stagnant areas of the Yakima near the confluence (Holroyd 1998). Another study, performed in 1991, by Berman and Quinn tracked the migrating patterns of adult spring Chinook in the Yakima River. They found that fish modified homing behavior to exploit cooler water areas, thereby optimizing internal body temperature. Locating areas of thermal heterogeneity within the lower Yakima River may provide an opportunity to determine areas of high priority importance for salmon habitat projects based on their potential for salmon refuge.

9.1 Importance of Thermal Heterogeneity In Rivers

According to Washington Department of Ecology, the upper Yakima River is on the 303(d) list for elevated water temperatures that exceed state standards. The most significant determinant of water temperature in the lower Yakima River is the temperature of incoming water from the upper Yakima (Wise et al. 2009). U.S. Geological Survey maintained continuous water temperature monitors at Kiona in the lower Yakima River from April 4, 2004 until September 30, 2008.

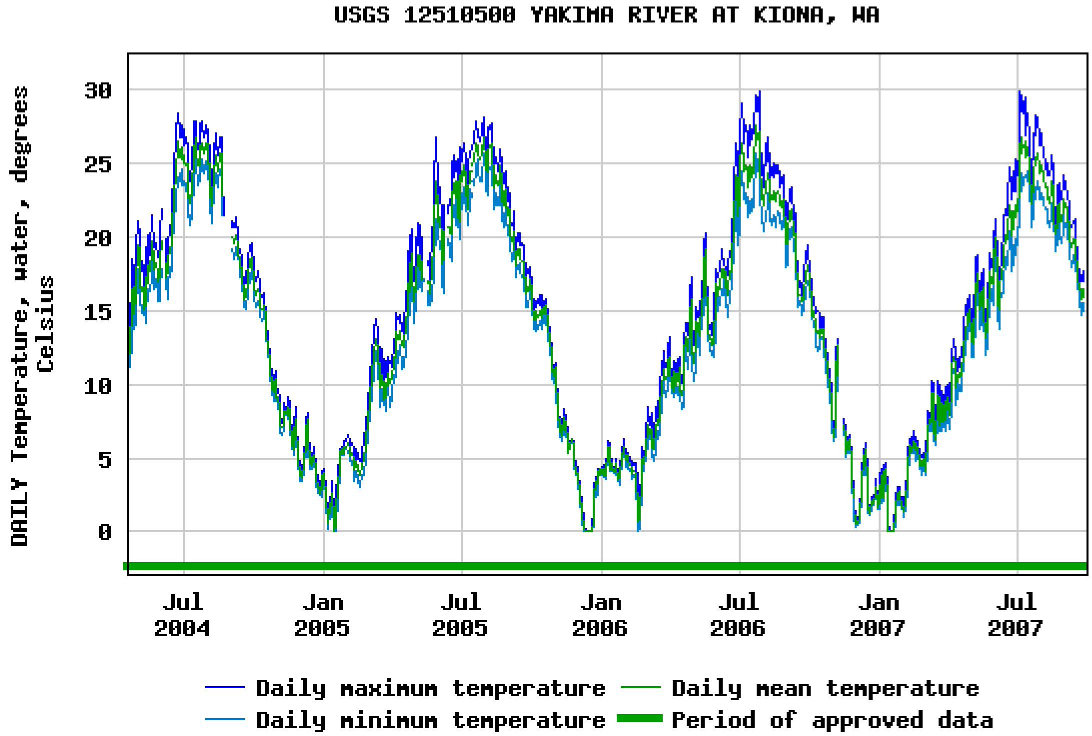


Figure 24. River temperatures at Kiona (2004-2007), http://waterdata.usgs.gov/nwis

As poikilothermic organisms, fish cannot regulate their internal body temperature independent of ambient water temperature. Thermal stress has real energetic costs associated with metabolic rate and energy storage capacity decreases with thermal stress (Heppell 2010). Therefore, even non-lethal thermal stress may compromise long-term fitness. Berman and Quinn (1991) tracked adult spring Chinook in the Yakima River with temperature-sensitive radio and ultrasonic transmitters to relate fish movements to specific water temperatures. They found that fish modified homing behavior to exploit cooler water areas, thereby optimizing internal body temperature. Freshwater fish are capable of detecting changes in water temperature as little as 0.05° C. During the study, the migrating adults maintained an average of 2.5°C body temperature below ambient water temperature. This 2.5° C average temperature difference enabled fish to lower basal metabolic rate by 25%. Since adult migrating salmonids do not feed for months during upstream migration, a 25% energy savings may be critical to completing migration to spawning grounds. Longer adult exposure to elevated temperatures may result in higher pre-spawn mortality due to infection or disease, reduced gonadal development or egg viability (Kinnison et al. 2001).

Berman and Quinn (1991) speculated there might be a trade-off between groundwater-fed cool water with low dissolved oxygen (DO) and warmer but more oxygenated water. Matthews and Berg (1996) tested this trade-off between relatively cooler water with low, possibly lethal levels of DO and lethally higher water temperature but high DO. They found that rainbow trout in thermally stratified pools significantly and consistently selected cooler water despite potentially lethally low DO. Berman and Quinn (1991) concluded that the practice of resting in cold-water refugia would enable fish to conserve energy for reproductive success including gamete production, mate selection, redd construction, spawning, and redd guarding. Berman and Quinn (1991) eloquently described that habitat restoration on spawning and rearing grounds may not be sufficient to ensure long-term survival of Yakima River salmonids without also protecting a series of cool water thermal refugia for migrating fish.

Thermal stratification has been shown to occur in riverine pools. Nielsen et al. (1994) measured surface water temperatures in stratified pools commonly 3-9° C higher than pool bottom water temperatures. They found that sixty-five percent of juvenile steelhead (*O. mykiss*) moved from adjacent reaches into stratified pools during periods of high ambient water temperatures (23-28° C). Juvenile steelhead remained in thermally stratified pools with little or no cover, making them extremely vulnerable to predation yet gaining benefits from thermal regulation. Stratified pool thermal refugia would also be critical to adult steelhead, since Fowler et al. 2009 found adult *O. mykiss* to be more susceptible to thermal heat shock than juveniles. This hypothesis was further supported by Nielsen et al. (1994) when they found adult steelhead deep in stratified pools when midday ambient stream temperatures ranged from 26-29° C and coldwater pockets averaged 3.5°C cooler. Even a shallow pool (<1 m deep) and completely exposed to solar radiation can stratify, with temperatures up to 4°C lower than mainstem temperatures. Although this study was conducted outside of the Yakima River, the watershed was characterized by high sediment loads, low summer flows and ambient summer temperatures at upper incipient lethal levels, similar to conditions in the Yakima.

Torgersen et al. (1999) asserted that thermal patchiness in streams should be recognized for its potential to provide habitat for species existing at the margin of their environmental tolerances, such as salmonids in the lower Yakima. Annual summer water temperatures regularly rise above 25° C, which is generally considered a lethal temperature for salmonids. Torgersen et al. (1999) noted that cool water pool availability and stream temperatures play important roles in determining carrying capacity of spring Chinook holding habitat. If thermal refugia in the lower Yakima are not adequately numerous or sufficiently proximate, then late spring, summer and early fall migrating life histories of salmonids will disappear. The size, quality, abundance and proximity of thermal refugia are critical considerations in restoration potential.

9.2 Study Area

Temperature profiling and depth studies were performed on the lower Yakima River from Prosser, Washington to the Yakima River Delta (Richland, Washington). The study area was divided into five reaches based on river access points. The five reaches are shown on Figure 26 and are as follows:

1. Prosser Wastewater Treatment Plant to Chandler Power House
2. Chandler Power House to Benton City
3. Benton City to Horn Rapids Park (West Richland, WA)
4. Snively Access (West Richland, WA) to Duportail Access (Richland, WA)
5. Duportail Access to Columbia River Confluence (Richland, WA)

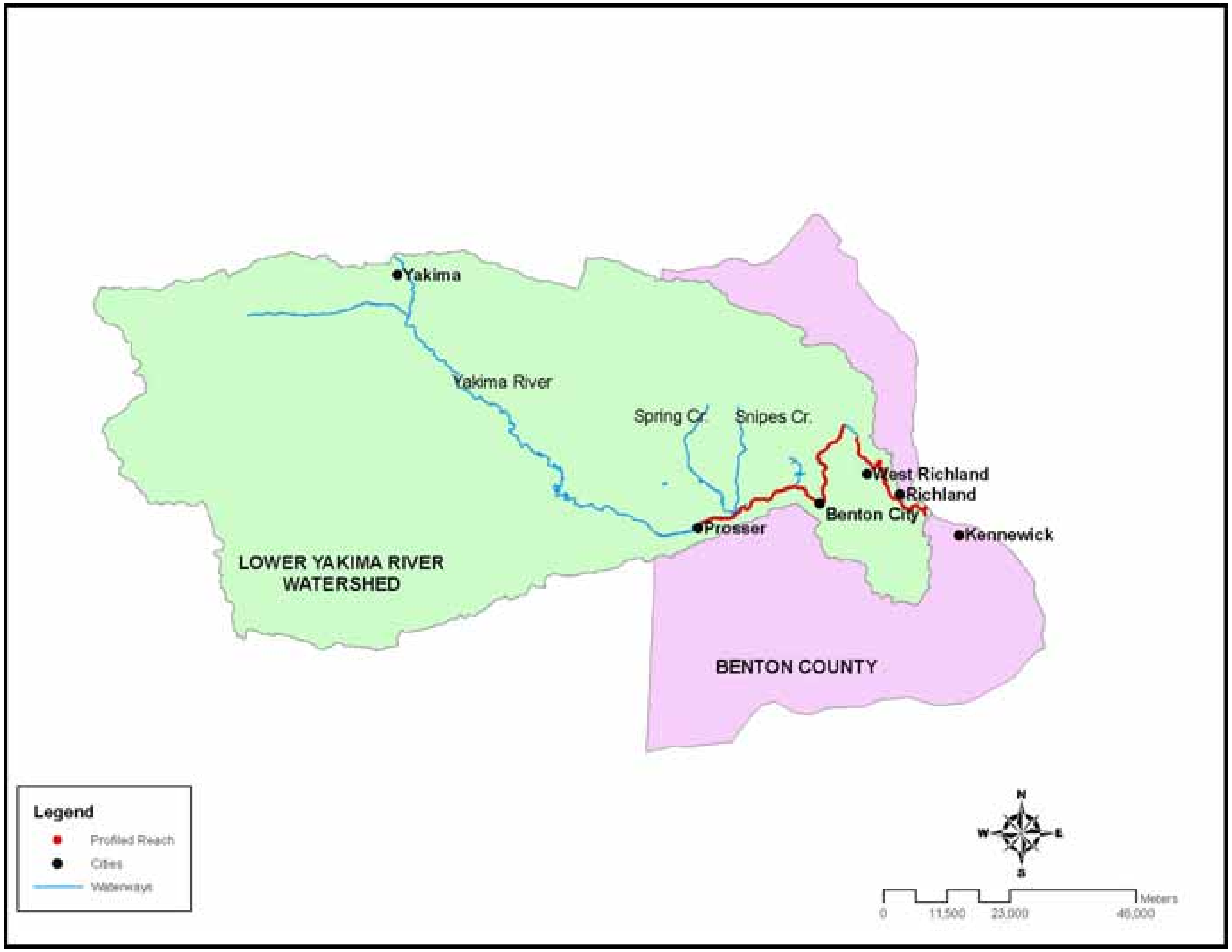


Figure 25. Profiled reach for collection of thermal data

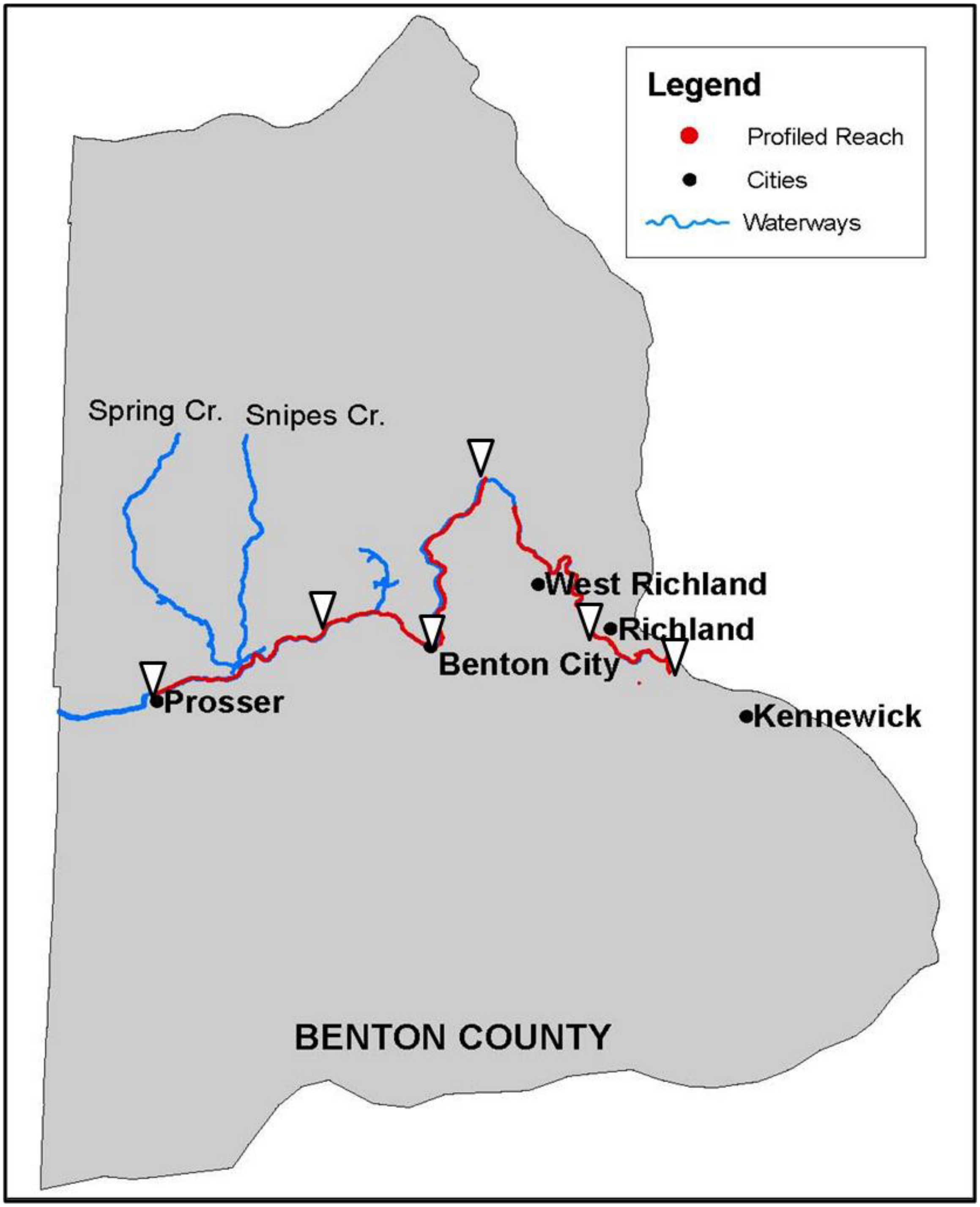


Figure 26. Profiled reach on Yakima River. Arrows indicate access points to the river

9.3 Methods

Temperature profile data were collected on the lower Yakima River from Prosser, WA to Richland, WA during the summer of 2008 and 2009. Methods were adapted from Vaccaro and Maloy (2006) that allow for profiling the temperature regime of a longer river reaches by towing temperature probes while simultaneously recording GPS coordinates. Vaccaro and Maloy (2006) profiled within a Lagrangian framework (moving downstream at the same velocity of the river), which allows for tracking temperature of a parcel of water as it moves downstream. For this work, when possible, boats floated with the velocity of the river; however, due to slow river velocities of the Lower Yakima River this was not always feasible.

Six continuous temperature monitoring probes (dipperLogs), made by Heron Instruments, Inc., were utilized for this study. The dipperLog probes are rated by Heron Instruments, Inc. with an accuracy of ±0.5°C and a resolution of 0.0625°C. All probes were calibrated prior to use to ensure that temperature differences were not the result of systematic differences between probes. Probes were encased in slotted PVC containers to protect the probes while traveling along the riverbed as described in Vaccaro and Maloy (2006). Probes were set to record temperature measurements every 3-5 seconds based on length of river segment and river velocity. A Garmin Rino 530HCx Global Positioning System (GPS) recorded position at the same interval as the temperature loggers. This allowed for a set of location coordinates to be linked to each temperature measurement.

When possible, four temperature probes were utilized to capture measurements within a stream segment in order to record right bank, left bank, and center of the river with a duplicate attached to the center boat. Additional probes were deployed at the upstream and downstream ends of a profiled reach to capture the diurnal change in temperature of the water entering and leaving the reach. For safety and logistic reasons, it was not possible to float three watercraft vessels on the Prosser to Chandler Powerhouse reach. This reach is characterized by large boulders and several small rapids that make it treacherous to navigate at lower flows. As such, only two pontoon boats were used to float this stretch of river capturing data on the left and right bank.

The 2008 floats were performed during the second and third weeks of August, with the Prosser to Chandler float occurring within the first week of September. The 2009 float data were collected consecutively during the last week of July to provide greater consistency within the 2009 data set. Thermal profiles of the lower Yakima River were collected during summer base flow when river temperatures are at their greatest.
During the 2009 float, continuous depth data were collected using a Lowrance HDS-5 Depthfinder/GPS Chartplotter unit. The unit was attached to the center pontoon boat and a rig was assembled with a mounting bracket to allow for the transducer to be raised in extremely shallow waters or when traveling over boulders. All temperature and depth data were analyzed and charted using ArcGIS Desktop 9.3.

9.4 Weather and River Conditions

The 2008 and 2009 floats were timed to coincide with base flow temperatures in the lower Yakima River. For both the 2008 and 2009 floats, flows were less than 2,000 cfs as measured at the Kiona USGS gauging station (Figure 27 and Figure 28). In 2008 the daily discharge was between 810 cfs and 1,558 cfs on float days. Daily discharge ranged between 848 cfs and 1560 cfs for the 2009 floats.

Maximum daily ambient air temperatures during the 2008 float were between 83°F and 97°F except for the Prosser to Chandler float which had a maximum daily ambient air temperature of 79°F. This float was later in the season after ambient air temperatures had began to decline. Maximum daily ambient air temperatures were greater during the 2009 float period and ranged between 96°F and 99°F.

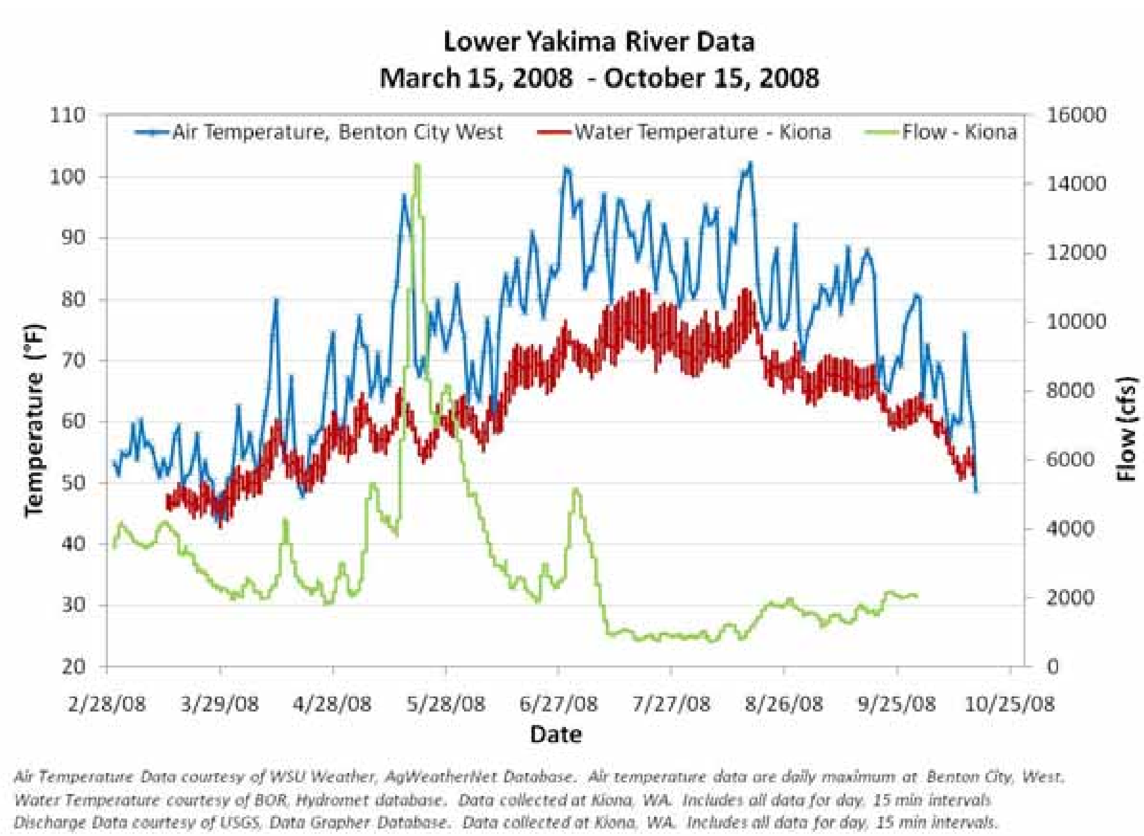


Figure 27. Flow, air temperature and water temperature during irrigation season 2008

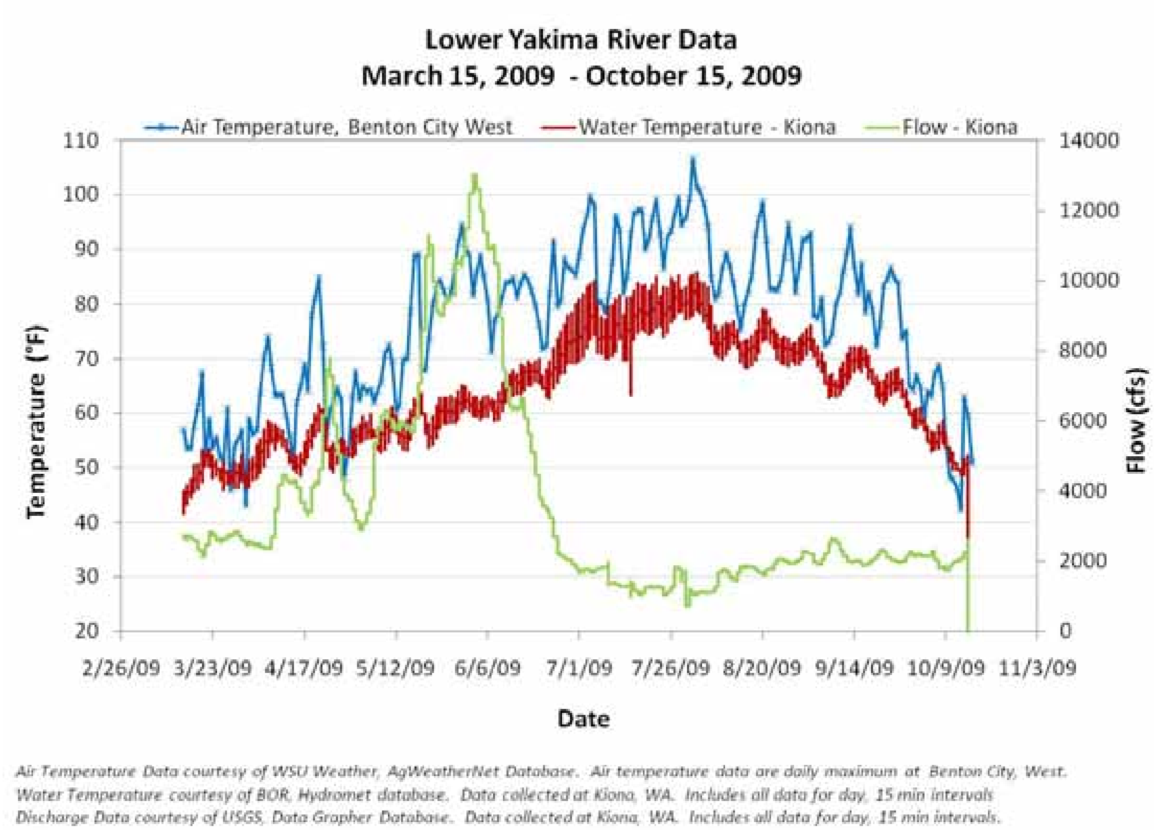


Figure 28. Flow, air temperature, and water temperature during irrigation season 2009

During the 2009 floats, flow increased significantly between Prosser and as a result of a break in the Kennewick Irrigation District (KID) Canal. Flow that would normally have been diverted for irrigation remained in the river and increased the lower Yakima River flow by approximately 400 cfs between Prosser and Benton City. This “bump” in flow can be seen in the hydrograph on 7/27/2009 (Figure 28, Table 4). This increased flow between Prosser and Benton City during the KID shutdown could not be positively correlated with a decrease in river temperature. Median float temperatures did decrease slightly, but this is more likely to be the result of a decrease in ambient air temperature and increased wind velocity during the period of the KID shutdown than from increased river flow (Table 4).

Table 4. Weather and river conditions during thermal profile 2009 float

Date	Avg Air Temp (F)	Max Air Temp (F)	Min Air Temp (F)	Avg Wind Speed (mph)	Total Solar Rad (MJ/m 2)	Median Float River Temp. (Deg. C)	Temp. Kiona at 15:00 (Deg C)	Max Flow - kiona (cfs)
7/25/2009	79.39	92.25	63.98	4.15	25.65	--	28.1	848
7/26/2009	80.73	93.50	66.33	4.46	25.51	--	28.9	994
7/27/2009	82.29	96.36	67.18	4.25	26.72	27.5	28.5	1545
7/28/2009	85.77	99.63	72.07	4.00	25.33	27.1	29.1	1558
7/29/2009	83.97	94.56	73.48	8.16	21.47	27.1	27.8	1438
7/30/2009	82.31	95.78	64.67	4.48	26.36	27	27.8	1504
7/31/2009	84.86	99.41	68.90	4.04	25.54	27	28.8	1235
8/1/2009	88.53	106.54	71.25	4.45	25.95	--	29.1	1163

Air Temperature Data - Collected at Benton City West. Data Courtesy of WSU Agweather.

9.5 Results and Discussion

9.5.1 Prosser Wastewater Treatment Plant to Chandler Powerhouse

The reach between Prosser Wastewater Treatment Plant and Chandler Powerhouse (subsequently referred to as the Prosser Reach) contains a distinct alternating riffle-glide sequence. The riffles are characterized by shallow, swift flowing waters with medium to large boulders and frequent small rapids. The glides contain higher amounts of aquatic plant growth, higher turbidity, and silt-laden river bottoms. There are few gravel beds, sedimentation is high and substrate condition is poor. This reach has two large islands, one fish hatchery, and the outlet for the Spring and Snipes Creek Irrigation Wasteways. The surrounding landscape is predominantly irrigated agriculture and livestock. Much of the river is constrained by large basalts cliffs as the river flows through a narrow valley.

In 2008 and 2009, several distinct “cooler” areas were identified on the float between Prosser and Chandler. The “cooler” areas can be categorized as: a) non-point source discharge (i.e., seeps) b) point-source discharge (i.e., Spring and Snipes Creek Wasteways) and c) temperature changes related to depth. The results of each of these are discussed below.

Non-Point Discharge (Seeps)

Several non-point discharge sources (shallow interstitial groundwater seeps) were identified along the riverbank during the 2008 and 2009 floats. Figure 29 and Figure 30 are plots of the temperature data versus time for the 2008 and 2009 floats, respectively (note: only the left bank data are provided for 2009 as a result of probe loss during the float). Surprisingly, all identified non-point sources provided cooler water to the mainstem of the Yakima River. It is hypothesized that these non-point sources are outlets for shallow groundwater fed by local irrigation recharge and river water. Several of these non-point sources were identified in both years, indicating that they are recurring sources of cooler water.

Temperature data were mapped onto satellite images, as presented in Figure 31and Figure 32, in order to identify the spatial location of cool areas on the river. Many of the seeps are clustered together within the upper portion of the reach as indicated by the number “1” on Figure 31and Figure 32. Seeps were also identified near Whitstran, WA (number “5”, Figure 31) and east of Chandler Power House (number “6”, Figure 31).

River temperatures at the seep discharge points measured anywhere from 1°C to 10°C cooler than the mainstem river water for the 2009 float. The temperature difference between the seeps and the mainstem river water was greater in 2009 than observed in 2008. The reason for this difference is twofold. Float methodology was improved for 2009, allowing for better data collection at the mouth of the seeps where the temperature difference between the river water and seep source is greatest. Secondly, the 2009 float was conducted in July when river temperatures were reaching their seasonal warmest thus the difference between mainstem and seep temperatures were greater. The 2008 thermal data were collected in September after river temperatures began to decline, becoming tolerable for incoming Salmon. As such, incoming seep temperatures in September were similar to that of mainstem river temperatures.

Although the identified incoming seeps do not have enough impact to lower the temperature of the mainstem Yakima River, they do provide a localized area of "cooler" water that may be beneficial for salmon refugia. Additional studies need to be performed to determine the extent of cooling, the impact of seasonal changes on the amount of discharge, and suitability of these areas for use as refugia (e.g., depth, cover, and water quality parameters, namely dissolved oxygen). Furthermore, the cumulative amount of discharge from these seeps to the Yakima River should be determined. It is possible that in time, as local irrigation practices improve and irrigation districts line canals for water savings, a significant source of water feeding these seeps may decline thereby removing the source of recharge for these seeps.

Point-Source Discharge

Spring and Snipes Creek Wasteways enter the Yakima River at location number "3" shown on Figure 31and Figure 32. In both 2008 and 2009, the Spring and Snipes Creek Wasteways discharge provided a source of cool water to the Yakima River. The 2009 data indicated that the confluence of the Wasteway discharge with the Yakima River resulted in a 3°C temperature change. These data are consistent with monitoring data collected by the Roza-Sunnyside Board of Joint Control (RSBOJC) Monitoring Program (RSBOJC 2009). From 2004 to 2007 the water temperatures in Spring and Snipes Creek Wasteways were cooler during the summer months and warmer during the winter months (RSBOJC 2009). The results of this study agree with the RSBOJC data and indicate that the Wasteways may provide benefit on a micro-habitat scale but do not influence river temperatures on a reach scale (2009).

Midday temperatures at the confluence of the Wasteways and Yakima River were well above optimal temperatures for salmonid survival during the 2009 July float, however, even a slight drop in temperature may relieve salmonid stress in an inhospitable river. Spring and Snipes Creek Wasteways are likely to provide some value as thermal refugia.

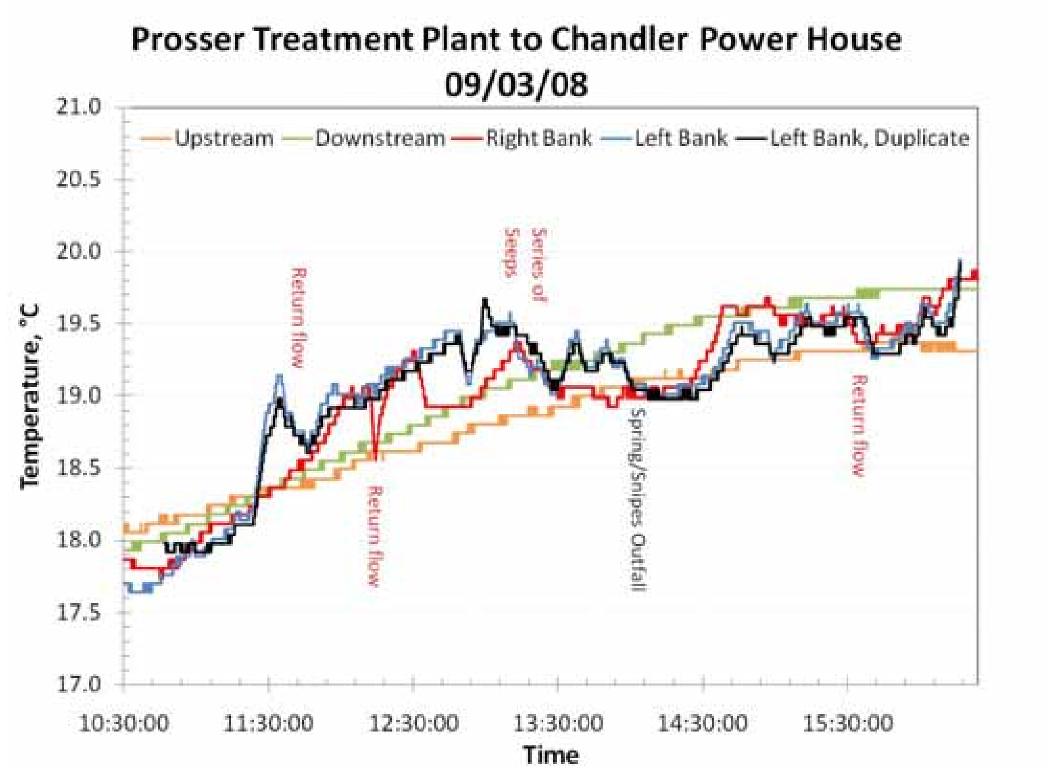


Figure 29. Thermal profile data for 2008, Prosser to Chandler

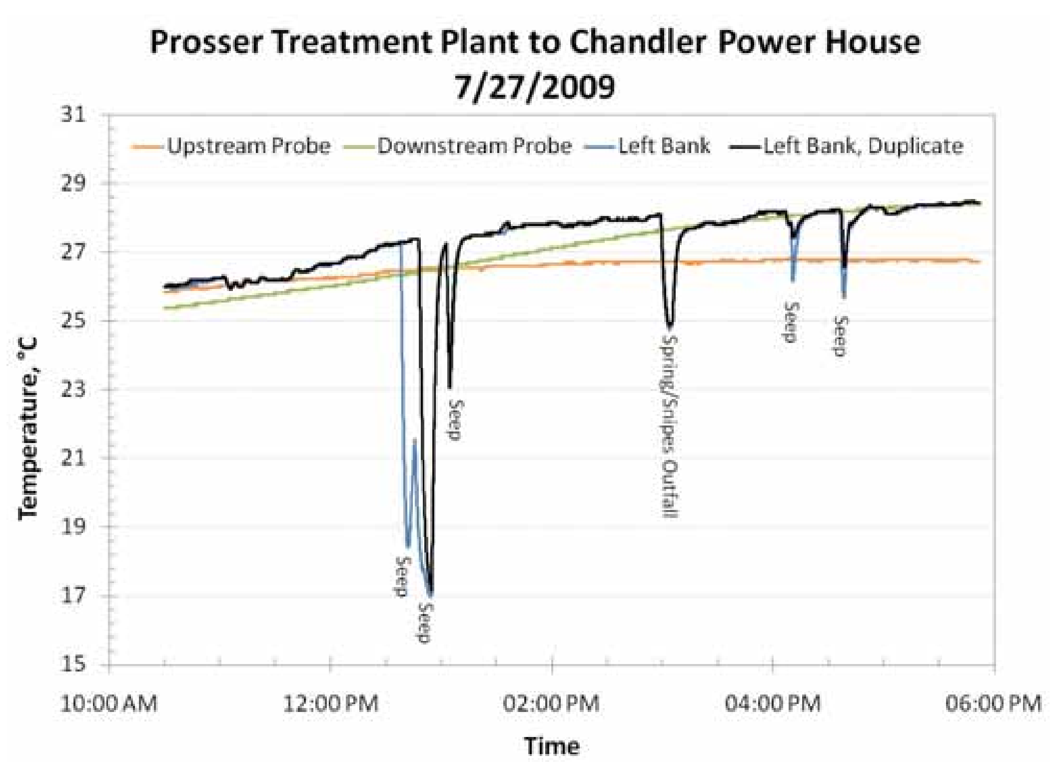


Figure 30. Thermal profile data for 2009, Prosser to Chandler

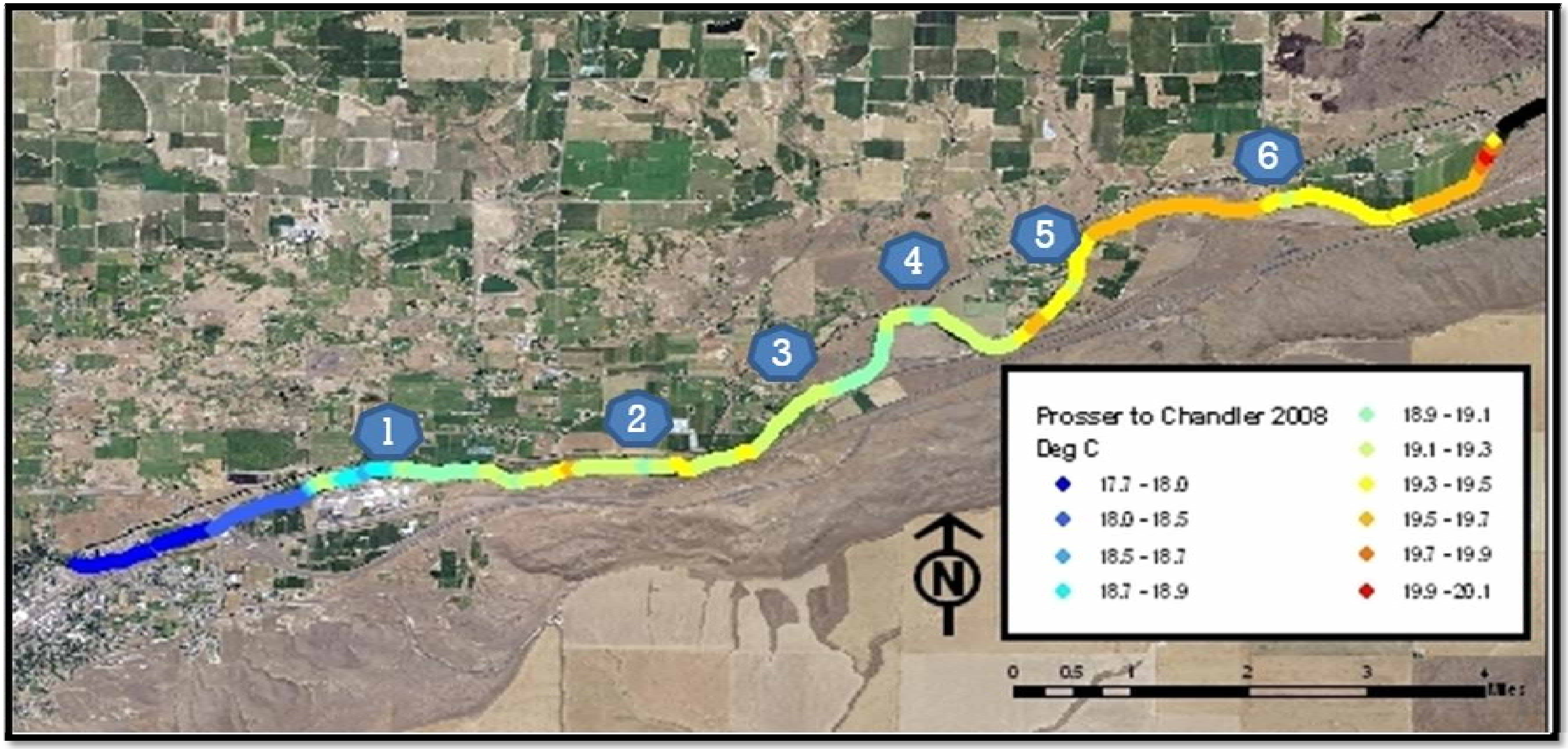


Figure 31. Thermal map for 2008, Prosser to Chandler. Numbers indicate areas of cooling

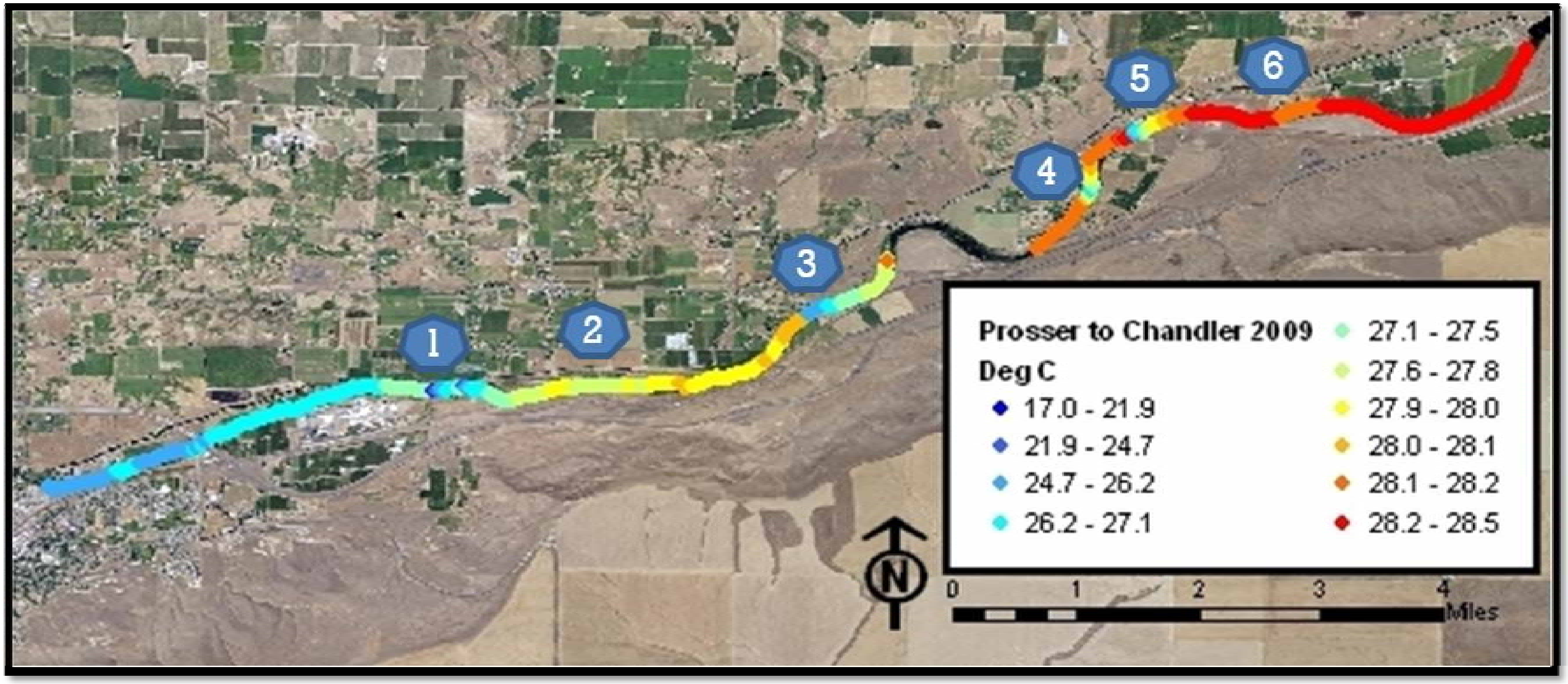


Figure 32. Thermal map for 2009, Prosser to Chandler. Numbers indicate areas of cooling

Depth Change

The area identified by number “2” in Figure 31 and Figure 32 displayed a change in temperature with change in depth. This area is a glide section following the end of a small river rapid. Temperatures decreased slightly within this section of the river as depth increased. Moreover, this area coincided spatially with several identified cool non-point source seeps. Downstream and adjacent to the glide is a large island that has been documented as historical fall Chinook spawning grounds. The glide/island area presents itself as a potential site for habitat projects and salmonid refuge area. A zoomed in section of the thermal map for the glide/island section is shown below (Figure 33).

Figure 33. Thermal map of island downstream of Prosser in 2008. Green and blue traces correspond to “cooler” temperatures

9.5.2 Chandler Power House to Benton City

The reach between Chandler Power House and Benton City is typically rural with irrigated agriculture, pasture, and rangeland. As the Yakima flows into Benton City there are a higher percentage of urban residential landscapes with grasses and turf abutting the river. The river does not have the large boulders and small rapids that are prevalent in the upstream reach between Prosser and Chandler Power House. There are a several shallow riffle areas with deeper glides upstream of Corral Creek Wasteway and three island masses downstream of Corral Creek Wasteway. Water stargrass becomes prominent within this stretch of the river. There are two major point sources on this stretch of the river: Knox Creek and Corral Creek Wasteway.

The Chandler to Benton City reach had fewer non-point source seeps than identified in the Prosser Reach. As with the Prosser Reach, all non-point source seeps were “cooler” in nature than the mainstem Yakima River temperatures. Several of the same seeps were identified between 2008 and 2009 indicating that they are recurrent between years.

Additional seeps were located in 2009 as a result of improved data collection methods (i.e., three parallel temperature probes instead of one).

Primarily, the "cooler" areas between Chandler and Benton City corresponded with point-source discharges, namely Knox Creek and Corral Creek Wasteway (Figure 35). Knox creek drainage is visible as #1 in Figure 36 and #3 in Figure 37. Corral Creek Wasteway is visible as #3 and #5 in Figure 36 and Figure 37, respectively. Both sources contribute cool water to the Yakima River with Knox Creek dropping the local temperature at the confluence from 26.5°C to 22°C in 2009. Corral Creek Wasteway also contributed cool water but not to the same extent as Knox Creek. Temperatures at the Corral Creek Wasteway confluence dropped the immediate river temperature 2°C from 26.7°C to 24.7°C in 2009.

Confluence of Yakima River and Knox Creek (left) and Corral Creek Wasteway (right)

Depth data for this float indicates that "holes" typically coincide with incoming waterways and seeps as previously discussed (Figure 22). For example, depths were greater than 8 feet at the confluence of Knox Creek. These "holes" should be further examined for suitability as thermal refugia including analysis of dissolved oxygen and microhabitat conditions.

The Chandler spillway was operating during the 2009 float. The float began upstream of the spillway so as to investigate changes in river temperature as a result of Chandler Operations. There was no discernable temperature change in the river downstream of Chandler Power House suggesting that incoming water from the Chandler spillway does not result in an area of localized temperature increase – if anything the waters were slightly cooler. The data collected by BCD in 2009 agrees with data collected by Payne and Associates (2001) and refutes the thermal imaging data collected by the Bureau of Reclamation in 1997 (Holroyd 1998) which suggested a warming influence from the Chandler canal. It is suspected that the thermal imaging data recorded higher temperatures within the spillway as a result of heat radiation from the concrete canal.

Figure 34. Chandler Spillway operating during 2009 float

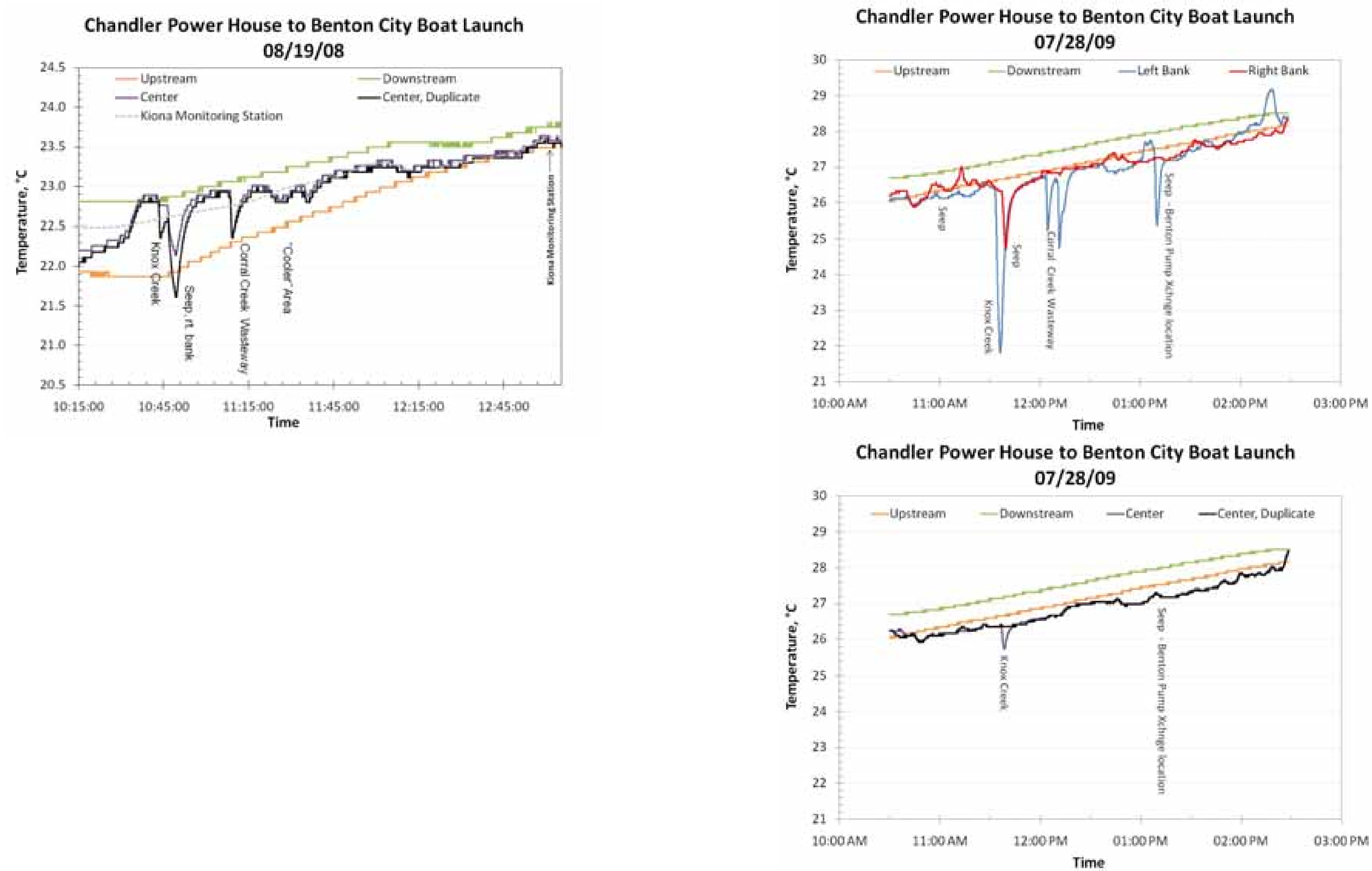


Figure 35. Thermal profile data for Chandler Powerhouse to Benton City boat launch for 2008 (left) and 2009 (right)

Figure 36. Thermal map for 2008, Chandler Power House to Benton City, WA

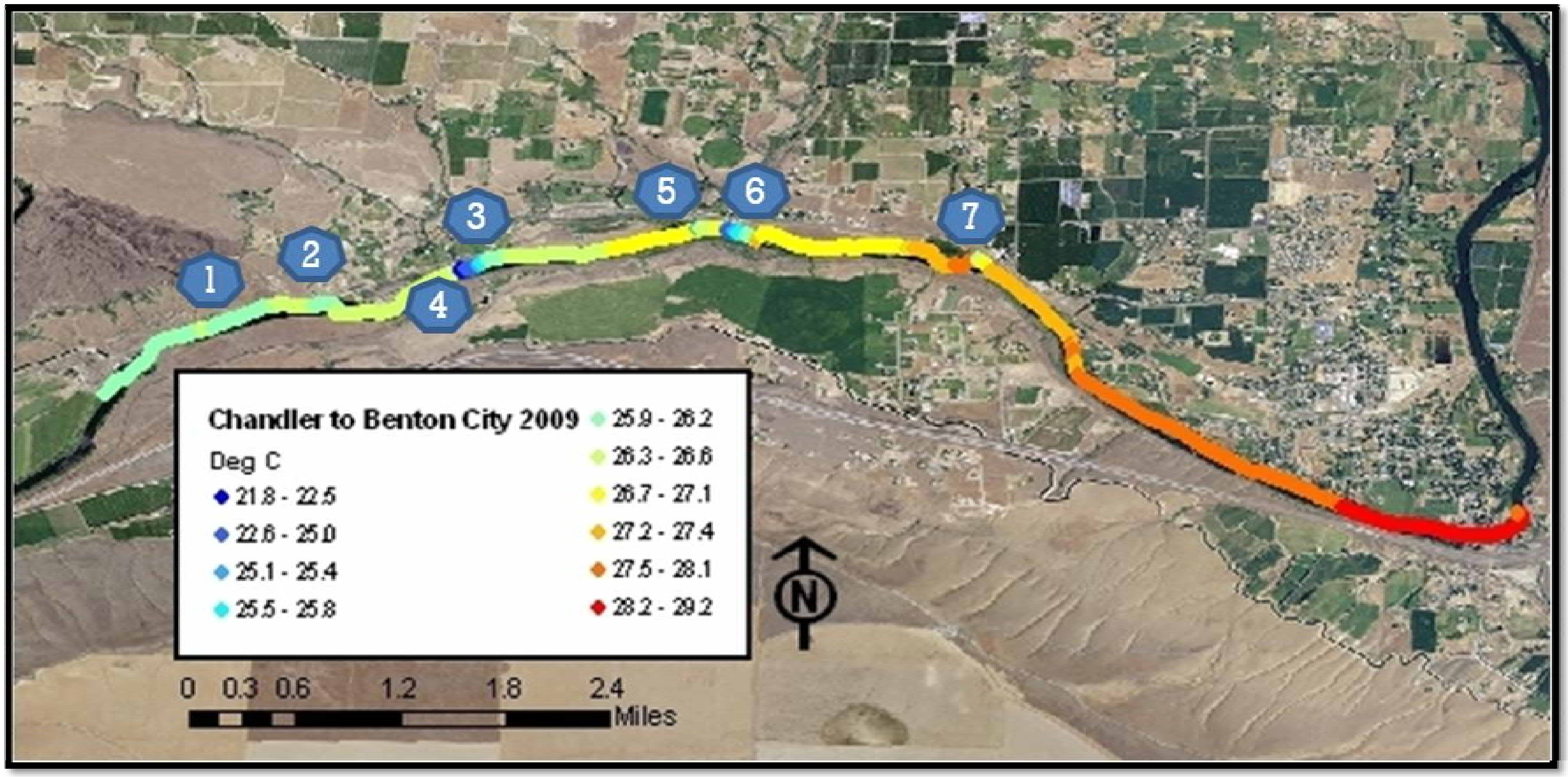


Figure 37. Thermal map for 2009, Chandler Power House to Benton City, WA

9.5.3 Benton City to Horn Rapids

Benton City is rural residential with irrigated agriculture, pasture, and lawn. In several locations the riverbanks have been heavily disturbed and vegetation is largely non-native. The landscape quickly changes at the edge of Benton City and becomes dry rangeland. From Kiona to the mouth there are good riffles and pools. Historically, this stretch of river hosted spawning grounds for fall Chinook but within the past decade water stargrass and sedimentation has choked out the spawning gravels (Mueller 2010). Large masses of water stargrass now cover most of the riverbed within this stretch of river. There are several large islands that provide excellent habitat opportunities but sedimentation as a result of water stargrass is diminishing them. Wildlands, Inc., a native nursery located outside of Benton City, maintains a healthy riparian bank located near an island and old historic spawning ground. Additionally, the property contains an old oxbow channel that has degraded and filled in with sediment in recent years. Kiona to the mouth is lacking in LWD.

The thermal profile data for Benton City to Horn Rapids is more erratic than seen in the upper reaches with several small "warm" peaks. There are minimal incoming seeps within this stretch of the river. Only three "cooling" areas were identified by the thermal data collected from Benton City to Horn Rapids in 2009 (Figure 38). One of these areas was identified in the 2008 data, the other two areas were most likely present in 2008 but not identified based on collection methods. The predominant seep identified in both years is located at the end of a large island near the beginning of the reach ("2" in Figure 39 and #1 in Figure 40). This island has been identified as having historical fall Chinook spawning, but large amounts of water stargrass have since choked the island side channel. The drop in temperature at the tail of the island is only 0.5°C from the mainstem river temperatures. This is not a large temperature drop, but it is one of the few localized "cooler" areas within the Benton City to Horn Rapids reach. This "cooler" area also coincides with a "hole" at the tail of the island.

In 2009 only two other inputs were identified: the Benton City treatment effluent and a small, unidentified inlet on the west bank of the river. The inlet temperature was 2 degrees centigrade lower than the mainstem Yakima River water. The Benton City treatment effluent is just slightly cooler than the mainstem Yakima River (only 0.2°C). Many of the warm peaks appearing in the thermal data typically resulted from island side channels. These are areas of shallow water, often with high amounts of water stargrass, so it is not surprising that they were warmer than the mainstem Yakima River. Benton City to Horn Rapids has several prominent islands. Although, the side channels do not provide thermal refuge they do provide valuable salmon habitat during periods of high flow. Increased amounts of water stargrass are leading to sedimentation within the side channels. Projects to protect island side channels by removing water stargrass and improving flow should be considered.

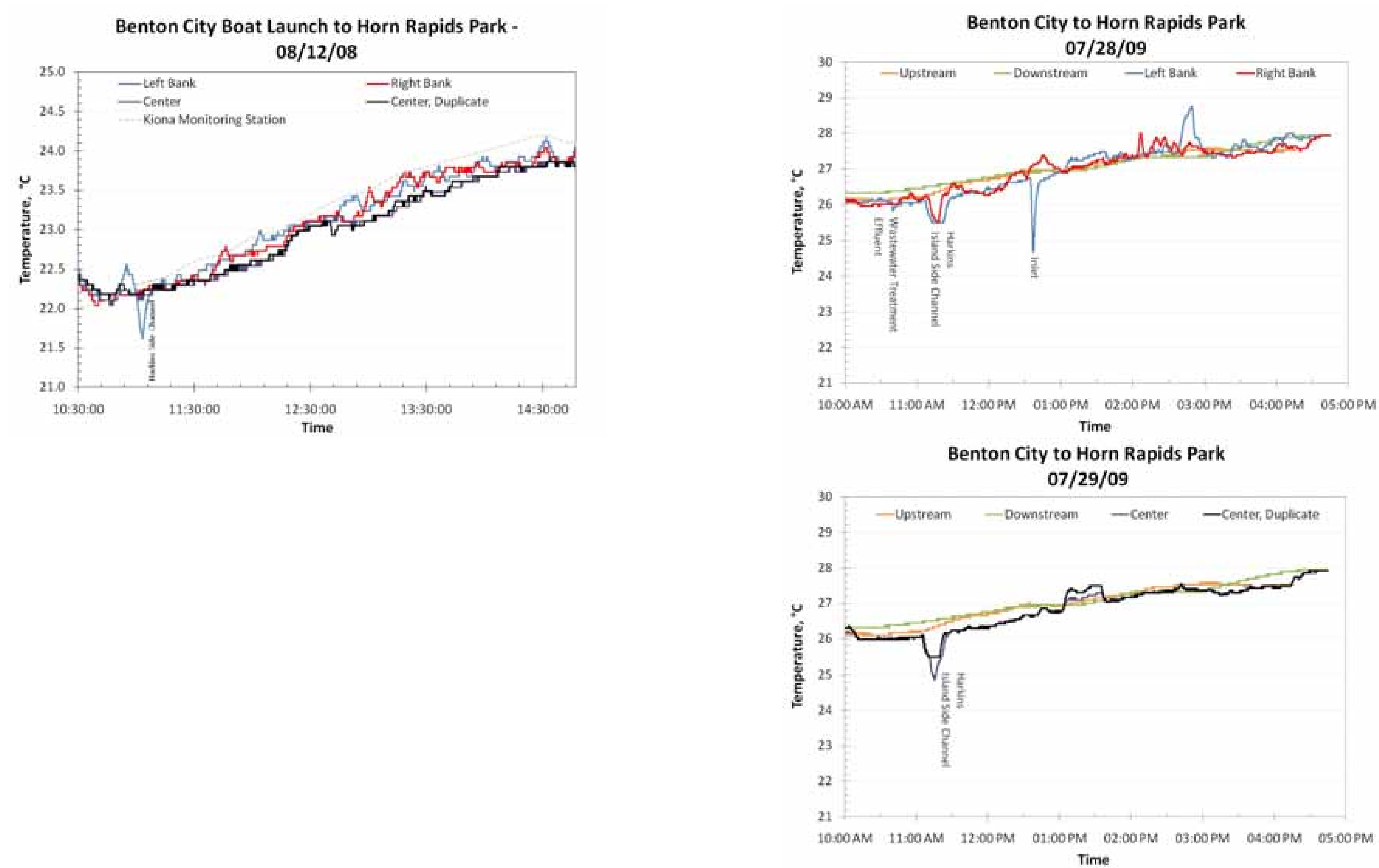


Figure 38. Thermal profile data for Benton City to Horn Rapids Park for 2008 (left) and 2009 (right)

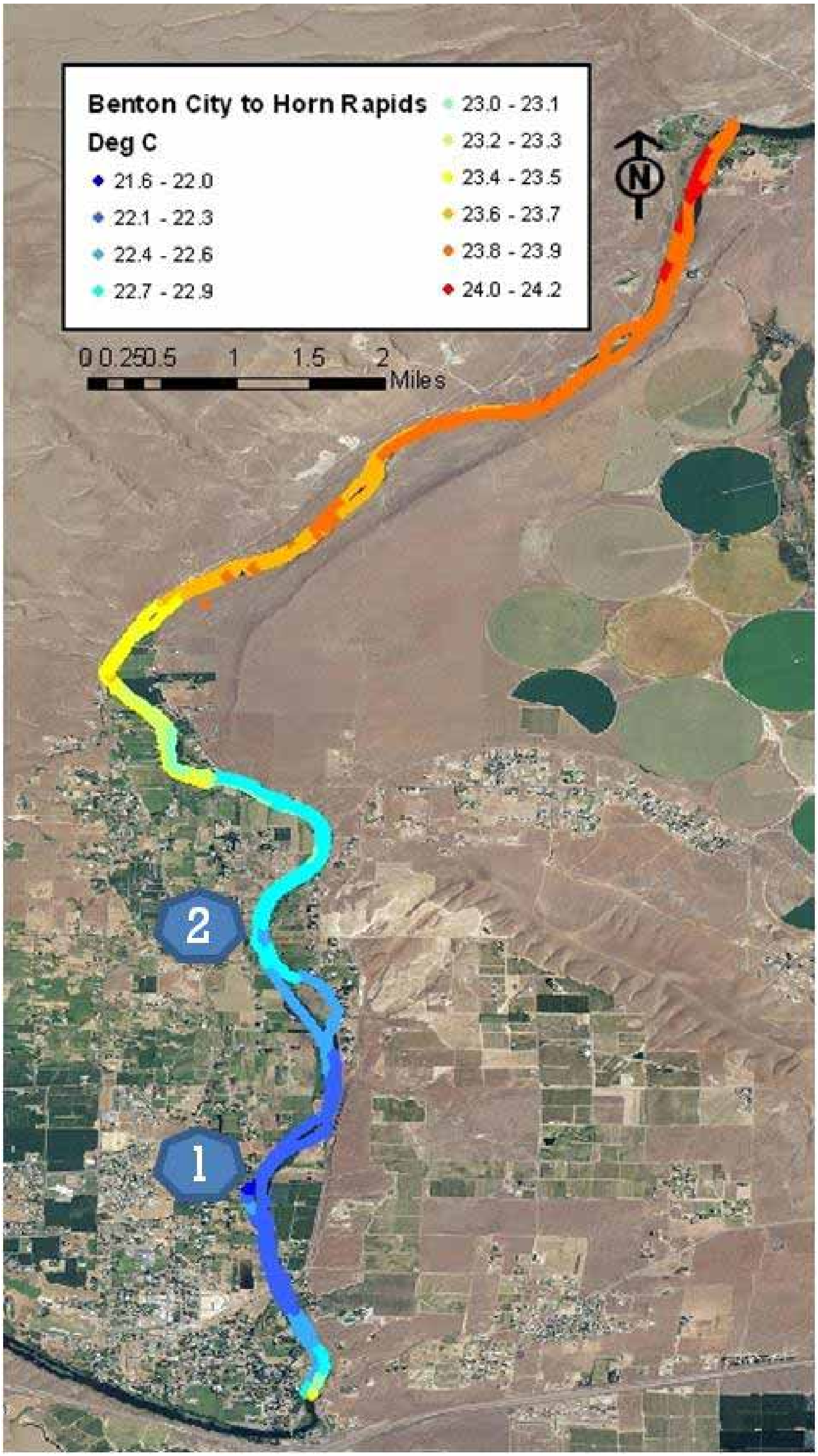


Figure 39. Thermal profile map for 2008, Benton City, WA to Horn Rapids Park

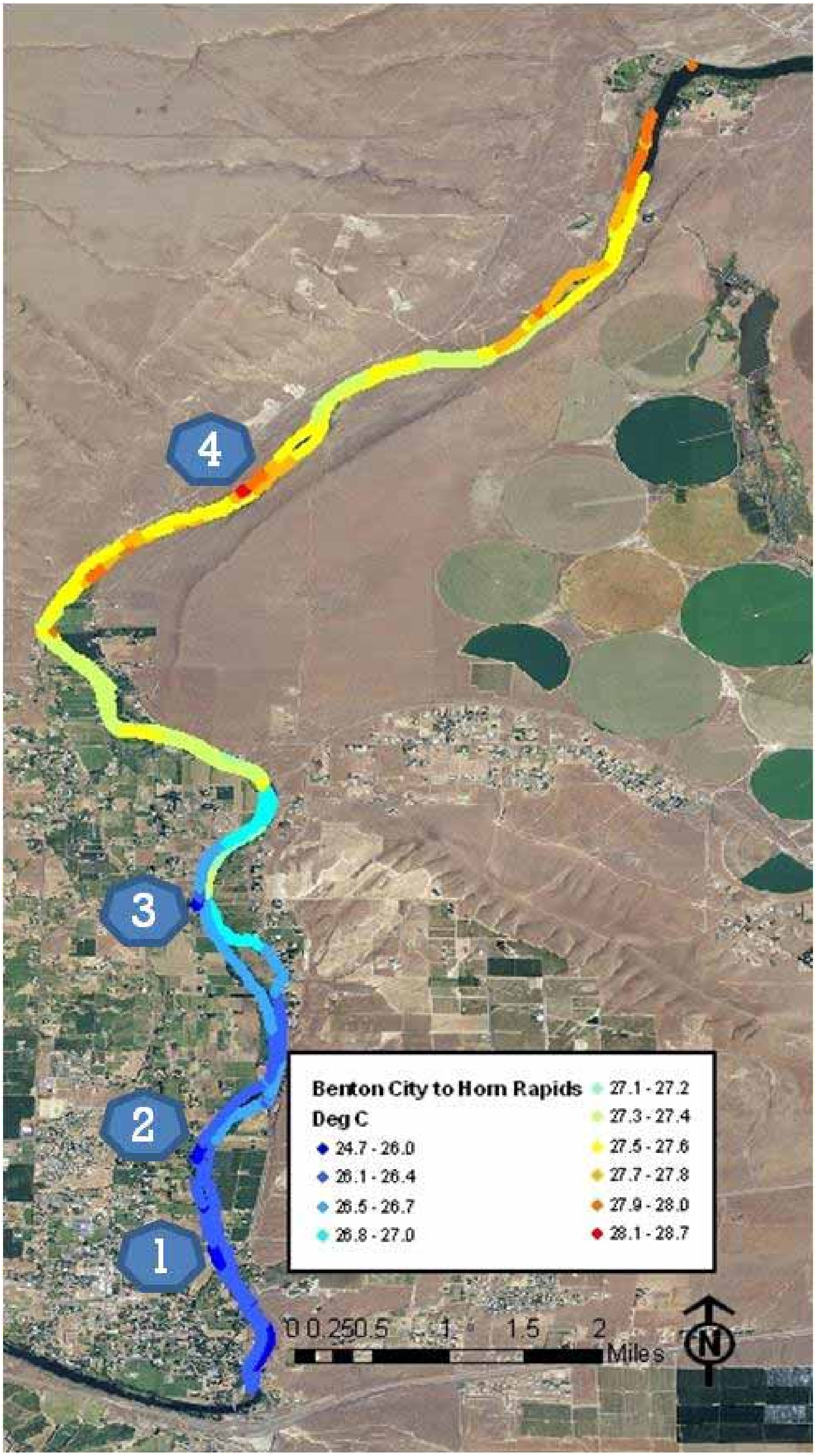


Figure 40. Thermal map for 2009, Benton City, WA to Horn Rapids Park

9.5.4 West Richland (Snively Boat Launch to Duportail Boat Launch)

West Richland has rich flood plains that are developed with irrigated agriculture and suburban residential. There is a significant conservation wetland area owned by Barker Ranch east of Horn Rapids Park. There are two golf courses within this stretch of the river along with the West Richland Wastewater Treatment Plant whose outfall discharges beneath the Yakima River riverbed. This reach contains a few larger islands that are currently privately owned (Fox Island and Twin Bridges) and should be considered for future acquisition possibilities in order to maintain their ecological value to the river system.

A levy is maintained on the right bank of the river within the city of West Richland for housing and city protection. This levy has resulted in the meander of the river to the left bank threatening Van Giesen Road (Hwy 224). A bank stabilization project for protection of Van Giesen Road (Hwy 224) was completed by the Washington State Department of Transportation after severe flooding in 2008-2009. The new levy incorporates large pieces of wood for a more ecologically friendly design (WSDOT 2007). The completed bank stabilization project can be seen in Figure 41.


Figure 41. WSDOT Bank Stabilization Project (Van Giesen Rd, West Richland)

The thermal profile data for West Richland does not have the strong input of groundwater recharge from incoming seeps as seen in the upper reaches; however, it does have several areas of suppressed temperatures that make it a rather interesting and unique reach.

In 2008 an area of attenuated temperature was located prior to and after Twin Bridges Island. The slope of the temperature data for the moving probes does not rise at the same rate as the stationary monitoring probes indicating temperature suppression (Figure 42). This area of attenuated temperature was not seen in the 2009 data. The attenuated temperatures seen in 2008 may be due to subsurface groundwater inputs from Barker Ranch operations. Barker Ranch is located on the north bank of the Yakima River and is maintained as flooded wetlands for waterfowl and other wildlife. Barker Ranch's irrigation operations were shut down in 2009 for implementation of a water savings project to line their irrigation canal. The thermal profile data between 2008 and 2009 suggest that seepage from irrigation operations at Barker Ranch provide enough groundwater to mildly suppress temperatures in the mainstem of the Yakima River. Small "cooler" seeps were observed within the Barker Ranch stretch of the river in 2008 that were not readily apparent in 2009. Additional data need to be collected on surface-groundwater interactions within this portion of the floodplain to determine extent of irrigation flooding practices on attenuating Yakima River temperatures.

In 2008 and 2009, a second area of attenuated temperature is apparent between the old relic oxbow on Barker Ranch and the town of West Richland (Figure 42 and Figure 44/Figure 1 Figure 44). This attenuated temperature may be in part due to increased depth within this portion of the river (Figure 21). Moreover, it is in an area that maintains two golf courses and is rich in irrigated agriculture. As such, given the high porosity of the floodplain soils, it is possible that there is irrigation driven groundwater recharge within this stretch of the river. Additional data collections are needed to determine the exact nature of the attenuated river temperatures within this portion of the Yakima River. Despite the areas of attenuated temperature, this reach is too hot for salmonid passage in the summer with minimal thermal refugia potential.

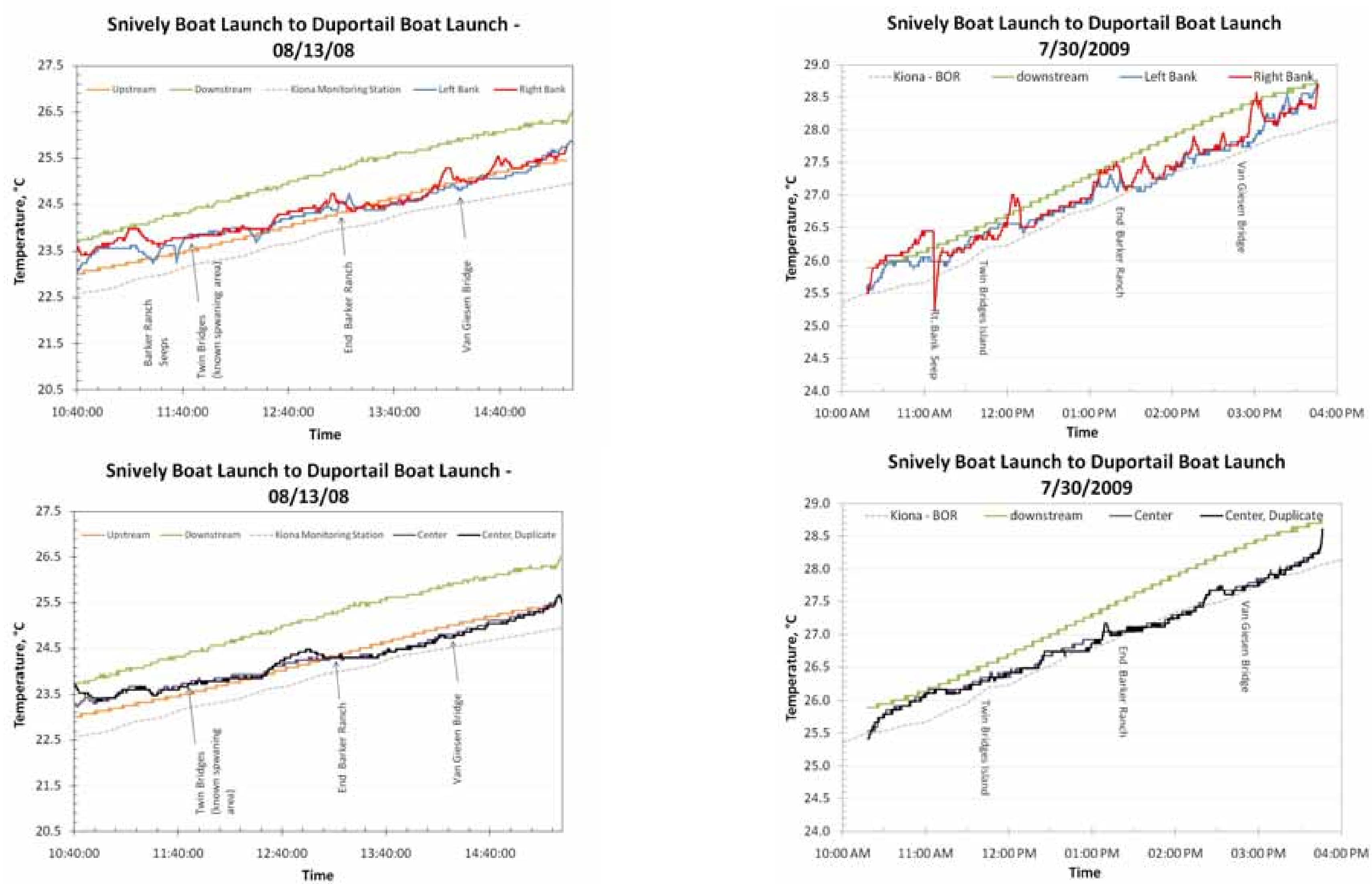


Figure 42. Thermal profile data for West Richland, WA (Snively Boat Launch to Duportail Boat Launch). 2008 data (left) and 2009 data (right)

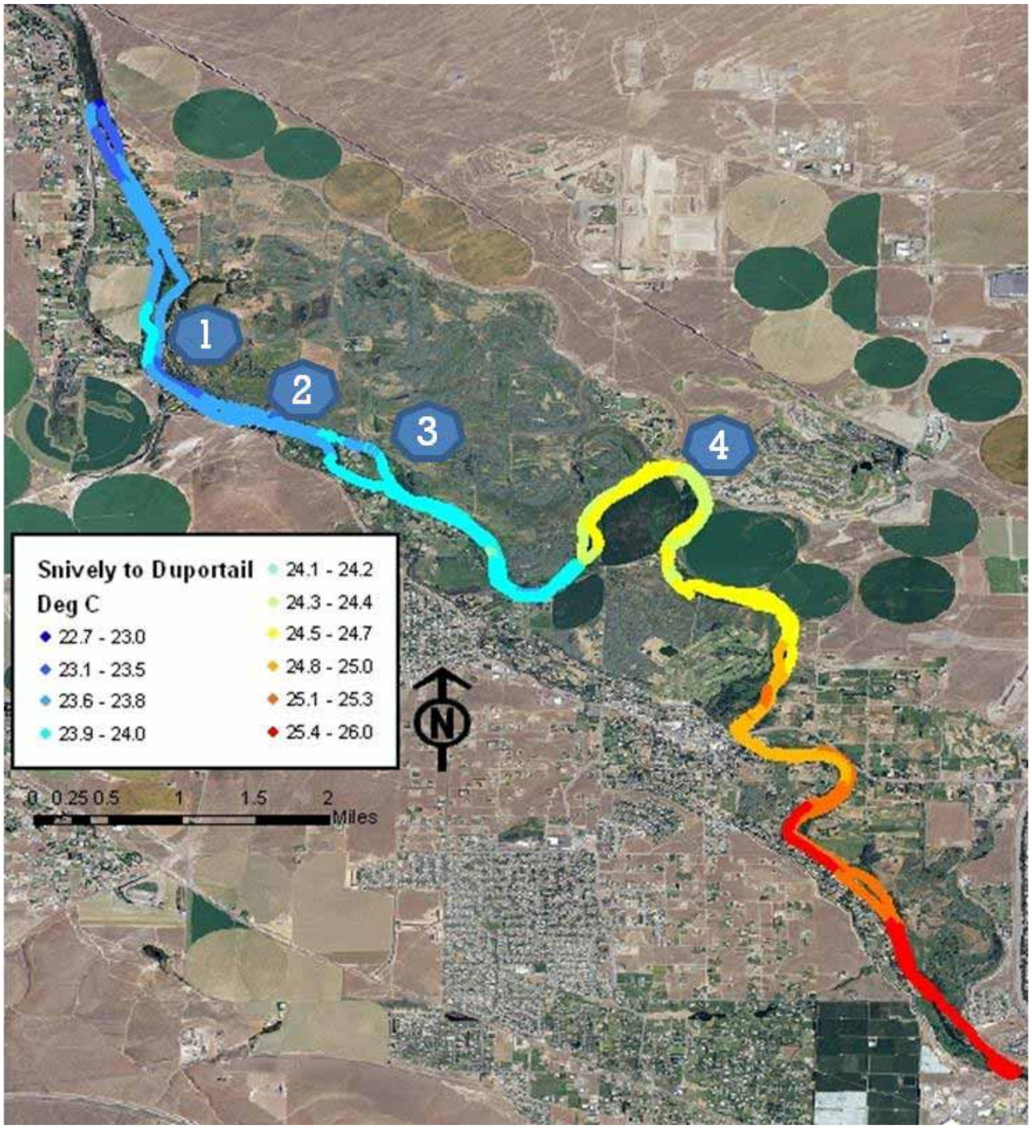


Figure 43. Thermal profile map for 2008, West Richland, WA

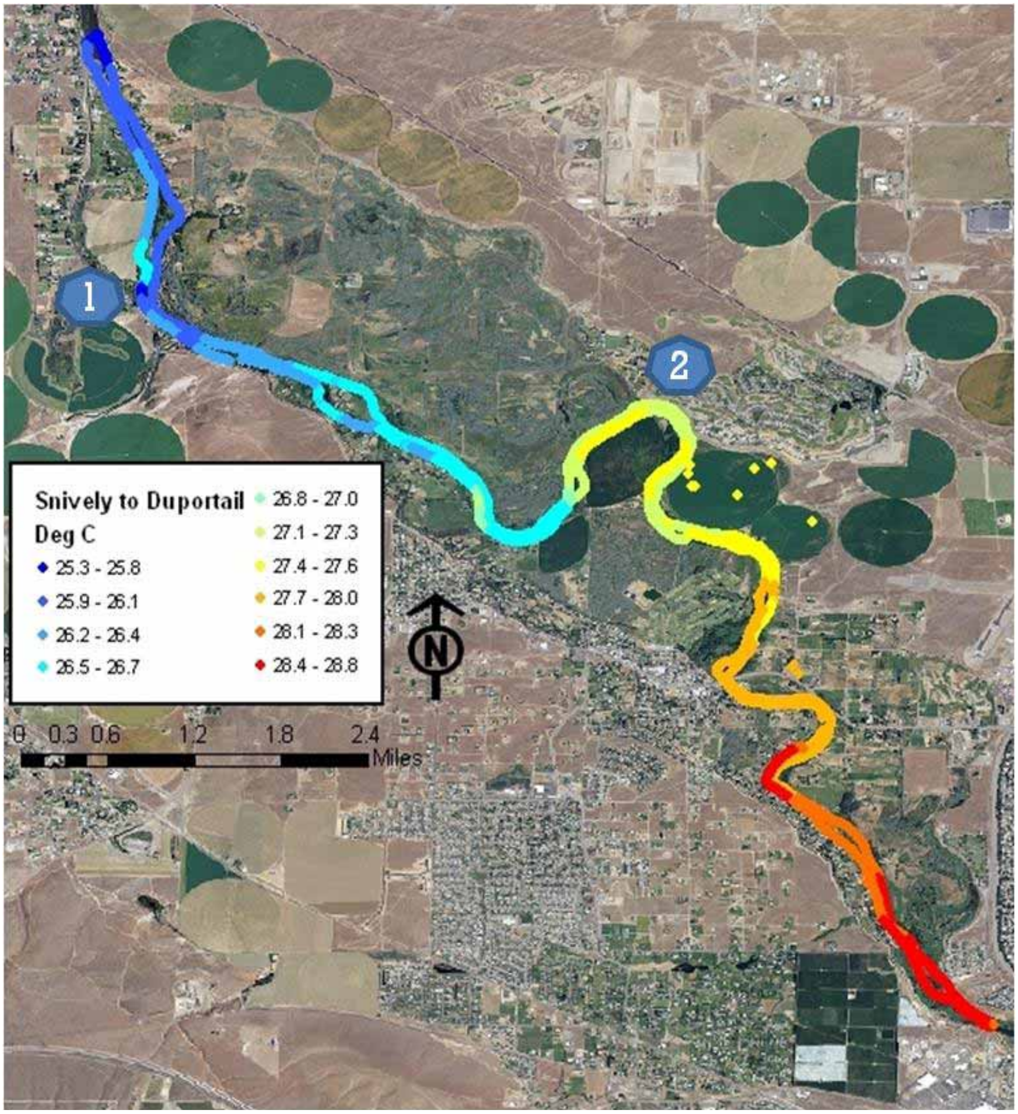


Figure 44. Thermal profile map for 2009, West Richland, WA

9.5.5 Richland (Duportail Boat Launch) to the Delta (Wye Park)

The warmest temperatures were observed on the float from Richland to the delta. Starting float temperatures were 24°C in 2008 and 27°C in 2009 as shown in Figures Figure 47, Figure 48, and Figure 49. The Kiona USGS monitoring station data are provided in Figure 47 to highlight the difference between temperatures at Benton City and the river delta. There is approximately a 2°C difference in temperature between Benton City and Richland at the start of the 2008 float.

Although temperatures were the warmest between Richland and the delta, there was very little increase in water temperature with daily warming. Temperatures stayed relatively constant prior to the entrance to the delta. This may in part be due to the greater river depth acting as a buffer to diurnal warming. Depths of over 7.0 feet deep were recorded throughout the stretch of river flowing through Richland. The greater depths may also inhibit nighttime cooling, thus keeping the lower river temperatures elevated to a greater extent than seen in the upper reaches. This phenomenon may warrant additional studies and modeling as this effect may be seen if upstream river depths are increased during the summer months.

In 2008, BCD investigated side channels located along the Yakima River. The thermal profile data reflects these deviations in the data as represented by the large temperature fluctuations. One of the prominent decreases in temperature was observed under the I-182 bridge where a significant amount of groundwater flows into a side channel of the Yakima River. The temperature of the groundwater spring was recorded at 19°C at its source (2008 data, Figure 47). The cool groundwater flows both east and west towards the mainstem of the Yakima River and as such cooler temperatures were measured at both the head and tail of the island. This incoming source of groundwater creates a significant decrease in temperature where the Yakima River and the cool groundwater meet. For instance, in 2009, the temperature dropped from 27°C to 22°C at the convergence of the side channel water and mainstem Yakima. Improvements within in the side channel may create an ideal area for salmon refugia.

Abandoned concrete pond structures are located within the island side channel. According to accounts by various BCD volunteers, these structures were originally designed and used for rearing fish in the lower Yakima River. These ponds are now completely sediment filled, however, with some restoration work, the concrete ponds may provide a potential area for salmonid rearing and acclimation within the lower Yakima River. Simple studies would need to be conducted to determine water quality suitability.

Amon Creek Wasteway provides a significant drop in river temperature at the confluence of the Wasteway and the Yakima River. Temperatures decreased approximately 3°C in 2008 and 4°C in 2009 (Figure 47and Figure 48, respectively). While temperatures remain above ideal temperatures for salmon it does provide an area of significant temperature decrease that may help with salmonid refugia.

Temperatures within the delta of the Yakima River rose sharply, up to 29°C in 2008 and even higher in 2009. In 2008, temperatures at the head of Bateman Island where the Columbia River and Yakima River experience mixing were measured. This is an extremely shallow area, and yet with the Columbia River influence temperatures were 2 to 3 degrees cooler than temperatures found within the confluence.

9.5.6 Yakima River Confluence

The Yakima confluence is an integral part of the salmonid history in the Yakima Basin. Historically, the confluence was used as tribal fishing grounds for salmonids as noted in the Lewis and Clark Journals:

> *I took two men in a Small Canoe and assended the Columbia river 10 miles to an Island [Bateman Island] near the Stard. Shore on which two large Mat Lodges of Indians were drying Salmon,* **...** *there is no timber of any Sort except Small willow bushes in Sight in any direction - from this Island the natives showed me the enterance of a large Westerly fork which they Call Tâpetêtt [Yakima River] at about 8 miles distant . . .* Clark Journals, October 17, 1805

The confluence, thought to be originally quite extensive and complex, is now subject to inundation, sedimentation, and erosion by the McNary pool which extends 3 km up the Yakima River channel (Snyder and Stanford 2001). Much of the original floodplain is submerged as a result of the construction of McNary Dam on the Columbia River and the river channel at the mouth is less constrained. Additionally, extreme temperatures and highly regulated flows create unfavorable conditions for migratory species. The confluence of the Yakima River is a critical migration corridor for adult and juvenile salmonids. Continued success of salmonid migration within the Yakima Basin depends on improved passage conditions at the mouth of the Yakima River

The LYRTAG identified the confluence of the Yakima River as an area with high potential for restoration activities. Based on data gathered by BCD in 2008 and 2009, the confluence maintains the warmest surface water temperatures within the lower Yakima River during the summer months. For instance, near surface temperatures within the Yakima River mainstem (near the Hwy 240 bridge) ranged from 26.6°C to 27.2°C as compared to 27.5°C to 32°C at the confluence (Figure 48). This warming trend at the confluence agrees with aerial thermal imaging data collected on August 15th 1997 by the Bureau of Reclamation (Holroyd 1998). Thermal imaging data indicated that the warmest waters in the lower Yakima River were within the confluence, specifically within the stagnant pools behind Bateman Island. The 1997 thermal imaging data showed a 1–2°C decrease in river temperature between the Yakima River confluence and the Yakima River mainstem, additionally there was a 3°C difference between the Columbia and Yakima Rivers (Holroyd 1998).

Thermal imaging data suggests that the large earthen causeway at the southern end of Bateman Island may decrease mixing of Columbia and Yakima River waters by preventing flow around the large island (Holroyd 1998). This in turn may result in a greater occurrence of stagnant water, increased surface water temperatures, and enhanced sedimentation rates within the confluence. BCD conducted a precursory temperature study of the confluence during the summer of 2009. Temperature probes were placed within the river, delta and Columbia River to record temperature variations from June to September. The locations of the temperature probes are shown in Figure 52. The locations of the probes were chosen so as to capture the temperature of a) the mainstem Yakima River b) the mouth of the Yakima River c) the pool behind the Bateman causeway and d) the Columbia River. All probes were suspended 2 feet above the river bottom and were submerged at least 1 foot under the surface water. The shallowest probe was located on the shelf of the Columbia River. GPS coordinates were collected during probe deployment and the Atomic Duck Diving club retrieved probes in late September.

Results of the study suggest that temperature dynamics behind the causeway are more complex than initially thought. The water temperatures behind the causeway did not have large daily fluctuations as seen in the mainstem of the Yakima River (Figure 52). Surprisingly, the temperatures lagged behind the Yakima mainstem and mouth river temperatures in June and July. Based on float data, it was theorized that temperatures from this probe would read higher than those in the mainstem. The surprising results may be the product of probe placement near the bottom of the pool. It is likely that the pool stratifies during the summer months with cool temperatures near the bottom and warmer temperatures at the surface. BCD volunteers from the Atomic Duck Diving Club examined the earthen causeway and did not locate any underwater culverts or piping. As such, Columbia River is unlikely to be the source of cooling. At present, little is known about the construction of the causeway and its impact on the Yakima River confluence. It has been suggested that the causeway was established prior to the Department of Defense purchase of the island in 1952 (pers. com. with Army Corps of Engineers). Today the causeway is maintained for emergency vehicle access as well as for recreational foot traffic access to the island.

It is worth noting that the Columbia River shelf temperatures were significantly cooler than those measured for the Yakima River for June thru August despite the fact that this probe was at the shallowest depth (only 1 foot under the surface water as compared to the other probes that were at least 3+ feet deep). Temperatures for the Yakima and Columbia waters began to converge the first week of September (Figure 52).

Figure 45. Probe casing and deployment for Bateman Island thermal data

Figure 46. Bateman Island Causeway (2009)

The extreme thermal conditions of the lower Yakima River during irrigation season provides a migration barrier to local salmonid species (Lilga 1998, Vaccaro 1986, Snyder and Stanford 2001). Juvenile salmonids and spring adult runs must adapt migration timing so that they are through the lower Yakima River before temperatures rise rapidly in June and July. Fall adult migratory species are thought to hold in the Columbia River while waiting for Yakima River temperatures to decrease in September and October. Further work needs to be done to investigate the flow dynamics, temperature profiles and sedimentation rates at the confluence and determine if removal or modification of the causeway will improve the flow and temperature conditions at the mouth of the Yakima River.

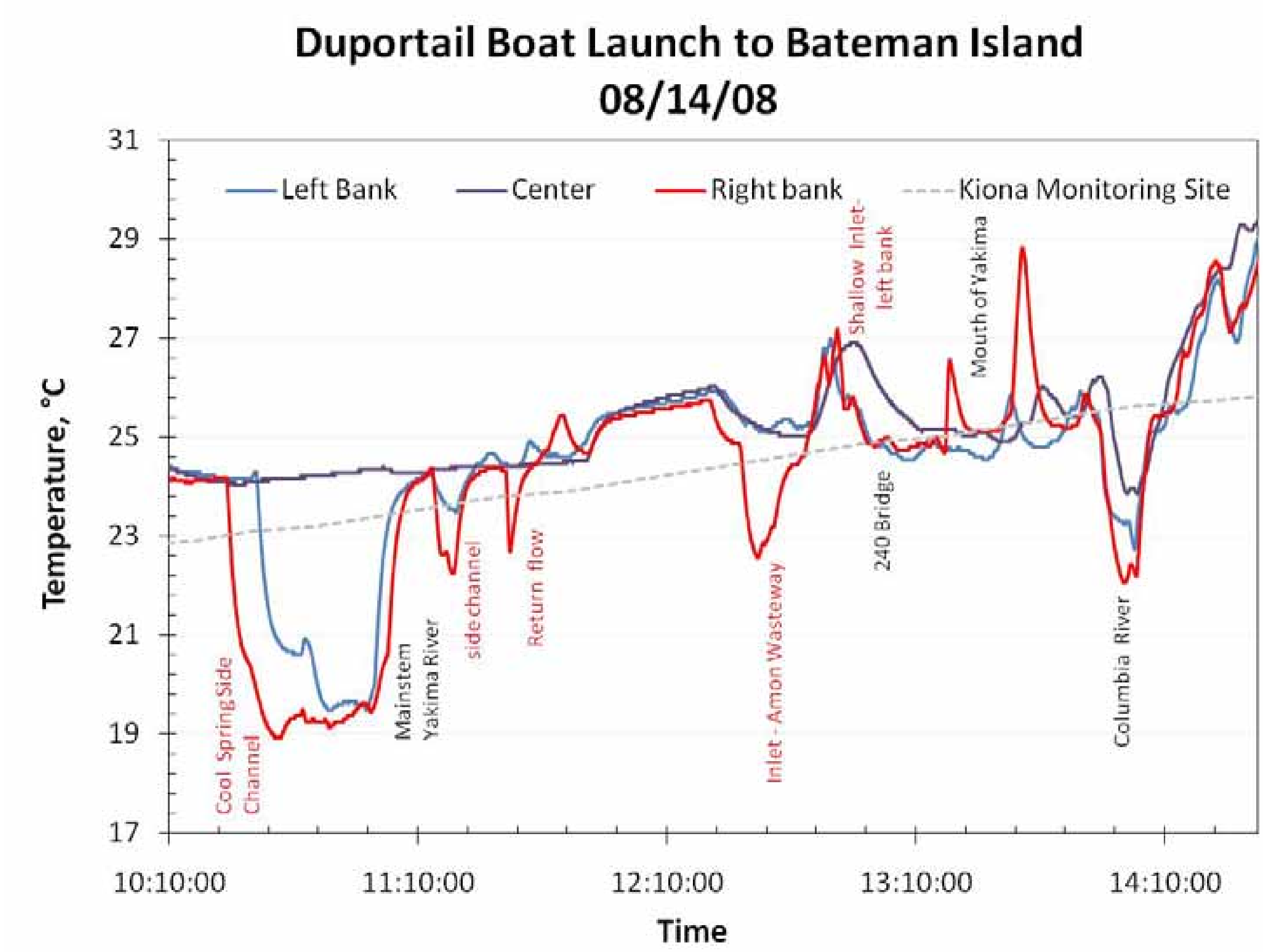


Figure 47. Thermal profile data for 2008, Richland, WA (Duportail Boat Launch to Bateman Island)

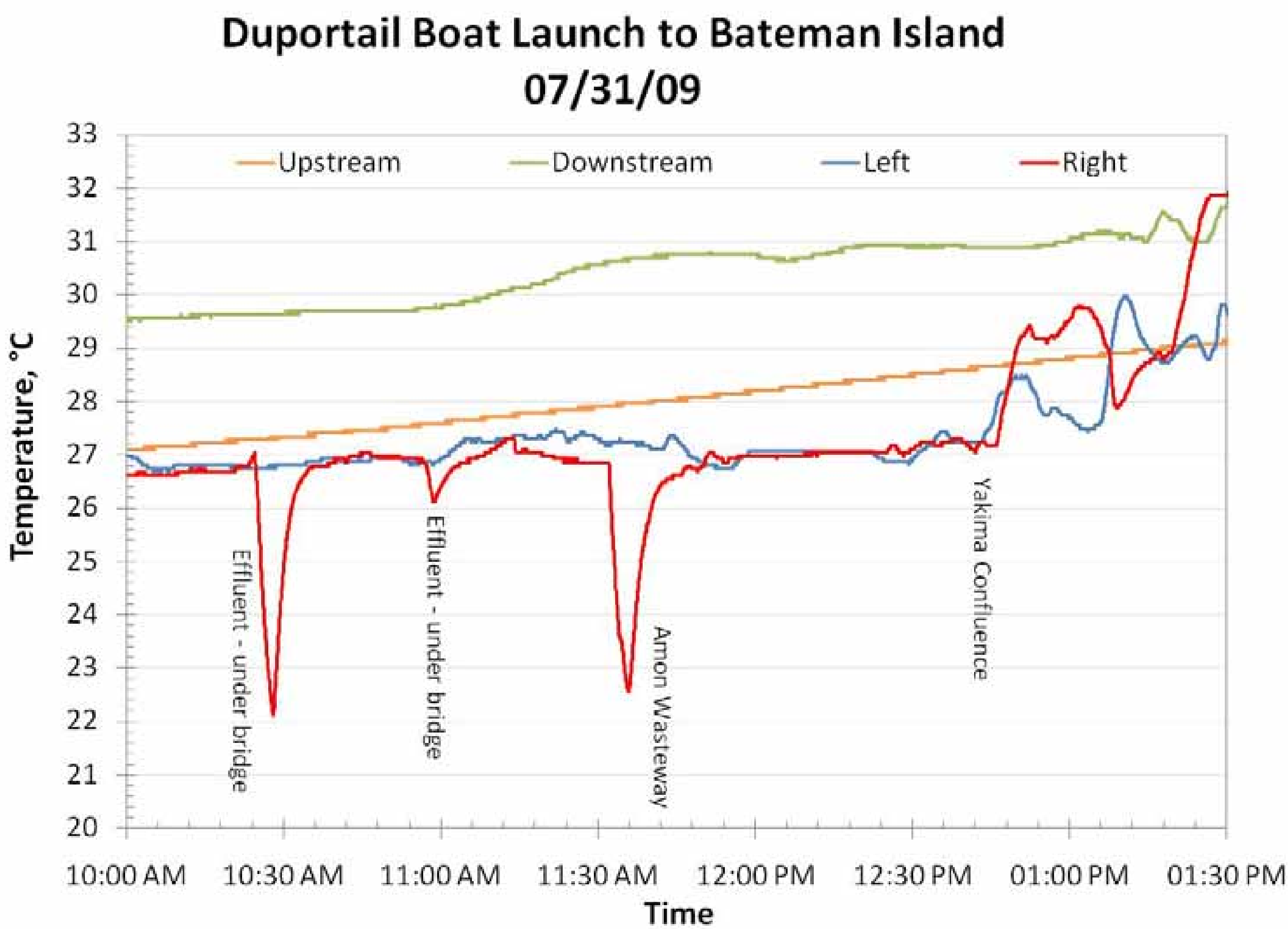


Figure 48. Thermal profile data for 2009, Richland, WA (Duportail Boat Launch to the Bateman Island). Data for Left and Right Bank

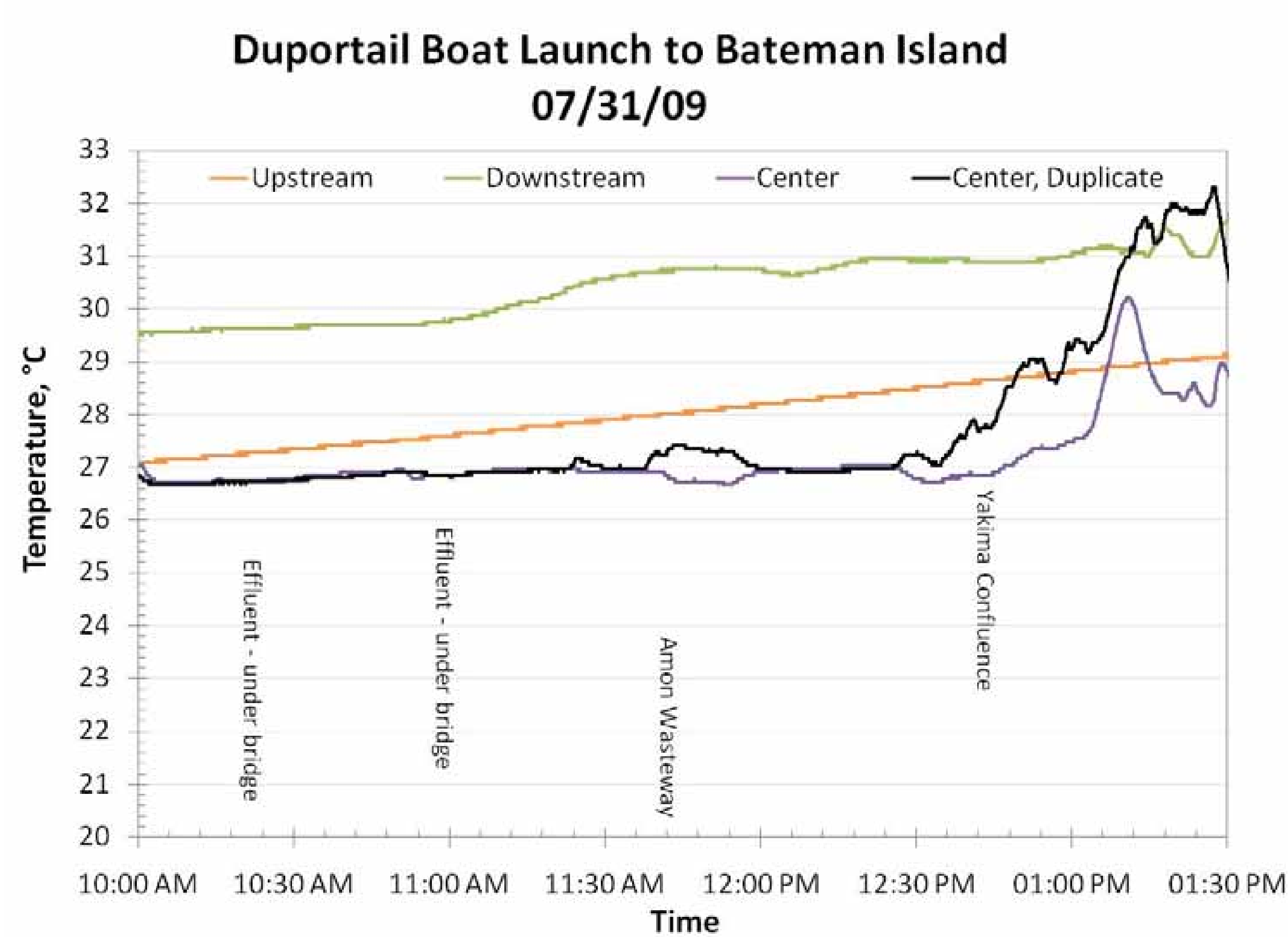


Figure 49. Thermal profile data for 2009, Richland, WA (Duportail Boat Launch to the Bateman Island). Data for center boat

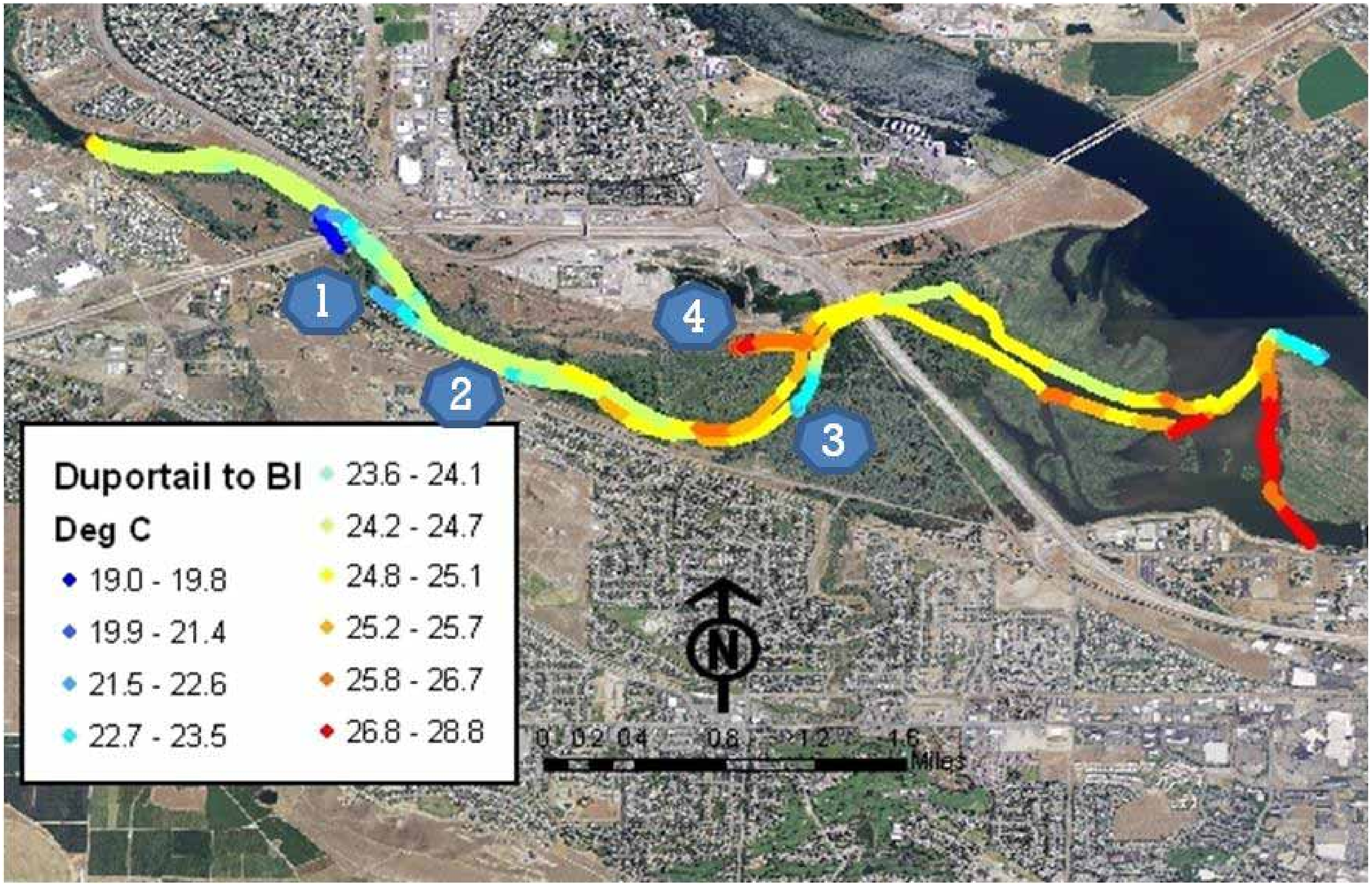


Figure 50. Thermal map for 2008, Yakima River confluence

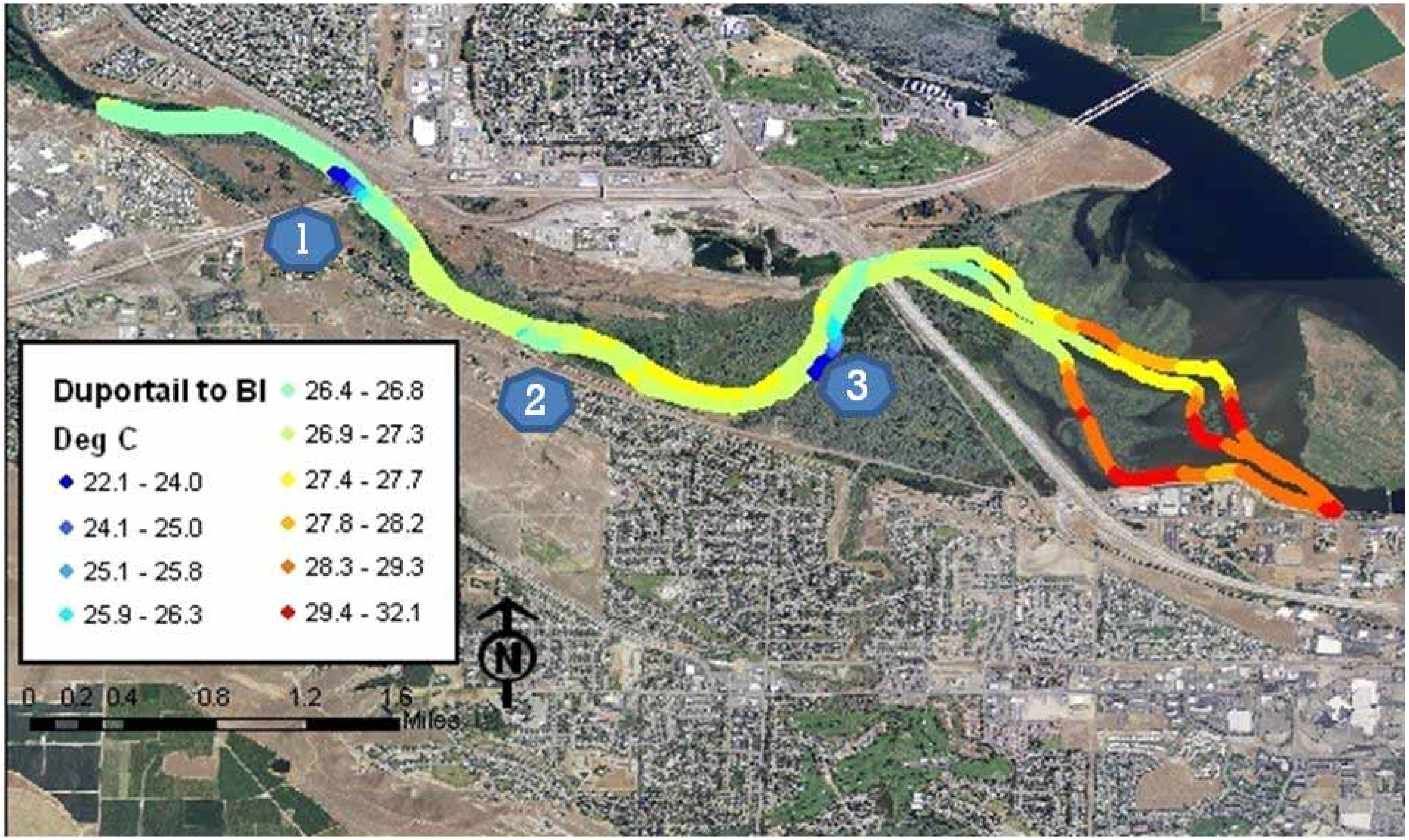


Figure 51. Thermal map for 2009, Yakima River confluence

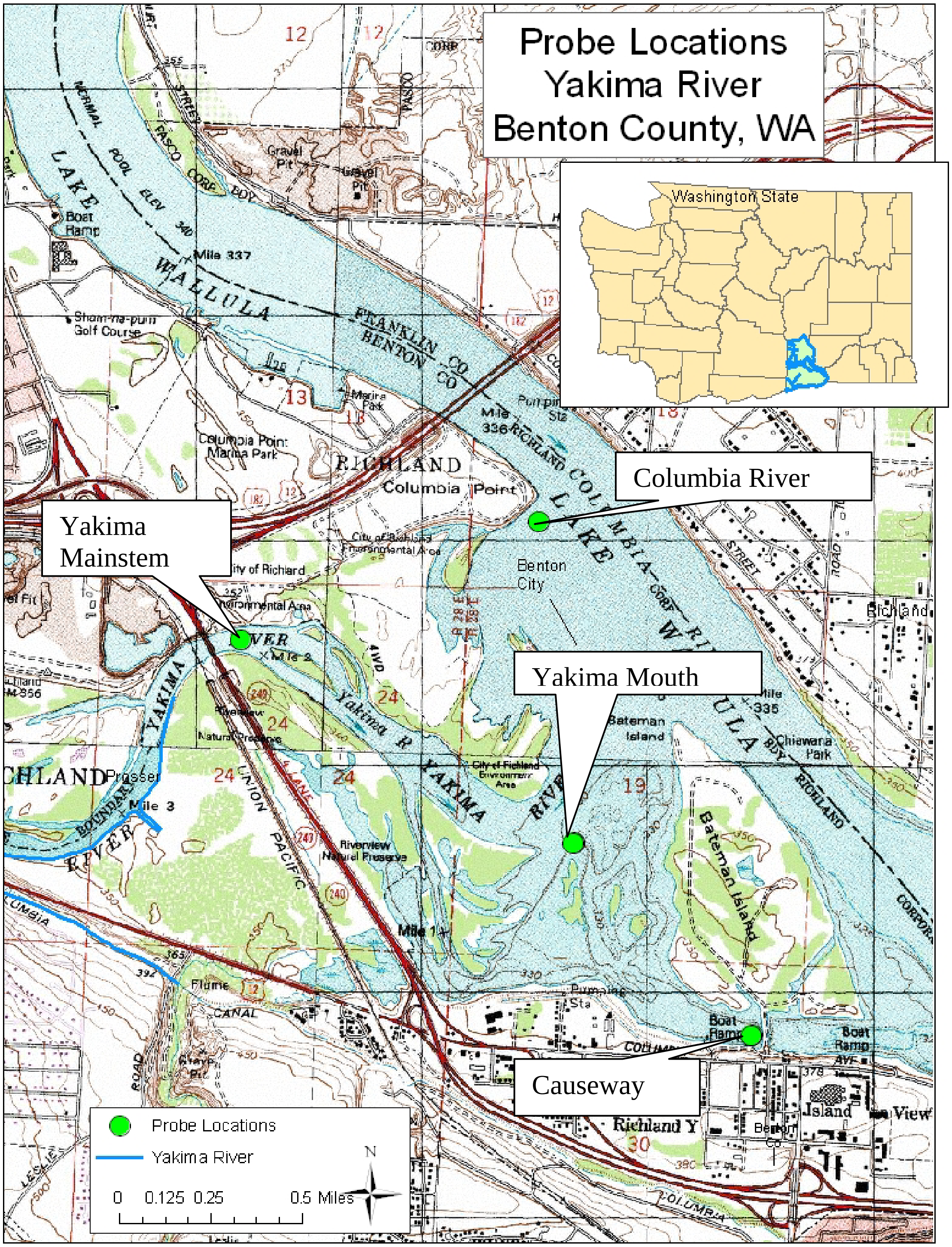


Figure 52. Temperature probe locations for Yakima Delta temperature study (2009)

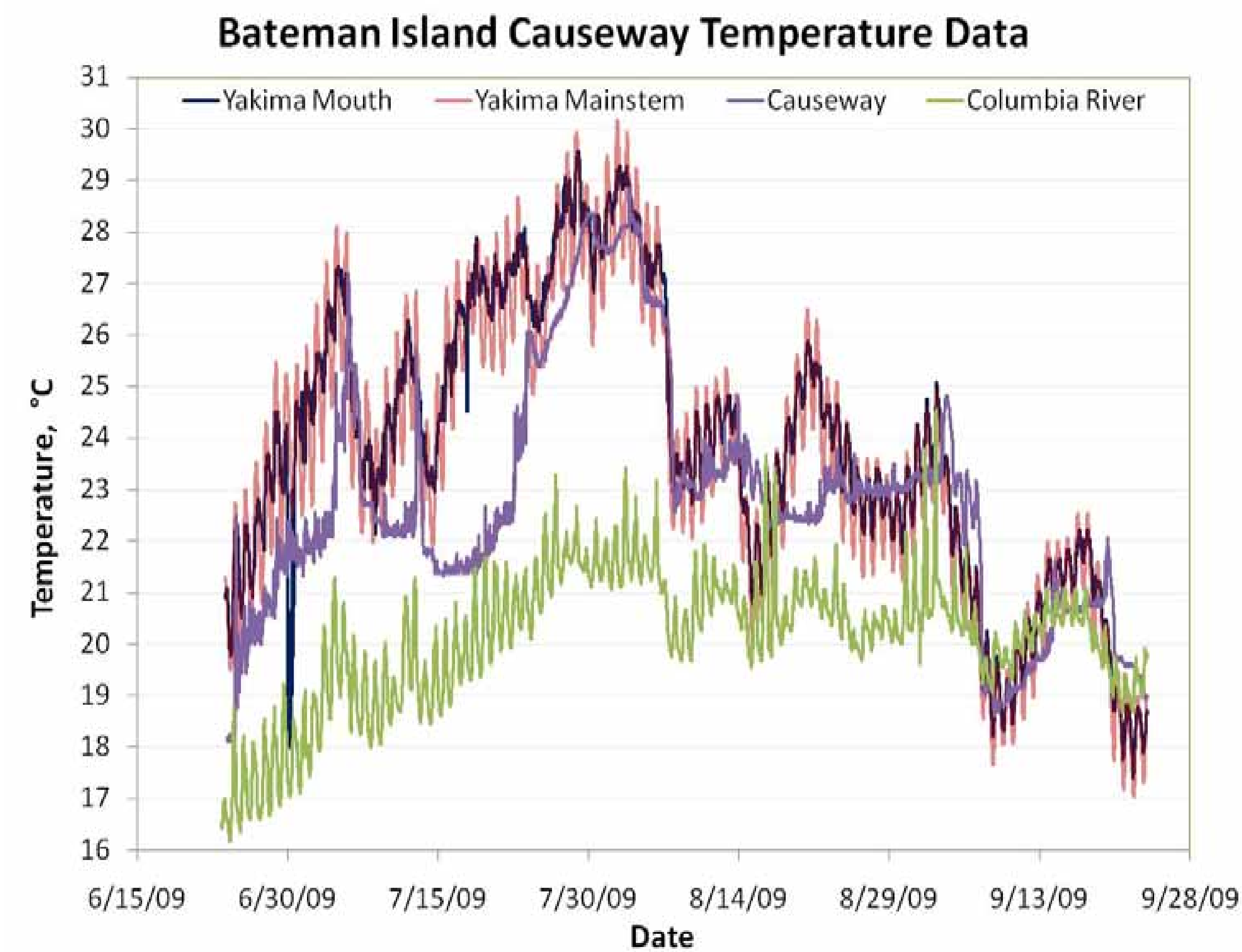


Figure 53. Thermal data for the Yakima confluence (2009)

9.5.7 Thermal Profile Conclusions

With temperatures well above 21°C for the 2008 and 2009 summer floats mainstem Lower Yakima River temperatures were inhospitable for salmon as expected; however, temperature heterogeneity within the lower Yakima River was identified. Although a predominantly, loosing reach, localized areas of cooler temperatures were identified. These "cooler" areas were the result of: a) non-point source seeps that are likely discharge points for shallow groundwater seeps fed by irrigation and river recharge, b) irrigation wasteways (e.g., Spring and Snipes Wasteways, Corral Creek Wasteway, and Amon Creek Wasteway c) and "holes" (e.g., tail of oxbow at Barker Ranch). The "cooler" areas are located along the riparian area and in some instances behind side-channels (e.g., island at I-182 bridge).

Only a couple identified areas can be classified as resulting in significant temperature drops for salmon refuge (< 21°C) during July and August. These included: a) series of groundwater discharge seeps below Prosser and b) groundwater discharge within the island side channel under the I-182 bridge. Amon Creek Wasteway and Knox Creek (2009 data) also significantly decreased temperatures at their confluence with the Yakima River as temperatures were decreased to 22-23°C, but were still above critical threshold temperatures for salmonids. Areas of significant cooling provide potential for salmonid habitat projects within the lower Yakima River. The series of cool seeps below Prosser are located before an island head that has shown to be historical fall Chinook spawning grounds. Large woody debris and riparian plantings may enhance this area for salmon. The groundwater seep under the I-182 bridge provides opportunity as both thermal refugia and as a salmonid acclimatization area for rearing and releasing salmon in the lower Yakima River. Improvements would need to be made to the island side channel to make it suitable for salmonid restoration work.

While several of the remaining "cool" seeps did not drop temperatures to below 23°C they still decreased river temperatures by 0.5°C to 2°C. It is possible that the temperature differential between the seeps and the mainstem a month earlier (i.e., June) may create ideal refugia possibilities for salmon caught at the end of migration when river temperatures are cooler, but rapidly rising. Moreover, a 0.5°C change in external water temperature is important to an already stressed salmonid caught in unfriendly warm waters and may help relieve thermal stress (Heppell, pers. comm. 2008).

Irrigation fed groundwater discharge appears to be an important source of cool water to the lower Yakima River. The data gathered in 2008 and 2009 at Barker Ranch suggests that subsurface runoff supported by irrigation may influence temperatures within a localized area of the river. It brings up an interesting question regarding the influence of irrigation water on temperatures in the lower Yakima River: do irrigation improvements that allow water to be left in the river provide more or less of a temperature advantage than subsurface irrigation return flow? Answering this question is outside the scope of this report; however, the influence of subsurface flow on temperature heterogeneity in the lower Yakima River should be further investigated in future studies.

Some of the most fascinating data were observed within the Yakima River delta. This area is identified as a high priority area for additional studies and potential habitat improvement projects. From the precursory study it appears that the Bateman Island Causeway may impede natural flow dynamics thereby exasperating already warm temperatures in the lower Yakima River and creating a warm plug for migrating salmon. Removal of this causeway may result in improved flow around Bateman Island and help with sedimentation and temperature issues. Additional data and modeling must be performed before these questions can be answered, but it is certain that improvements within the delta that provide increased salmon passage would greatly benefit all salmon restoration projects within the Yakima Basin.

CHAPTER 10 LARGE WOODY DEBRIS

Historically, the presence of large woody debris in the lower Yakima River is not well documented. The following historical account of large wood in the lower Yakima River was recorded in the General Land Office 1863 document "Land Status and Cadastral Survey Records":

> *Although this township (9) greatly needs timbered lands, the banks of Yakama River are generally lined with young cottonwood trees and willows of enormous size. Yearly the Yakama River disgorges from its mountain source 70 in. diameter and from 100 to 250 feet in length of Fir and Cedar timber are often seen winding their way down its current into the broad waters of the Columbia.*

With river regulation and damming, the timber that was documented as flowing to the Yakima River Confluence is no longer present. As seen in Figure 54, much of the large woody debris (LWD) for the lower Yakima River is currently captured at Prosser Dam. The Bureau of Reclamation removes this wood and places it on the downstream end of the dam. Without large scouring floods, this wood typically remains at the base of the dam. This local source of LWD represents an economic source of material for use in downstream projects. There is potential to restore some of the lost LWD to the lower Yakima River through management of the LWD captured by Prosser Dam.

The Yakima River is highly regulated, with multiple impoundments and bridge footings that restrict the downstream movement of LWD. As upstream contributions and riparian sources have dwindled, the lower Yakima channel has suffered from reduced LWD structure. Large woody debris can be important in formation of pools that provide thermal refugia for both juvenile and adult salmonids (Nielsen et al. 1994). Future projects should be developed to retain and recruit large woody debris into the lower Yakima to restore and enhance habitat. Engineered logjams designed to trap and recruit future LWD are appropriate will aid in channel complexity and protect thermally stratified pools. If placed appropriately, engineered logjams will enhance flow into sidechannel areas choked out by water stargrass and off-channel habitat disconnected from the mainstem.

Figure 54. Prosser Dam with captured large woody debris (2010)

There is a popular misconception that LWD does not collect in the lower Yakima River and does not provide ecological benefit. This is simply not the case. The lower Yakima River has several islands that capture LWD during flood events and high flow. For instance, flooding in 2009 resulted in the collection of LWD at island heads throughout the lower Yakima River. Figure 55 shows one such example where the amount of large woody debris increased significantly between 2008 and 2009 at the head of an island located west of Benton City. In 2009 increased amounts of wood debris were also seen along the riverbanks and within lower floodplains. Placement of LWD in the lower mainstem, either through the introduction of captured wood from the Prosser Dam or deliberate placement of LWD may be beneficial to the lower Yakima River. LWD may help scour and restore degrading side channels that have been prone to sedimentation with increased water stargrass proliferation. Future projects should be developed to retain and recruit large woody debris into the lower Yakima to restore and enhance habitat. Engineered logjams designed to trap and recruit future LWD are appropriate projects for the lower Yakima to develop channel complexity and protect thermally stratified pools. Projects to install LWD in the lower Yakima River must consider the risk of possible predation issues on juvenile salmonids.

Figure 55. Lower Yakima River Island head with large woody debris after 2009 flood

AmeriCorps removing water stargrass in lower Yakima River, Benton City. The cobble substrate in the island side channel has been heavily silted in due to low water velocity. LWD could increase channel complexity while directing increased flow.

CHAPTER 11 FISH SCREENING NEEDS

Land use for the lower Yakima River Basin is primarily irrigated agriculture, irrigated pastureland, and residential. With an average of 6 inches of rainfall per year, communities rely on water withdrawal from the Yakima River to support agricultural production, livestock and local economies. Finding a balance between these two river needs (salmonid survival and water withdrawal) is critical for this region.

The start of frost protection and irrigation season in March coincides with the juvenile life stage of both resident and anadromous fish in the lower Yakima River. Several of the lower Yakima River irrigation intakes are located near known fall Chinook spawning grounds or are located within island side channels that provide rearing habitat and cover for juvenile salmonid species during the winter and early spring. It is imperative that during these critical life stages, when juvenile are rearing in the lower Yakima River, that irrigation intakes be properly screened, especially those in key habitat locations.

In 2008, the Benton Conservation District (BCD) performed an assessment of the lower Yakima River to identify screening needs. As part of this assessment, irrigation intakes in the lower Yakima River were tallied, water rights were examined, landowners were contacted, and previous Washington Department of Fish and Wildlife (WDFW) screening files were located (Figure 56). These combined resources indicate that there are over 60 irrigation intakes in the lower Yakima River many of which are utilizing older non-compliant fish screens, “home-made” fish screens, or have non-screened intakes. As a result, out-migrating juvenile salmonids may become impinged on outdated screens or entrapped within non-screened intake lines.

Several of the fish screens currently used within Benton County were installed by the Washington Department of Fish and Wildlife in the late 1980s. These screens are not compliant with current National Marine Fisheries Service (NMFS) screening criteria, as they do not protect fish from impingement. Older screens were designed to prevent entrainment; however, higher external velocities surrounding the pump screen resulted in juvenile impingement. Current screens are designed to prevent both impingement and entrainment. New fish screens are designed with an inner baffle to alleviate high in-flow velocities surrounding the exterior of the fish screen. As such, velocities external to the fish screen match that of the river flow and juvenile salmonids are able to escape impingement.

Only recently, local screening programs have become available to irrigators within Benton County through the Benton Conservation District’s fish screening program. The BCD started its pilot fish screening program in 2008 with funding provided by the Salmon Recovery Funding Board. In just one year, the BCD generated enough interest to successfully install 10 new NMFS compliant fish screens and generate a waiting list for the following irrigation season. BCD was awarded additional funding by SRFB in 2009 to continue the screening program for an additional 13 screens by 2012. The continued funding of this program and screening of private irrigation intakes will be beneficial to the survival of federally listed juvenile steelhead as well as juvenile spring and fall Chinook.

Example of non-compliant fish screen (top) replaced with NMFS compliant fish screen (bottom). New fish screen was installed in Yakima River by BCD Screen Program (2009).

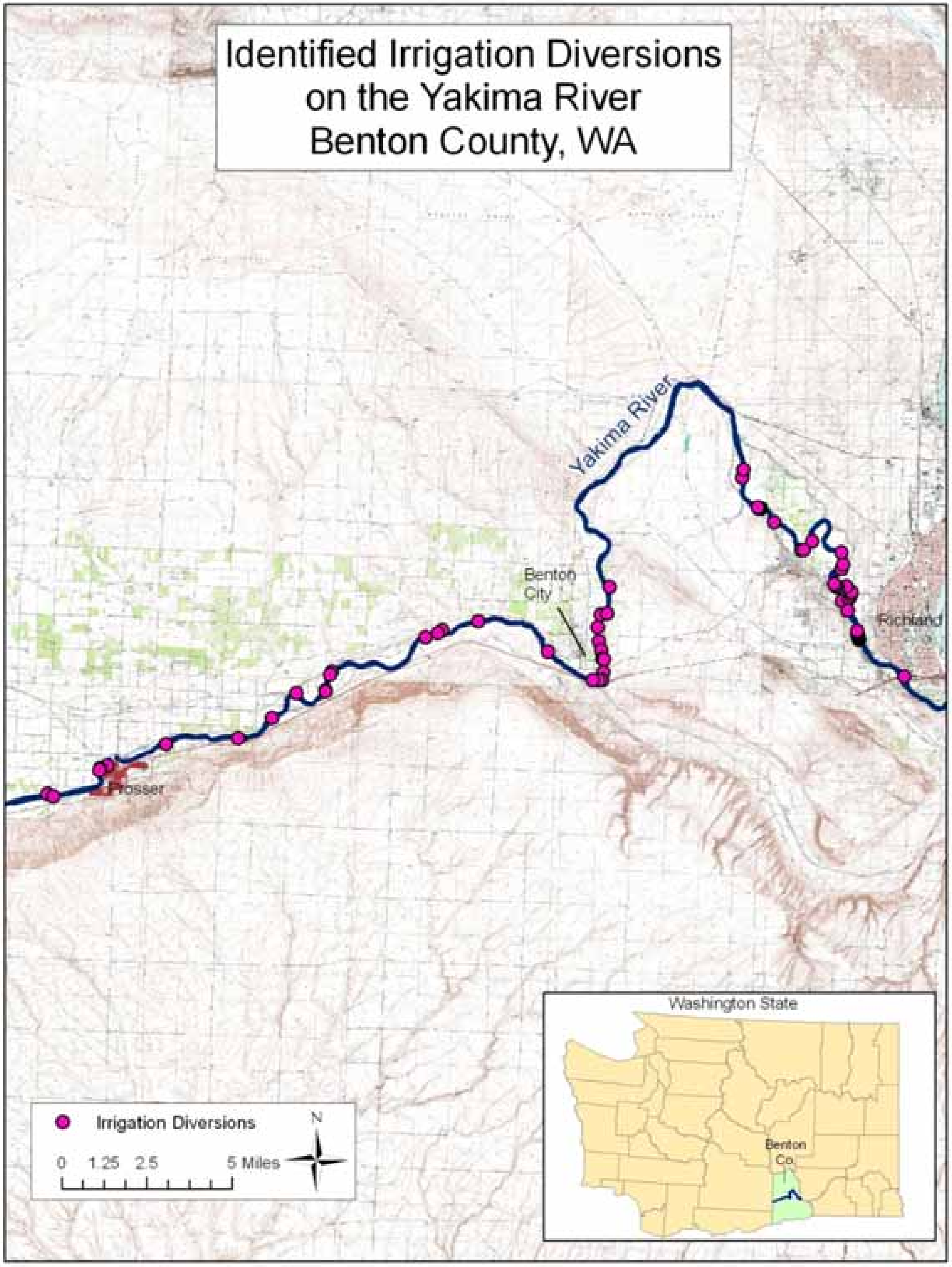


Figure 56. Identified irrigation diversions on the lower Yakima River (2008)

CHAPTER 12 RIPARIAN PROJECT POTENTIAL

Many areas of the Yakima River riparian corridor have been severely degraded through years of urbanization and agricultural use (YSRP 2008). Floodplain functionality and riparian vegetation have been lost (YSRP 2008). Consequently, the lower riparian corridor does not provide the necessary in-stream habitat diversity that migrating salmon require. The 2008 Yakima Steelhead Recovery Plan (YSRP) states that:

> *Lower river conditions play a major role in migration timing for adults and survival of out-migrating smolts. Protecting and restoring mainstem and off-channel habitats (especially those that provide thermal refugia) is critical for these life states. Work may include protecting habitat through…activities like riparian plantings, reactivation of side channels, and winter irrigation to saturate floodplains (pg. 154).*

The lower Yakima River riparian corridor is primarily privately owned and used for agriculture, livestock grazing, and private residential use. Most Yakima River riparian projects must be implemented on private land. Before these projects can occur, relationships and trust must be built with landowners. BCD has established programs for working with local landowners to educate landowners and restore river corridor functionality.

The biggest issues with respect to the lower Yakima River corridor are streamside grazing, removal of riparian vegetation for agriculture and urbanization, and non-native vegetation. Streamside grazing along the Yakima River increases sediment and nutrient loads to the river, is a source of harmful fecal coliform bacteria, and creates compaction of soil and a loss of riparian vegetation, which can lead to erosion and flooding. Similarly, removal of riparian vegetation for scenic views or grass lawns provides a source of nutrient, insecticide and herbicide run-off, soil erosion, and both a loss of floodplain functionality and critical habitat for migrating salmon. Removing livestock from the river and incoming waterways as well as installing riparian buffers on the lower Yakima River can mitigate these problems. Appendix D**: Yakima River Riparian Restoration Projects in Benton** highlights several of the riparian projects recently implemented by BCD in conjunction with landowners. Many of these projects were identified during the assessment and subsequently implemented. Much work remains to restore the Yakima River riparian corridor and continues to be an area of high priority.

Figure 57. Example of need for riparian fencing and bank improvement (2009)

CHAPTER 13 PROPOSED PROJECT LIST

The following is a list of high priority actions identified for the lower Yakima River salmon recovery efforts as a result of this project.

1. **Yakima River Delta and Bateman Island Causeway**. Elevated temperatures at the Yakima Delta confluence with the Columbia River are causing adult salmonids to delay migration. Further investigation is needed to determine if removal of the Bateman Island Causeway will result in increased mixing with the Columbia River, decreased sedimentation, and decreased temperatures within the Yakima Delta, thereby improving delta function and minimizing water temperature issues.

2. **Fish Screening and Irrigation Water Conservation**. Over 60 privately owned irrigation intakes were identified during this assessment. River floats indicated that at least half of these intakes were not compliant with current fish screening standards and need to be updated. Outdated irrigation systems should be converted for irrigation efficiency and water savings as well as protecting salmon from uptake and impingement.

3. **Restoration of Riparian Buffers**. Shoreline residential development, grazing, and non-native riparian vegetation are common on the lower Yakima River. Working with private landowners to restore native riparian buffers and to manage streamside grazing is imperative.

4. **Side Channel Restoration and Protection (Prosser to Richland)**. Side channel degradation is apparent by many of the islands, especially between Benton City and Richland. Degradation appears to be due to extensive water stargrass, sedimentation, low flows, and non-native vegetation. Projects aimed at restoring side channels either through water stargrass removal or scouring with large woody debris (LWD) should be considered. Priority should be given to islands near identified thermal refugia pockets and/or historical spawning grounds. Projects will need to be implemented with community support, as the islands and neighboring lands are primarily privately owned.

5. **Off-channel Restoration and Re-connectivity (Benton City to Richland)**. Previous research found off-channel habitat has been lost as a function of lower flows (Stanford et al. 2001). Managing higher summertime flow is outside of the scope of this assessment, however, projects aimed at enhancing current flow scenarios (especially spring-time flows) to off-channel habits and promoting scour are recommended. Much of this land is privately owned and located between Benton City (e.g., Benton City oxbow, Floodplain adjacent to Songbird Island) and West Richland/Richland (e.g., Fox Island channel, Island habitat under I-182 bridge).

6. **Island and Floodplain Protection (Benton City and West Richland)**. Investigations to lease or purchase floodplain habitats in Benton City and West Richland and islands (e.g., Fox Island, Twin Bridges Island) from willing participants should be further explored. Partnerships with other entities such as Benton County and Tapteal Greenway may foster management of riparian areas for both conservation and recreation.

7. **Protection, Enhancement, and Further Analysis of Thermal Refugia Potential**. Although predominantly a losing reach, this study determined that thermal heterogeneity is present along the lower Yakima River and may provide critical temperature differentials for migratory species at the tail end of out-migration and front-end of in-migration. Additional studies should be performed to determine dissolved oxygen levels and temperature differentials between the identified "cooler" areas and the average river temperature at the end of spring run-off and the beginning of fall migration to determine the suitability of existing cool pockets as migratory thermal refugia.

   Pockets of cooler water were mainly associated with interstitial groundwater flow along riverbanks and point-and non-point source irrigation returns. A few "holes" were identified that also coincided with localized decreased temperatures. Segments of the river within West Richland had thermal suppression; this may be in part due to West Richland's extensive floodplains and irrigation. The sources of water for these cool pockets (i.e., percentage of river recharge vs. irrigation recharge) should be investigated to help with future decisions of river management. Projects coupled with these identified "cooler" areas are likely to provide the greatest benefit.

8. **Water Stargrass Management**. Removal of water stargrass and development of removal techniques in critical salmonid habitat areas should continue as water stargrass represents both a direct physical threat to habitat and a threat to water quality and temperature. It is recommended that removal efforts be targeted at historical fall Chinook spawning grounds and threatened side-channel habitats.

9. **Large Woody Debris (LWD).** Historical documentation indicates that the lower Yakima River and delta primarily obtained its large woody debris from upstream sources with only minor contribution from growth along the lower riverbanks. Capture of wood at the Prosser Dam needs to be managed so as to promote the continuation of wood downstream within the lower Yakima River. Large woody debris is captured by island heads and floodplains within the lower Yakima River and along the banks during high flow events. Placement of LWD may help with island side channel scour, habitat complexity, and enhance areas of thermal refugia.

10. **Levees and Flooding**. Options should be investigated for converting the existing levees (e.g., Yakima Delta) to more fish friendly levees that provide both flood control protection and ecological benefit. In addition to improving the levees,

other programs to reduce fecal coliform contamination should be developed to help reduce the impact of flooded areas contiguous to the river that contain pasture and old septic systems.

CHAPTER 14 LOWER YAKIMA RIVER GOALS RELATED TO FOCAL SPECIES

Combining the knowledge of the lower Yakima River's past with the future direction of water usage and restoration goals we conclude the following with regards to restoration actions and priorities for salmonid speciation recovery goals in the lower Yakima River. Many of these priorities are large-scale problems that will only be accomplished with many state, federal, and private entities working together.

1. Maintaining and enhancing September thru early June migration conditions for juvenile steelhead, coho and spring Chinook is a primary goal. This includes:
    a. Work to reduce bird and bass/pikeminnow predation
    b. Reduce diversion related injury and mortality at chandler
    c. Use of pulse flows to encourage movement in low water springs
    d. Improve selected microhabitats in reach (wood/riparian projects associated with cooler flows, side channels, mouths of wasteways)
    e. Improving the delta temperature and flow

2. Enhancing late June thru Sept migratory conditions are an area of growing focus for adult sockeye, summer Chinook and lamprey. The following improvements are priorities in the lower Yakima River to help these species:
    a. Protect and enhance cool water refugia (improve riparian cover, wood, and pool scour)
    b. Explore use of pulse flows around storage control to encourage adult movements through lower river if temp conditions allow
    c. Explore use of pulse flows during cooling periods to create windows of passage in August early September
    d. Support for ongoing water quality improvements
    e. Delta temperature and flow improvements

3. Management of lower Yakima mainstem for year-round use by juvenile salmonids is not realistic based on temperature issues during July and August. Warm summer temperatures do not significantly constrain the movement and survival of adult steelhead, spring and fall Chinook and coho as these species have learned to adapt to current Yakima River conditions.

4. Improve conditions for fall Chinook spawning and rearing in the lower Yakima River:
    a. Efforts to remove water star grass from prime spawning areas
    b. Efforts to clean and work gravels in embedded reaches
    c. Improve selected microhabitats in reach (wood/riparian projects associated with cooler flows, side channels, mouths of irrigation wasteways)
    d. Work to reduce bird, bass, and pikeminnow predation
    e. Reduce diversion related injury and mortality at chandler

f. Use of pulse flows to encourage movement in June and July around storage control (trigger juvenile movement to Columbia prior to greatest warming)
g. Support for ongoing water quality improvements
h. Delta temperature and flow improvements

5. Irrigation wasteways provide marginal year-round habitats with political and practical barriers to enhancement; however, there are many opportunities to work with local landowners and irrigation districts for implementing best management practices that would improve water conservation and quality. Wasteways may also provide possibilities for thermal refugia within the lower Yakima River.

CHAPTER 15 CONCLUSIONS

The Yakima River below Prosser Dam has enormous potential for restoration activities and habitat enhancement projects. Although, a confined reach, the importance of floodplains for habitat and structure between Benton City and the delta should not be quickly dismissed. Enhancing flow and scour within off-channel habitats, acquisition of floodplain properties and ecologically valuable islands, restoration of riparian buffers, and restoration of side-channels are all feasible actions that would significantly improve habitat within the lower Yakima River. Moreover, these actions are opportunities that can be completed independent of future temperature and flow management scenarios.

While mainstem temperatures are intolerable during the summer months, temperature profiling of the lower Yakima River highlights that there is thermal heterogeneity within the lower Yakima River. Determining ways to maximize and utilize this heterogeneity for thermal refugia potential in the late spring/early summer and late summer/early fall may significantly improve fish production and survival in the lower Yakima River. Shifting the current view of the lower Yakima River as one continuous slug of warm water to a model that incorporates thermal heterogeneity could have an impact on future management discussions of the lower river.

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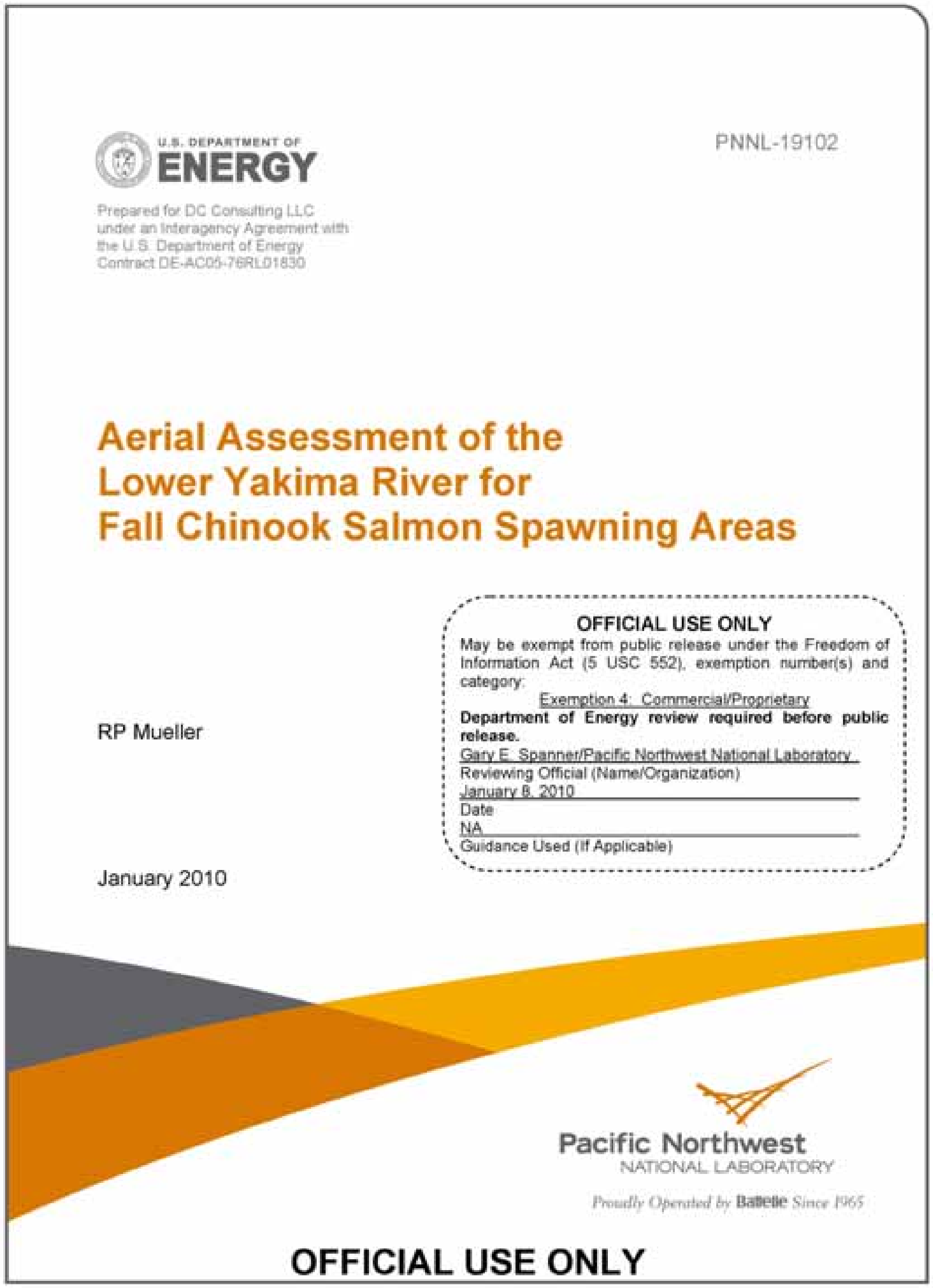
Appendix A: PNNL Aerial Flight Results - 2009 Fall Chinook Redd Locations



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PNNL-19102

Prepared for DC Consulting LLC
under an Interagency Agreement with
the U.S. Department of Energy
Contract DE-AC05-76RL01830

Aerial Assessment of the Lower Yakima River for Fall Chinook Salmon Spawning Areas

RP Mueller

January 2010

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1.0 Introduction

The Benton Conservation District (BCD) is currently working on a grant awarded through the Salmon Recovery Funding Board to identify high-priority actions for the lower Yakima River that will directly benefit local salmonid species. The objective of the grant is to perform an assessment of the lower Yakima River with the end goal of identifying potential future projects that would enhance, protect, or restore spawning and rearing habitat in the lower Yakima River. Over the past year, the BCD has been compiling literature on previous research performed in the lower Yakima River and is investigating potential data gaps that currently exist. In support of the BCD, DC Consulting LLC contacted the Pacific Northwest National Laboratory (PNNL) to conduct aerial surveys of fall Chinook salmon spawning areas in the lower Yakima River in fall 2009.

In previous years, only limited aerial surveys had been conducted for spawning locations in the lower sections of the river because of degraded water clarity. The most recent of those was done by PNNL in 2002, when 176 redds were counted between the Highway 240 bridge and Wanawish Dam. During the past several years, however, water quality and clarity have improved as a result of recent irrigation methods and drainage improvements. The Yakama Nation now conducts boat-based redd surveys in the Yakima River upstream of Prosser, and the Washington Department of Fish and Wildlife (WDFW) conducts raft surveys in the lower river downstream of Prosser. Fall Chinook salmon escapement to the Yakima River has been determined using the redd counts, carcass surveys, and sport catch in the lower river (downstream of Prosser Dam) and the adult count at Prosser Dam, which is monitored by the Yakama Nation. Based on past surveys by the Yakima Nation, minimal fall Chinook salmon spawning is expected to occur on the Yakima River upstream of Union Gap, Washington (near river mile 107). The BCD is currently working in tandem with another Salmon Recovery Funding Board assessment being performed in the Wapato Reach of the Yakima River. Accurate redd counts in the lower sections of the Yakima River (from Union Gap downstream to the confluence with the Columbia River) would be highly beneficial to state and federal agencies and support all ongoing research within the basin.

The specific objective of the PNNL assessment was to determine and enumerate, via aerial observation, the spawning areas throughout the spawning range of fall Chinook salmon in the lower Yakima River. The BCD will use this information to determine the general locations where salmon are spawning; the other physical data collected along the river will be used to further characterize these and other locations that are providing suitable spawning habitats.

2.0 Methods

Visual surveys were conducted from a fixed-wing aircraft (Cessna 182) flying about 700 ft above the water surface at air speeds ranging from 110 to 130 km/h. The flight plan for each survey included departure from the Richland Airport and flight along the Yakima River from the Highway 240 bridge in Richland to just downstream of Union Gap, Washington (Figure 1). The total flight time to complete each survey was generally around 2.5 hours. River discharge data for each flight date were obtained via a real-time database from a U.S. Geological Survey gauging station located at Umtanum, approximately 25 river miles upstream from the city of Yakima.[1] The redds of fall Chinook salmon, which can attain an overall size of about 100 ft^2, were distinguished by light-colored patches, suggesting clean or disturbed substrates that indicate nest sites. As redds were observed, their numbers were tallied and the locations were marked on corresponding maps of the river during the flights.

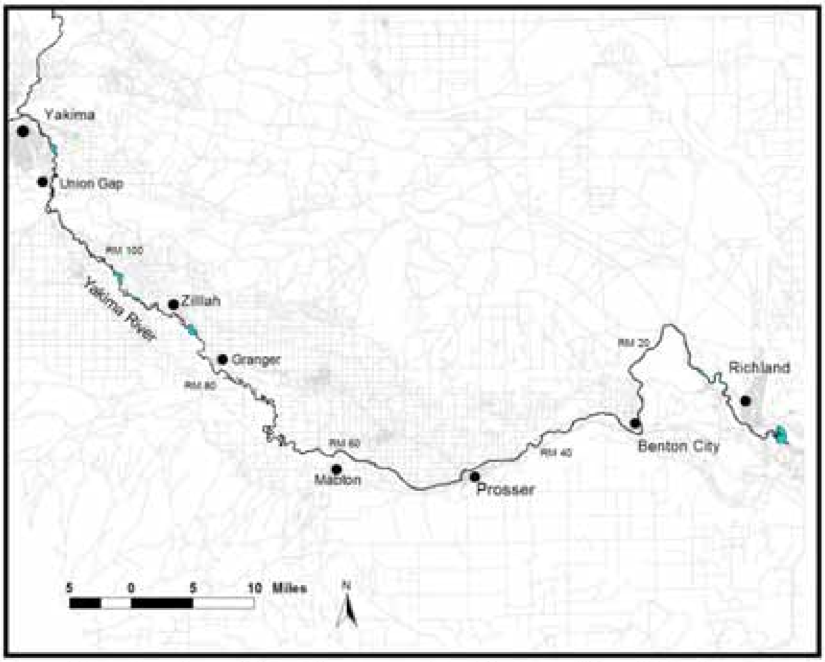

Figure 1. Lower Yakima River survey site, with cities and river miles indicated

3.0 Results

Four survey flights were conducted between 18 October and 14 November 2009. The river stretch of interest was subdivided into six segments for reporting purposes. The highest redd count for all river segments occurred on 14 November, when 473 redds were counted. More than half of all redds observed (52%) occurred from Granger to Zillah, and 94% of the peak count were located upstream of Prosser (Table 1).

River flow recorded at Umtanum varied from a high of 1,070 cfs on 18 October to 856 cfs on 14 November. Water clarity was good for all survey dates except for 24 October, when increased turbidity

[1] http://waterdata.usgs.gov/wa/nwis.

was observed from the discharge outlet at the Chandler Power Plant and Pump Station extending downstream to the city of Richland.

Redds were observed on the first flight conducted on 18 October and were detected easily from the plane. Figures 2 and 3 show redds occurring about 1 mile upstream of Granger near river mile 85. Figures 4 through 11 show the general areas in which redds were observed from the aircraft. Redd locations are indicated by the red circles within the survey region. No redds were observed in the lower reach of the Yakima River from river mile 5 to 30 near Benton City.

Table 1. Fall Chinook salmon redd counts in the lower Yakima River, river flows, and flight conditions during aerial surveys conducted October and November 2009

Redd Count	Survey Date			
River Segment	18 October	24 October	9 November	14 November
HWY 240 bridge to Wanawish Dam	0	0	0	0
Wanawish Dam to Prosser	0	0	13	24
Prosser to Mabton	0	0	0	0
Mabton to Granger	10	35	55	124
Granger to Zillah	41	60	77	248
Zillah to Union Gap	0	41	62	77
Total redds counted	**51**	**136**	**207**	**473**
River flow (cfs) at Umtanum	1,070	963	918	856
Flight conditions	Partly cloudy/ light wind	Sunny/ light wind	Overcast/ light wind	Sunny/ light wind

Figure 2. Several salmon redds near river mile 85

Figure 3. Several salmon redds near river mile 84.5

Figure 4. Redds observed at river miles 26–35, lower Yakima River

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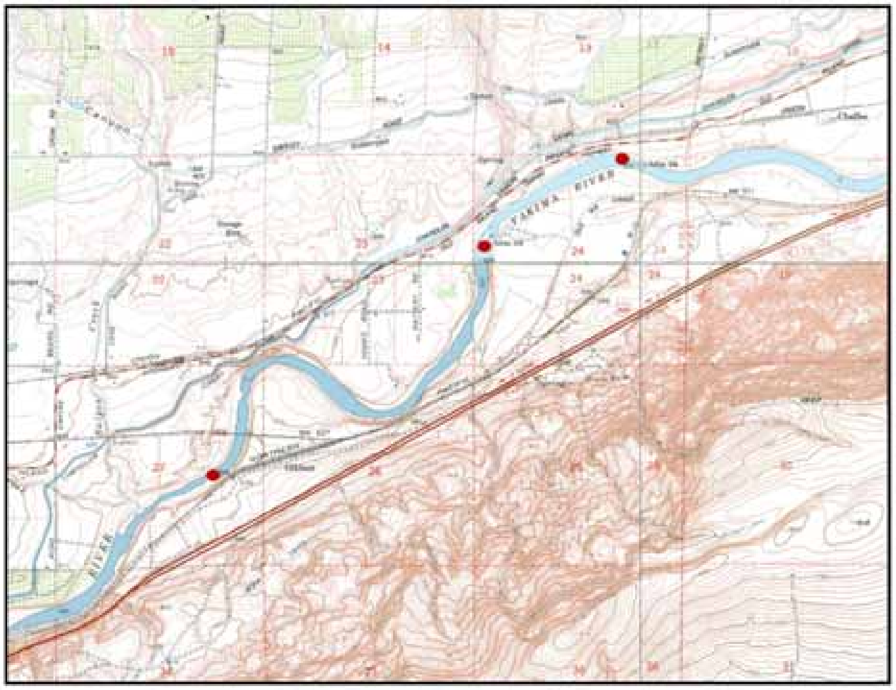

Figure 5. Redds observed at river miles 36–43, lower Yakima River

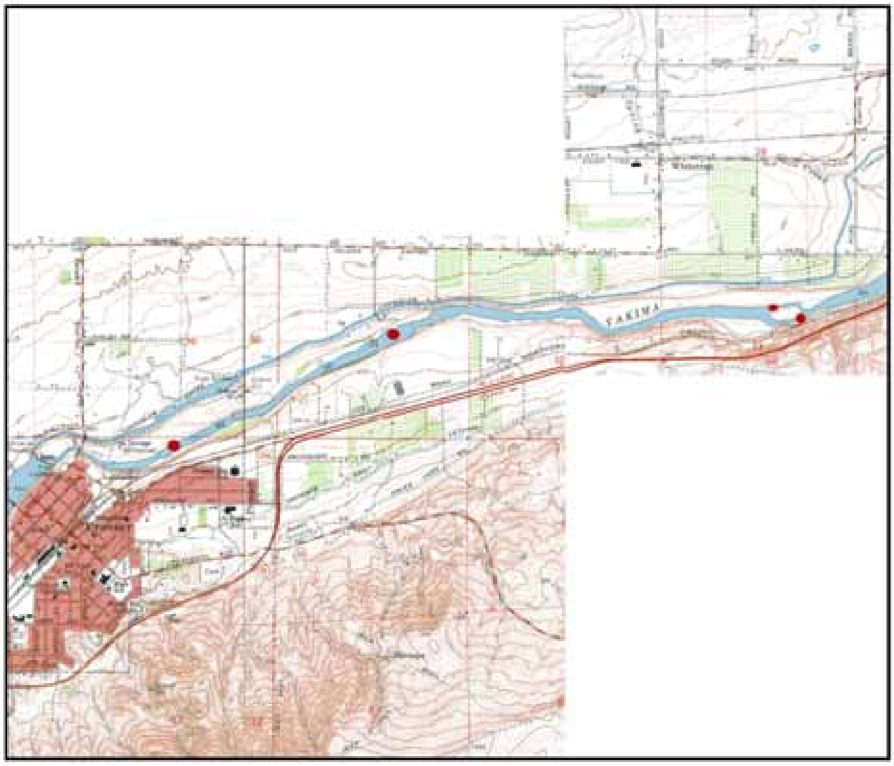

Figure 6. Redds observed at river miles 43–48, lower Yakima River

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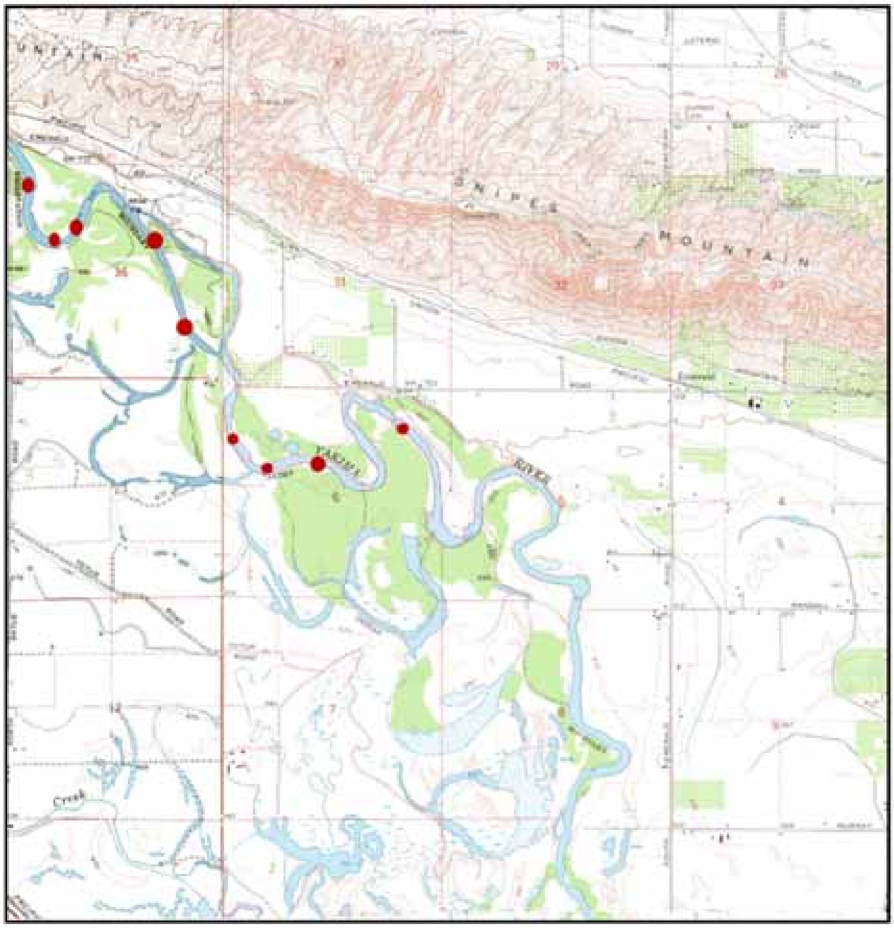

Figure 7. Redds observed at river miles 73–77, lower Yakima River

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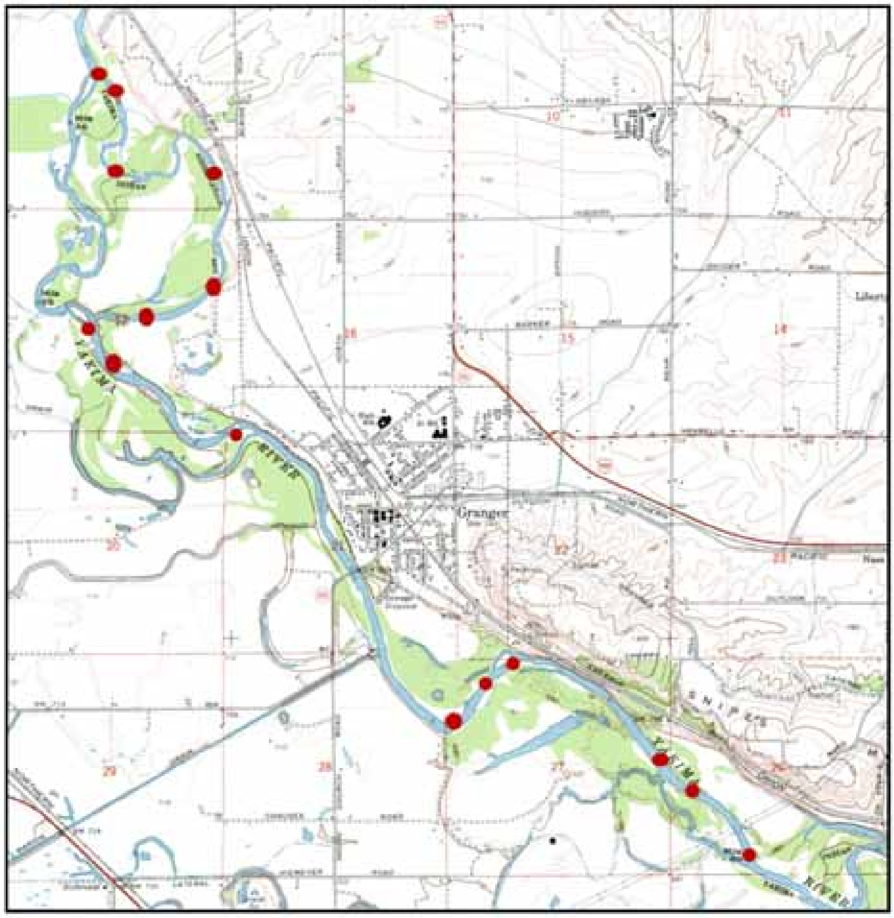

Figure 8. Redds observed at river miles 77–87, lower Yakima River

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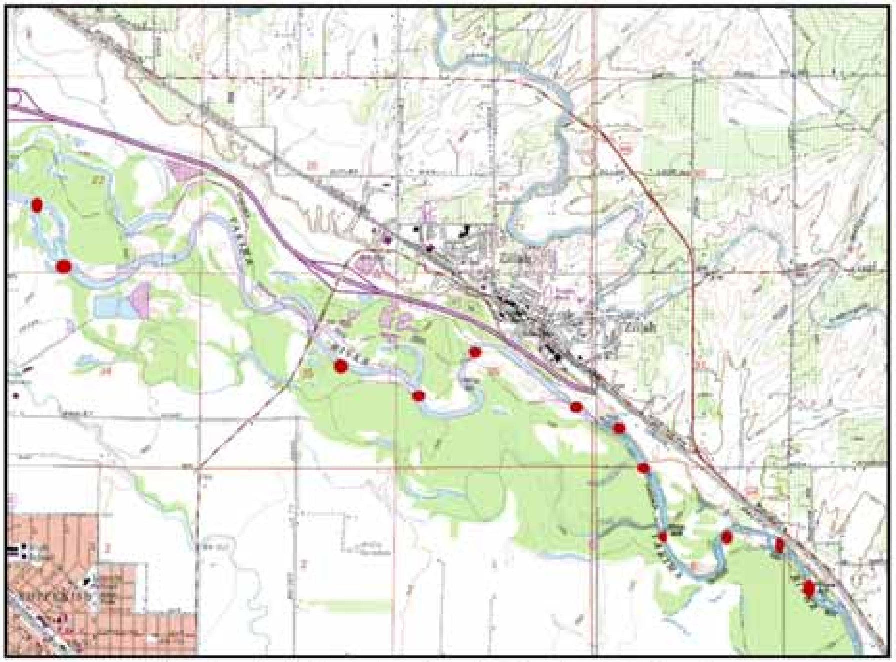

Figure 9. Redds observed at river miles 87–93, lower Yakima River

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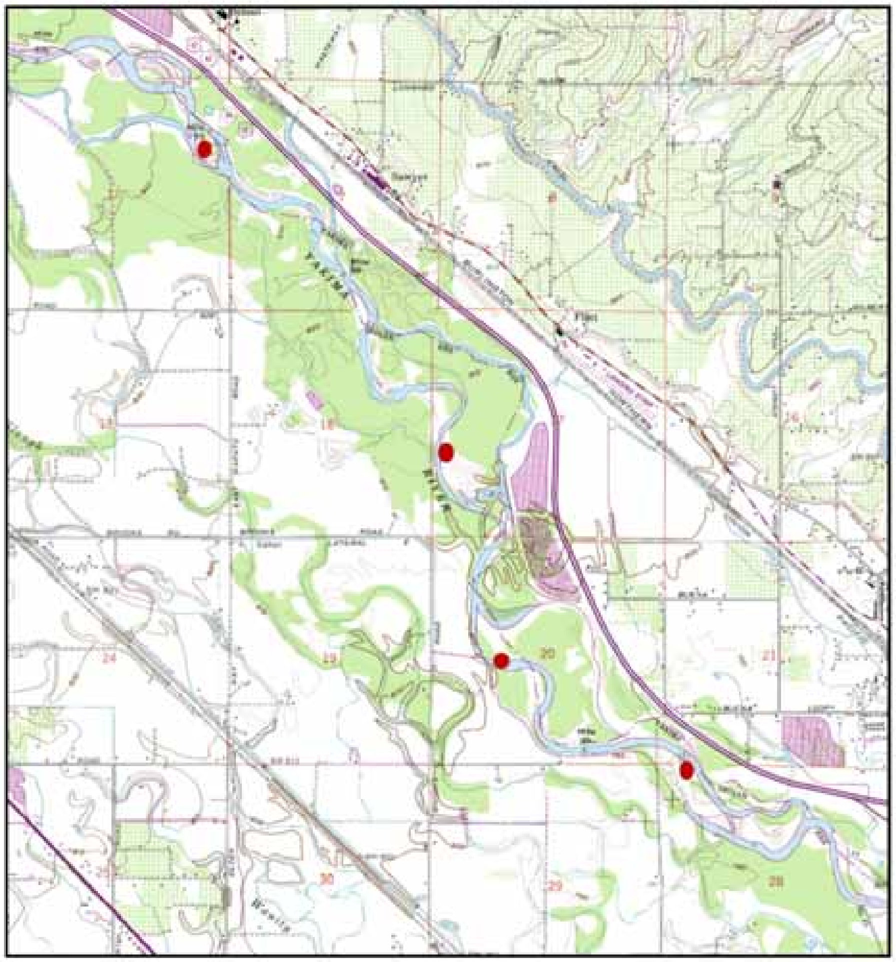

Figure 10. Redds observed at river miles 93–100, lower Yakima River

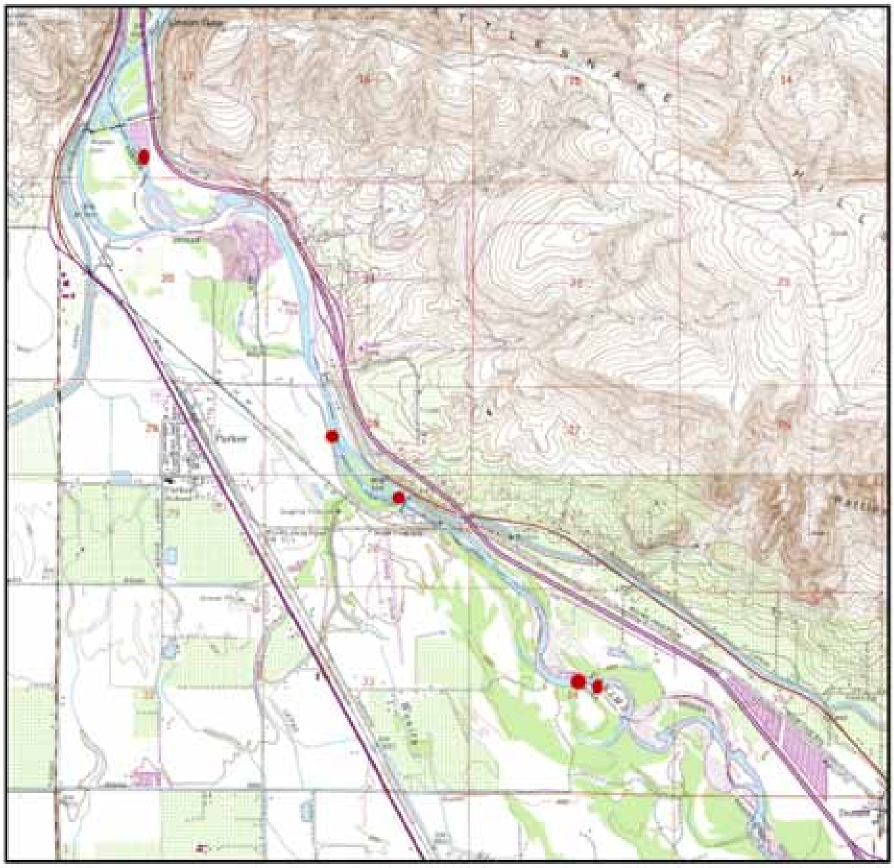

Figure 11. Redds observed at river miles 100–107, lower Yakima River

4.0 Discussion

Based on the results of the aerial surveys, most fall Chinook salmon spawning in the lower Yakima River is currently occurring upstream from Prosser; the majority of redds (248 of 449) were counted from Granger to Zillah. Redds were fairly easy to detect due to the flight and water clarity conditions during the initial two surveys. Redds in the riffle areas and redds located where trees cast shadows along the river were more difficult to detect. By the fourth survey flight on 14 November, the redds already were becoming slightly less obvious. The peak spawning period was estimated to occur between the two surveys conducted on 9 November and 14 November. River discharge measured at Umtanum was fairly uniform and averaged 951 cfs for the survey period.

Adult passage for fall Chinook salmon at Prosser Dam during 2009 was 2,398 adult fish (DART 2009). Based on the adult count at Prosser Dam, the ratio of adult fish to redd for the PNNL aerial count was approximately 5.3:1. This ratio is slightly lower than the average of 9.4:1 for fall Chinook salmon spawning in the Hanford Reach of the Columbia River (Dauble and Watson 1990).

PNNL had previously conducted a few flights on the lower reaches of the Yakima River in 2002 from the Highway 240 bridge to Wanawish Dam, and a total of 176 redds were observed (PNNL unpublished data). According to the WDFW, prior to 2001 about 70% of the Yakima River salmon spawned downstream of Prosser. In contrast, during 2004 to 2008 about 80% of the estimated escapement was upstream of Prosser. In 2002, the WDFW counted more than 1,000 redds in the lower Yakima; by 2008, that count had dropped to 42 (Hoffarth 2009). During 2009, the WDFW conducted raft surveys and counted 70 redds from 26 October through 29 November in the lower Yakima between the Chandler station and Prosser. This slight increase is likely due to the increase in adult escapement to the Yakima River, from 137 in 2008 to 269 adult fish in 2009 (Hoffarth, in press).

Over the last 15 years, irrigators within the lower Yakima River basin have switched from furrows, which sent tons of soil into the river, to sprinkler and drip irrigation, reducing the amount of sediment entering the river by about 80%. This change has resulted in increased water clarity, which is beneficial to adult salmon by creating more suitable substrates and may result in higher egg-to-fry survivorship by reducing the probability of redds becoming covered with fine sediments. Another dramatic change in the river over the last 10 years has been an increase in the macrophyte water star grass (*Heteranthera dubia*), a native species named for its small pale yellow flowers that has taken over the lower Yakima (Marcella Appel, water resource specialist, BCD, personal communication, 1 December 2009). A combination of nutrients and sunlight reaching the bottom of the river starting around 2000 and 2001 may have encouraged the growth of the water star grass, which is advancing at the rate of about 10 miles a year (Paul Hoffarth, WDFW, personal communication, 15 November 2009). The prevalence of this substrate-covering aquatic plant discourages salmon from spawning in these areas; fall Chinook salmon require clean substrates and steady, relatively fast current (~3 ft/s) in order to spawn successfully.

The results of this initial survey by PNNL in 2009 indicate that aerial surveys are an effective method for determining redd locations as well as estimating redd numbers in the Yakima River. A total of four flights seemed to be adequate to get a good representation of the spawning locations, enumerate the redds, and determine the approximate peak spawning date. With this information, the BCD now is in a better position to further characterize these locations to determine if they offer more suitable spawning conditions (i.e., water velocity, temperature, and substrates) compared to other river sections where spawning is not occurring.

Because the overall run size has a direct correlation to redd numbers, additional redd surveys are needed to get a better indication of spawning site fidelity. One minor drawback associated with the aerial surveys was the constant maneuvering required to fly along the river in the meandering braided channels that occur between Mabton and Union Gap. The use of a helicopter would be beneficial in future aerial surveys so that counts can be made without having to fly at a minimum airspeed.

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Appendix B: PNNL Aerial Flight Results - 2010 Fall Chinook Redd Locations

U.S. DEPARTMENT OF ENERGY

PNNL-20183

Prepared for DC Consulting LLC
under an Interagency Agreement with
the U.S. Department of Energy
Contract DE-AC05-76RL01830

Aerial Assessment of the Lower Yakima River for Fall Chinook Salmon Spawning Areas, 2010

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Exemption 4: Commercial/Proprietary

Department of Energy review required before public release.

Gary E. Spanner/Pacific Northwest National Laboratory
Reviewing Official (Name/Organization)

Date: February 7, 2011

Guidance Used (If Applicable): NA

RP Mueller
DB Child

February 2011

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Richland, Washington 99352

[1] DC Consulting LLC, Yakima, Washington.

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Abstract

The Benton Conservation District, Washington Department of Fish and Wildlife, and Confederated Tribes and Bands of the Yakima Nation, with a variety of other partners, are currently working on grants awarded through the Salmon Recovery Funding Board to identify high-priority actions for the lower Yakima River and the Wapato Reach of the Yakima River (from Mabton to Union Gap) that will directly benefit local salmonid species. The objectives of the grants are to perform assessments of the lower Yakima River and the Wapato Reach. The end goal is to identify potential future projects that would enhance, protect, or restore spawning and rearing habitat in the Yakima River and its side channels. To assist in the assessments of both the lower Yakima River and the Wapato Reach, DC Consulting LLC (a technical advisor for the assessments) contracted the Pacific Northwest National Laboratory (PNNL) to conduct aerial surveys of fall Chinook salmon spawning areas in the lower Yakima River in 2009 and 2010.

The specific objective of the PNNL assessment was to determine and enumerate, via aerial observation, the spawning areas throughout the spawning range of fall Chinook salmon in the lower Yakima River. This report documents the surveys conducted in 2010. This information will be incorporated into the planning processes for both the lower Yakima River and the Wapato Reach assessments to determine the general locations where salmon are spawning. Other physical data collected along the river will be used to further characterize these and other locations that provide suitable spawning habitats.

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1.0 Introduction

The Benton Conservation District (BCD), Washington Department of Fish and Wildlife (WDFW), and the Confederated Tribes and Bands of the Yakama Nation, with a variety of other partners, are currently working on grants awarded through the Salmon Recovery Funding Board to identify high-priority actions for the lower Yakima River and the Wapato Reach of the Yakima River (from Mabton to Union Gap) that will directly benefit local salmonid species. The objectives of the grants are to perform assessments of the lower Yakima River and the Wapato Reach; the end goal is to identify potential future projects that would enhance, protect, or restore spawning and rearing habitat in the Yakima River and its side channels. To assist in both the lower Yakima River assessment and the Wapato Reach assessment, DC Consulting LLC (a technical advisor for the assessments) contacted the Pacific Northwest National Laboratory (PNNL) to conduct aerial surveys of fall Chinook salmon spawning areas in the lower Yakima River in 2009 and 2010.

PNNL conducted four aerial flights in the lower Yakima River in 2009 and documented an estimated 473 fall Chinook salmon redds located from Richland to near Union Gap. In 2010, PNNL was able to conduct only two aerial flights in the lower Yakima River but documented an estimated 200 fall Chinook salmon redds. Prior to these surveys, only limited aerial surveys had been conducted for spawning locations in the lower sections of the river because of degraded water clarity. The most recent of those was done by PNNL in 2002, when 176 redds were counted between the Highway 240 bridge and Wanawish Dam. During the past several years, however, water quality and clarity have improved as a result of recent irrigation methods and drainage improvements. The Yakama Nation now conducts boat-based redd surveys in the Yakima River upstream of Prosser, and the WDFW conducts raft surveys in the lower river downstream of Prosser. Fall Chinook salmon escapement to the Yakima River has been determined using the redd counts, carcass surveys, and sport catch in the lower river (downstream of Prosser Dam) and the adult count at Prosser Dam, which is monitored by the Yakama Nation. Based on past surveys by the Yakima Nation, minimal fall Chinook salmon spawning is expected to occur on the Yakima River upstream of Union Gap, Washington (near river mile 107). The BCD is currently working in tandem with other entities to get a more accurate account of spawning within the lower river. The agency has also been active in a pilot program to remove water stargrass (*Heteranthera dubia*) within certain locations and determine if salmon are utilizing these regions for spawning.

The specific objective of the PNNL assessment was to determine and enumerate, via aerial observation, the spawning areas throughout the spawning range of fall Chinook salmon in the lower Yakima River. Both the lower Yakima River assessment and Wapato Reach assessment planning processes will use this information to determine the general locations where salmon are spawning; other physical data collected along the river will be used to further characterize these and other locations that are providing suitable spawning habitats.

2.0 Methods

Visual surveys were conducted from a fixed-wing aircraft (Cessna 182) flying about 700 ft above the water surface at air speeds ranging from 110 to 130 km/h. The flight plan for each survey included departure from the Richland Airport and flight along the Yakima River from the Highway 240 bridge in Richland to just downstream of Union Gap, Washington (Figure 1). The total flight time to complete each survey was generally around 2.5 hours. River discharge data for each flight date were obtained via a real-time database from a U.S. Geological Survey gauging station located at Kiona (river mile 30). The redds of fall Chinook salmon, which can attain an overall size of about 100 ft^2, were distinguished by light-colored patches, suggesting clean or disturbed substrates that indicate nest sites. As redds were observed, their numbers were tallied and the locations were marked on corresponding maps of the river during the flights.

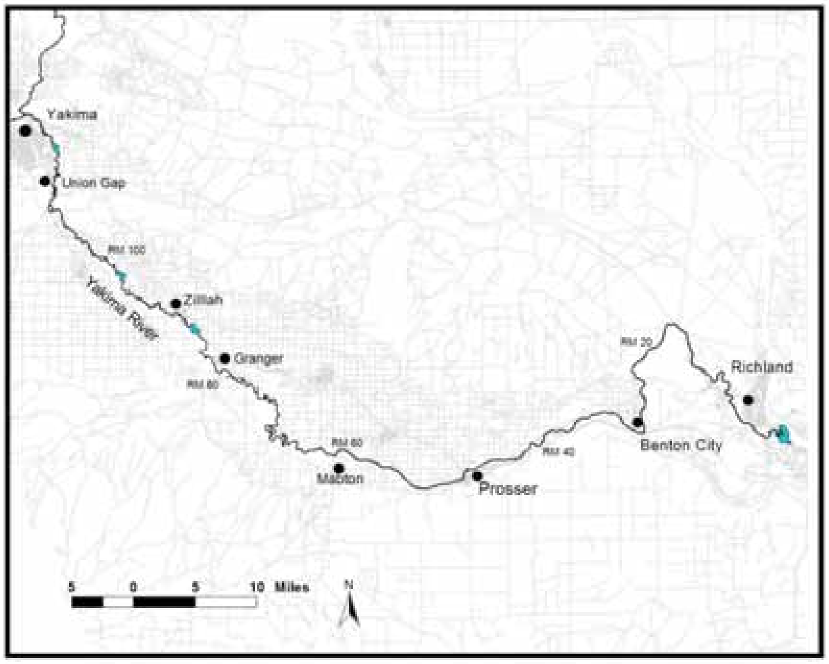

Figure 1. Lower Yakima River survey site, with cities and river miles indicated.

3.0 Results

Two survey flights were conducted—27 October and 10 November 2010. The river stretch of interest was subdivided into six segments for reporting purposes. Several additional attempts were made to conduct additional surveys, but either poor weather or turbid water conditions precluded these flights. Redds were observed during both flights, with 98 counted on the October flight and 200 on the November flight. The highest redd count for all river segments was the region between Granger and Zillah where 96 redds were counted. The majority of all redds (87%) were observed upstream of Mabton (Table 1).

Table 1. Fall Chinook salmon redd counts in the lower Yakima River, river flows, and flight conditions during aerial surveys conducted October and November 2010.

Redd Count	Survey Date	
River Segment	27 October	10 November
HWY 240 bridge to Wanawish Dam	0	7
Wanawish Dam to Prosser	3	18
Prosser to Mabton	0	0
Mabton to Granger	35	47
Granger to Zillah	46	96
Zillah to Union Gap	14	32
Total redds counted	**98**	**200**
River flow (cfs) at Kiona	2,600	2,800
Flight conditions	Sunny/ light wind	Partly cloudy/ light wind

River flow recorded at Kiona was 2,600 cfs for the first flight and 2,800 cfs for the second. Water clarity was good for both surveys with slightly turbid conditions.

Fall Chinook salmon redds were observed on both surveys. Redds were observed on the first flight conducted on 18 October and were detected easily from the plane. Figures 2 and 3 show redds occurring about 1 mile upstream of Granger near river mile 85. Figures 4 through 15 show the general areas in which redds were observed from the aircraft. Redd locations are indicated by the red circles within the survey region. Few redds were observed in the lower reach of the Yakima River from river mile 5 to river mile 30 near Benton City, although seven were observed downstream of Van Giesen Road at river mile 7.8 in West Richland, for the first time.

Figure 2. Several salmon redds near river mile 85.5, upstream of Granger.

Figure 3. Several salmon redds located downstream of Granger at river mile 61.8.

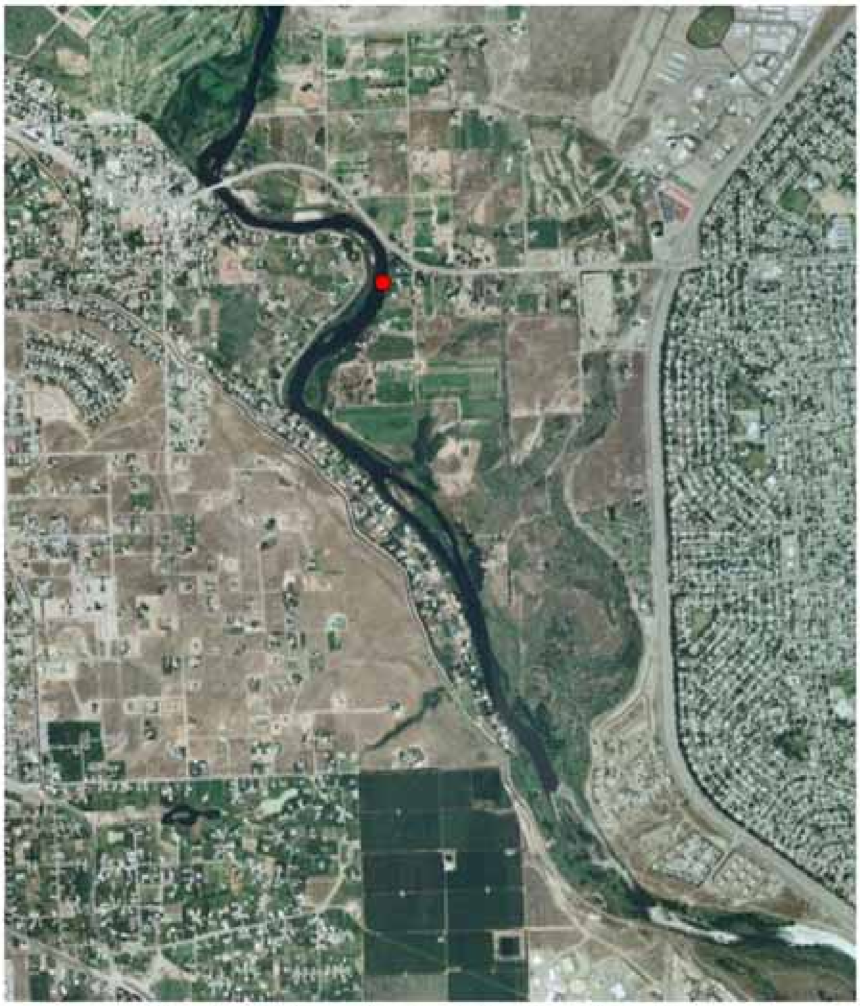

Figure 4. Redds observed at river miles 5–9, lower Yakima River.

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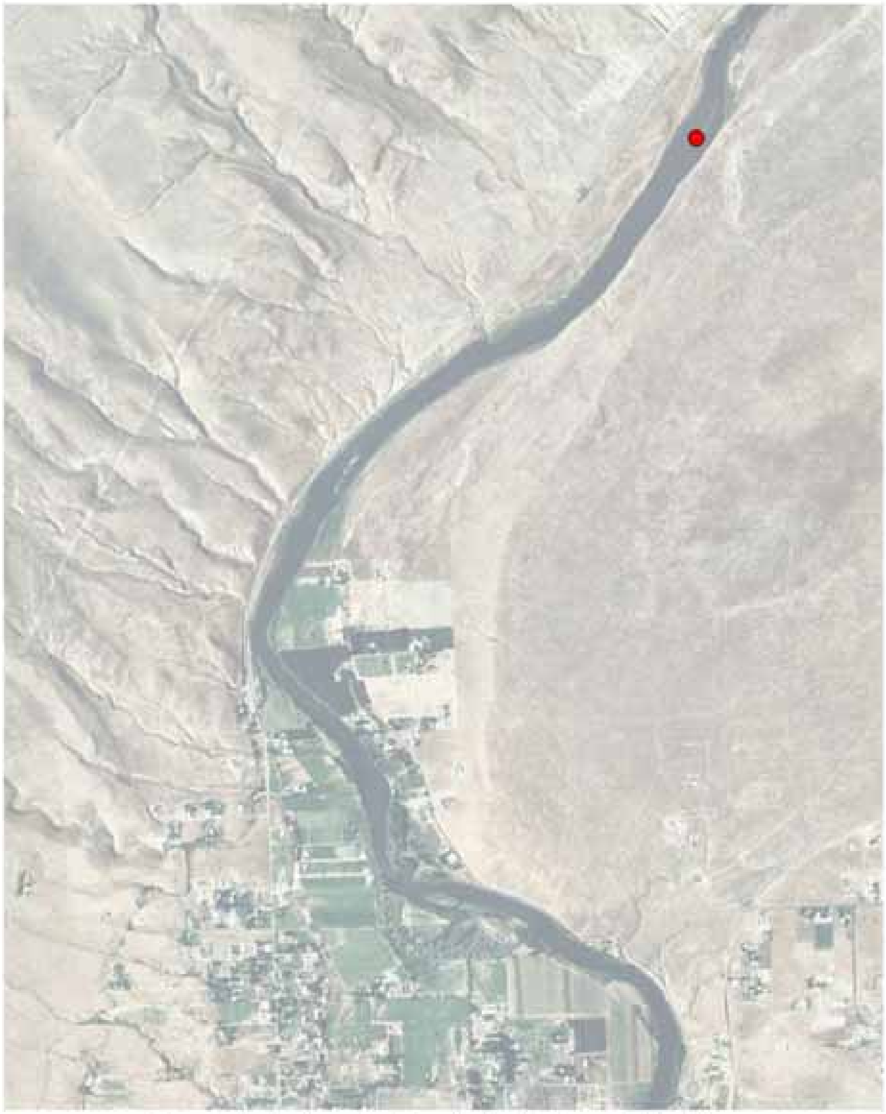

Figure 5. Redds observed at river miles 21.5–26, lower Yakima River.

Figure 6. Redds observed at river miles 29–33.5, lower Yakima River.

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Figure 7. Redds observed at river miles 73–78, lower Yakima River.

Figure 8. Redds observed at river miles 78–83, lower Yakima River.

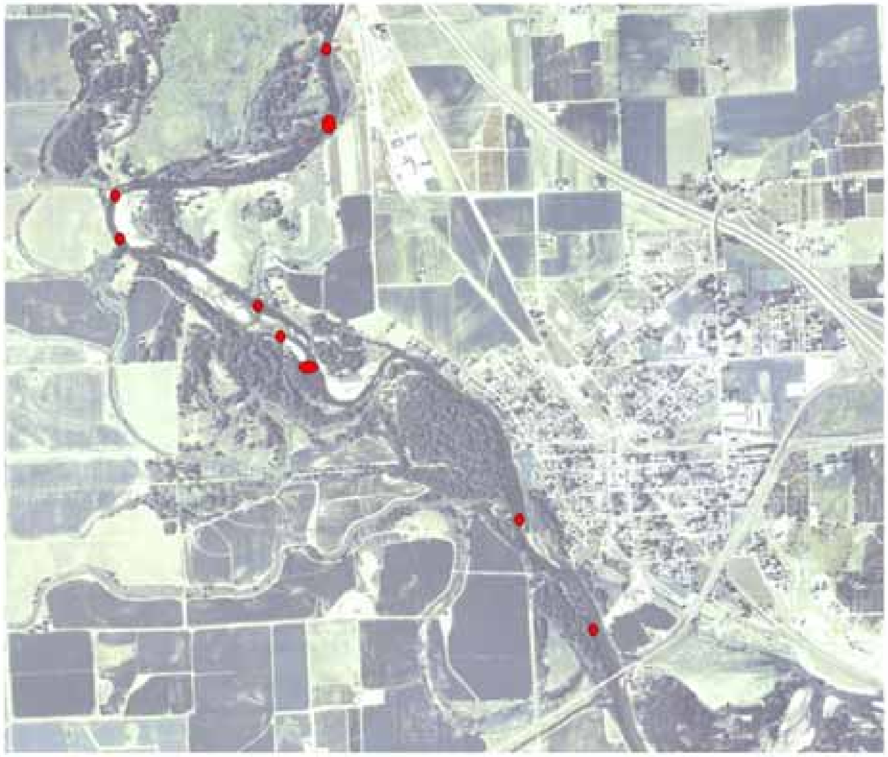

Figure 9. Redds observed at river miles 83–86, lower Yakima River.

Figure 10. Redds observed at river miles 86–88, lower Yakima River.

Figure 11. Redds observed at river miles 88–91, lower Yakima River.

Figure 12. Redds observed at river miles 91–94, lower Yakima River.

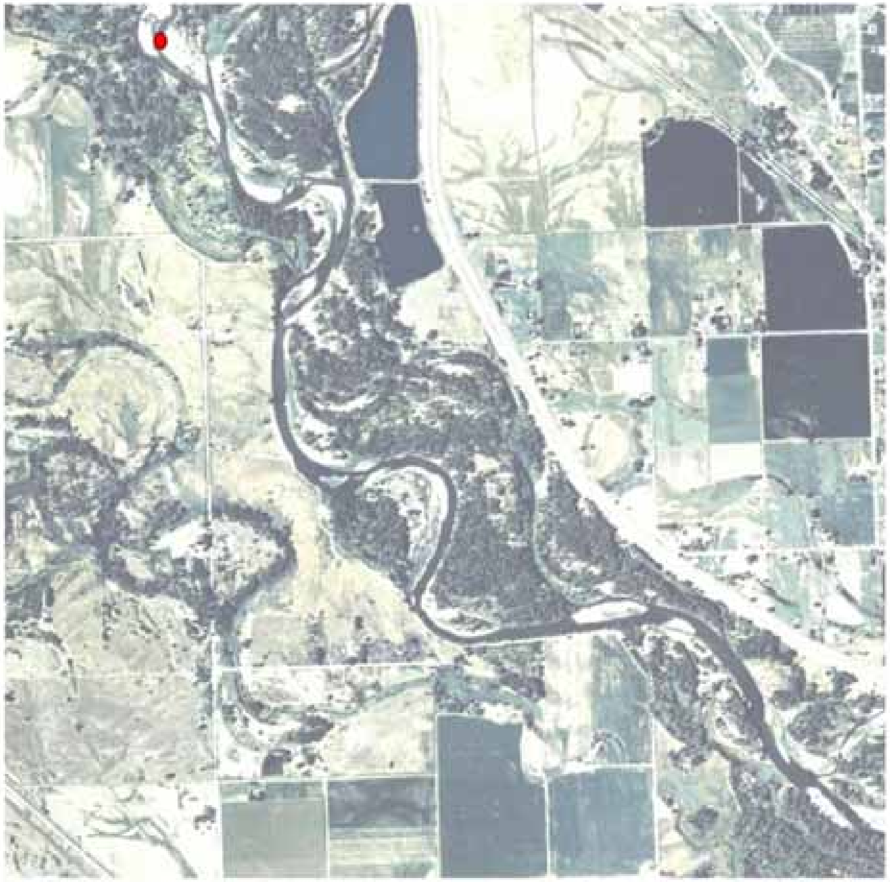

Figure 13. Redds observed at river miles 94–97, lower Yakima River.

Figure 14. Redds observed at river miles 97–100, lower Yakima River.

Figure 15. Redds observed at river miles 100–104, lower Yakima River.

4.0 Discussion

As observed in 2009, most of the fall Chinook salmon spawning in the lower Yakima River is occurring upstream from Prosser; the majority of redds (175 of 200) were counted from Mabton to Union Gap. Flight conditions during the two surveys were very good with slight water turbidity, which enabled good observation conditions. The peak spawning period was estimated to occur near the second survey on 10 November. In 2009, the peak was estimated to occur near 9 November. River discharge measured at Kiona was very similar for both surveys averaging 2,700 cfs.

Adult passage for fall Chinook salmon at Prosser Dam during 2010 was 2,763 adult fish (DART 2010). This was a slight increase from the 2009 count of 2,398. In 2009, PNNL counted 449 redds in the lower Yakima River during the four survey flights conducted. If weather or river conditions would not have precluded additional flights, we predict that a higher redd count would have been made in 2010.

Since 2007, the BCD and volunteers have been conducting a water stargrass removal project aimed at clearing sections of the pervasive macroinvertebrate from the river bottom. Water stargrass is a native perennial plant that forms a dense 2-inch-thick mat of roots. These thick mats cover potential spawning gravels and force fall Chinook salmon to search for more suitable spawning regions farther upstream. Through the summer of 2010, BCD staff and volunteers cleared 1.5 acres of the riverbed at several sites. These included locations downstream of the Benton City bridge, a small island near river mile 28, and near Songbird Island at river mile 26.5. Raft surveys by WDFW indicated three redds upstream of a small inlet downstream of a railroad bridge at the island site at river mile 28; we did not document any redds from the aerial surveys at this location. Water turbidity or redd size may have influenced the ability to detect these redds. We did observe one redd upstream of a small island at river mile 22 and seven additional redds downstream of the Van Giesen bridge at river mile 7.8. No redds were found in the region between Benton City and the Highway 240 bridge during intensive surveys by PNNL in 2009 (Mueller 2010).

During 2010, the WDFW conducted raft surveys and counted a total of 53 redds from 25 October through 5 December in the lower Yakima River between the Chandler Powerhouse and Prosser and an additional 4 redds from Duportail Road to the Chandler Power Station. This count was a slight decrease from the 2009 count of 70 totals redds (Hoffarth in press).

As determined in 2009 and again in 2010, aerial surveys can be an effective method for determining redd locations as well as estimating redd numbers in the Yakima River, provided that weather and river conditions are adequate. Based on the results from identical surveys in 2009 flights, a total of four flights seem to be adequate to get a good representation of the spawning locations and overall redd counts.

5.0 References

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Appendix C: General Land Office Survey Notes (1860's) For Lower Yakima River

The following notes are found within the "General Description" section of the 1860 surveys of Benton County. These notes highlight that the most profitable and desirable land surrounded that of the Yakima River. These historical accounts from early surveys can be found

9N 29E (Confluence of Yakima and Columbia Rivers)

General notes of 1864 survey, p. 212: "Along the banks of the Yakima and Columbia rivers, also on Backworth's Island (Bateman Island) there is a heavy growth of grass valuable for hay… At the mouth of the Yakima there is a dense growth of small willows."

T10N27E (Barker Ranch through Horn Rapids)

"The township contains a large amount of rich bottomlands situated on both sides of Yakama River, which is navigable for steamboats of light draught through the township from its junction with Columbia river…"

Surveyors' notes describe Fruit and Grub Islands: " . . . the soil on this Island is 1st rate, it is well timbered with Cottonwood, Alder and Ash - undergrowth - same, with Cherry, Crabapple and Willow (October 6th, 1863).

T9N27E (Yakima River North and East of Benton City)

Noted in survey of W boundary: "land in bottom sandy and second rate- covered with tall wild rye with scattering cottonwood & willows on the river bank…"

"The banks of the Yakama River are generally lined with young cottonwood trees and willows of enormous size." 1863 survey

Section 6, 1863: "This island has high banks with scattering cottonwood and willows thereon- no timber elsewhere- land high and dry- soil first rate."

T9NR26E (upstream of Benton City)

General Description: ". . . Its whole is well watered by the river and occasional springs and brooks are very desirable for pasture. On both banks of the river in every section are beautiful groves of Balm(?) Aspen Alder and Willow and fine particles of Gold not in paying quantities can be found upon every bar." October 26th, 1870

T9N25E (below Prosser)

“Yakima river bears swiftly through the township…”

"This township contains some good pasture land, is alone watered by the Yakima river, and is destitute of timber, except some small willows, cottonwood, and quaking aspen, that grow at intervals on the river bank." Nov. 3rd 1867.

General Observations

In their general notes of the 1863 survey of Township 9N Range 27E (including the Yakima River north of Benton City), General Land Office surveyors note the general absence of timber in the township, but then state:

“Yearly, the Yakama River disgorges from its mountain sources [an] abundance of driftwood, composed of the finest quality of timber, whole trees from 20 to 70 in diam. And from 100 to 250 feet in length of fir and cedar lumber are often seen winding their way down its current, into the broad waters of the Columbia.”

Appendix D: Yakima River Riparian Restoration Projects in Benton County

BCD Riparian Planting Projects

Ballman Properties

In 2006 the Benton Conservation District implemented a bank stabilization project on the South bank of the Yakima River at river mile 13.44 for Lynn Ballman. The site was stabilized with erosion control blanket; small diameter logs were placed in shallow trenches along the slope to provide additional stability. The site was then planted to native trees and shrubs.

Ballman Property Riparian Restoration with LWD

Martinez and Klingle Properties

In the spring of 2009 the Benton Conservation District planted 400 linear feet of eroding shoreline with native trees and shrubs on the Martinez and Klingle properties in Prosser WA. The site had been previously used for sheep grazing and was badly degraded.

Martinez and Klingle Bank Restoration.

Corral Creek Wasteway

The Corral Creel Wasteway Project allowed for 40 feet along both sides of Corral Creek Wasteway to be planted to native trees, shrubs and perennials. This work was completed in conjunction with the landowner and the Benton Irrigation District to restore native vegetation to the confluence of the wasteway.

Corral Creek Wasteway bank enhancement project

Twin Bridges

Twin Bridges Island, located in the Yakima River, West Richland is frequently flooded and the island has been subject to sever erosion on its south bank. To help mitigate erosion, planting was conducted in the spring of 2010 and allowed for the enhancement of 1,200 linear feet of riparian habitat.

Map of Twin Bridges Island highlighting bank planting project

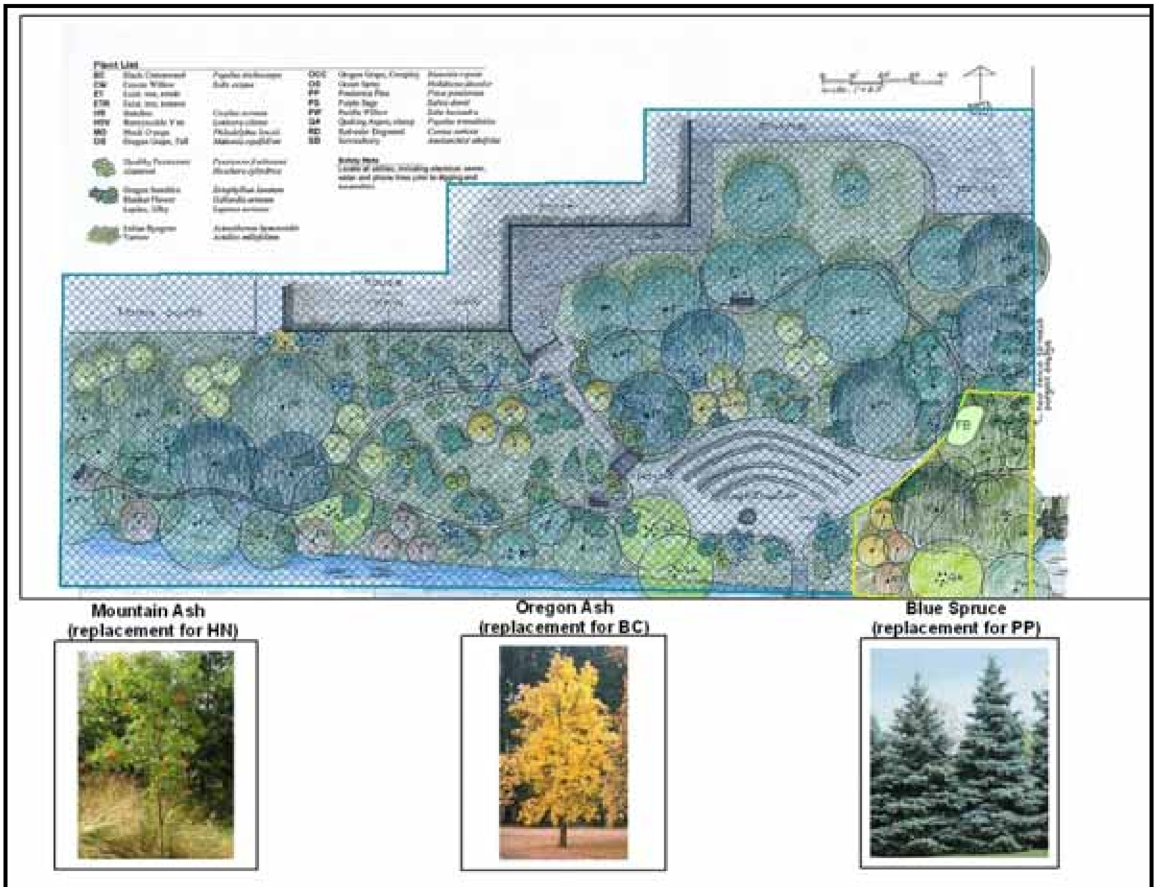
Caldwell Site

Phyllis Caldwell's property outside of Prosser, WA borders the Yakima River. After consulting with the Benton Conservation District a riparian planting plan was developed for the entire width of her property to restore 134 feet of riparian property. This area was planted to native shrubs and perennials.

Caldwell Riparian Restoration

The 4 Seasons River Inn

The 4 Season River Inn, owned by Nancy Bender, is located outside of Prosser, WA. The demonstration site highlighted in yellow was planted in November 2010. The 4 Seasons River Inn borders the Yakima River and is comprised of rolling green lawn from the Inn to the shoreline. The demonstration area is approximately 40 feet by 60 feet and was established with native trees, shrubs and perennials.



Planting design for 4 Seasons River Inn (top). Picture of demonstration area (bottom).

Crawford Site

Vickie Crawford's property located outside of Benton City, WA had 240 feet of severely eroding shoreline and horses that had direct access to the Yakima River. The Benton CD applied for a Hydraulic Project Approval and County Variance to grade the bank back so that it could be properly stabilized and planted. The landowner fenced the horses off of the river, grading was completed in early November 2010 and the plantings were completed by volunteers and District Staff on November 20th 2010.

Riparian stabilization at Crawford Property. Prior to restoration (top), after restoration (bottom).

Barker Ranch

Barker Ranch, a conservation area located in West Richland, maintains X head of cattle to help graze the dry grassland areas. Barker Ranch installed 7,900 linear feet of fencing in conjunction with BCD to exclude cattle from the Yakima River.

Fencing project at Barker Ranch to keep cattle out of Yakima River