Wyoming Game and Fish Department
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2019 Annual Monitoring Report for the North Platte River Restoration Project

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ABSTRACT

In 2019, the Wyoming Game and Fish Department (WGFD) continued annual monitoring efforts to evaluate the impacts of restoration projects on the North Platte River through Casper. The restoration projects are being completed in phases across seven project sites. In 2016, restoration was completed at sites 2 and 3, the Wyoming Boulevard and Water Treatment reaches. Monitoring of the two sites, collectively termed the "Wyoming Blvd reach", began in 2017, following protocol outlined in the monitoring plan (WGFD 2017). The monitoring plan identified three geomorphic goals to assess: 1) narrow the over-widened river, 2) improve fisheries habitat, and 3) stabilize stream banks. The results and interpretation of monitoring from 2017 to 2019 are reported and discussed in this document.

Monitoring data indicate that reconstruction of the river channel and banks achieved the primary goals for the Wyoming Blvd reach. In-stream structures are largely intact and functioning as intended to maintain the improved stream channel characteristics and provide habitat diversity for fish. Some rock vanes may be experiencing undesirable erosion or deposition and these structures should be monitored in the future to determine whether they impact each structure's function. A narrower and deeper river channel is maintained through the project reach and entrenchment ratio, bank-height ratio, and width-to-depth ratio largely remain within the desired ranges. Bankfull flows are able to access more floodplain area, there is no evidence of lateral channel migration, and risk of bank erosion has been reduced throughout the reach. Riparian and wetland vegetation have established well along many of the new stream banks and wetlands, although it is much sparser in the lower part of the Wyoming Blvd reach.

Fish habitat has been improved with three deep pools and one more shallow pool that are maintained throughout the Wyoming Blvd reach, in addition to a fourth very deep pool that was not modified by the restoration work. The Morad Park fish sampling reach was expanded in 2018 and 2019 to include the upper half of the Wyoming Blvd reach. In both years, fish sampling data indicated no significant difference in either abundance or biomass of trout between the upstream control reach and the Morad Park restored reach.

To complete the monitoring of the Morad Park and Wyoming Blvd reaches, in 2021 the WGFD will collect the full suite of monitoring data outlined in the monitoring plan. Recommendations are provided for adjustments in future monitoring and include adding additional rating categories to the structural integrity and erosion/deposition rapid assessment protocol, removing the bankfull line mapping component, maintaining consistency in BEHI ratings by comparing stream banks in the future with photos from 2019, and conducting future BEHI ratings according the Wyoming Stream Quantification Tool.

INTRODUCTION

The North Platte River is a valuable resource to the City of Casper and great efforts have been made in recent years to enhance the aesthetics and increase angling opportunities in the river through town. In addition to a large volunteer effort, a coalition of multiple private organizations and governmental agencies has acquired funding to hire engineering and construction firms to conduct restoration within the river corridor and improve the function of the river. An assessment of 13.5 miles of the North Platte River through the Town of Mills and City of Casper revealed areas of mass wasting and divided channels where areas of high shear stress contributed to accelerated bank erosion (Stantec 2012). Amount and quality of fish habitat was also low because long sections of the river lacked riffle-pool complexes. The North Platte River Master Plan (Stantec 2012) provides an overview of these pre-project conditions in the river and goals for each phase of the project. There are three focal areas for restoration efforts within this plan: improvement and stability of stream channel characteristics, enhancement of fisheries, and restoration of native riparian vegetation.

Seven individual restoration sites in the 13.5-mile river corridor were identified for restoration efforts (Stantec 2012). To verify that restoration efforts meet the intended goals of the project and evaluate the need for future maintenance efforts, a comprehensive monitoring plan was developed (WGFD 2017). The plan calls for annual monitoring for five years at each site, beginning one year after site restoration is completed. Monitoring will document whether intended benefits were achieved and assess stream channel and structure condition and function. Restoration was completed at site 1 (Morad Park reach) in 2015 and restoration was completed at sites 2 and 3 (Wyoming Boulevard and Water Treatment reaches) in 2016. The Wyoming Game and Fish Department (WGFD) began monitoring the Morad Park restored reach in 2016. Monitoring reports are available from both 2016 and 2018 for the Morad Park reach (Robertson 2016, Harter 2018).

This report provides results of annual monitoring completed from 2017-2019 for site 2 (Wyoming Boulevard) and site 3 (Water Treatment) (Stantec 2012). Sites 2 and 3 were combined into one continuous project with a final design length of 4,671 ft (Stantec 2015). The two reaches are immediately adjacent to each other, the design plans encompass both reaches, and they have previously been referred to in monitoring documents as one site. Accordingly, in this monitoring report, they will also be referred to as one project reach: the Wyoming Blvd reach (Figure 1).

Prior to restoration, the river through the Wyoming Blvd reach was moderately to deeply incised, with a high width-to-depth ratio typical of a channel that has difficulty moving sediment (WGFD 2017). In the upper 500 ft of the reach the channel bed was wide and shallow with no distinct pools. Immediately adjacent to Wyoming Boulevard there were several pools over 12 ft deep but their location next to the roadway was a concern. The downstream (lower) 1,600 ft was overly wide and shallow, with multiple split flow paths, and localized contraction scour pools (Figure 2). The split flow paths were associate with excessive shear stress and bank erosion along both left and right banks.

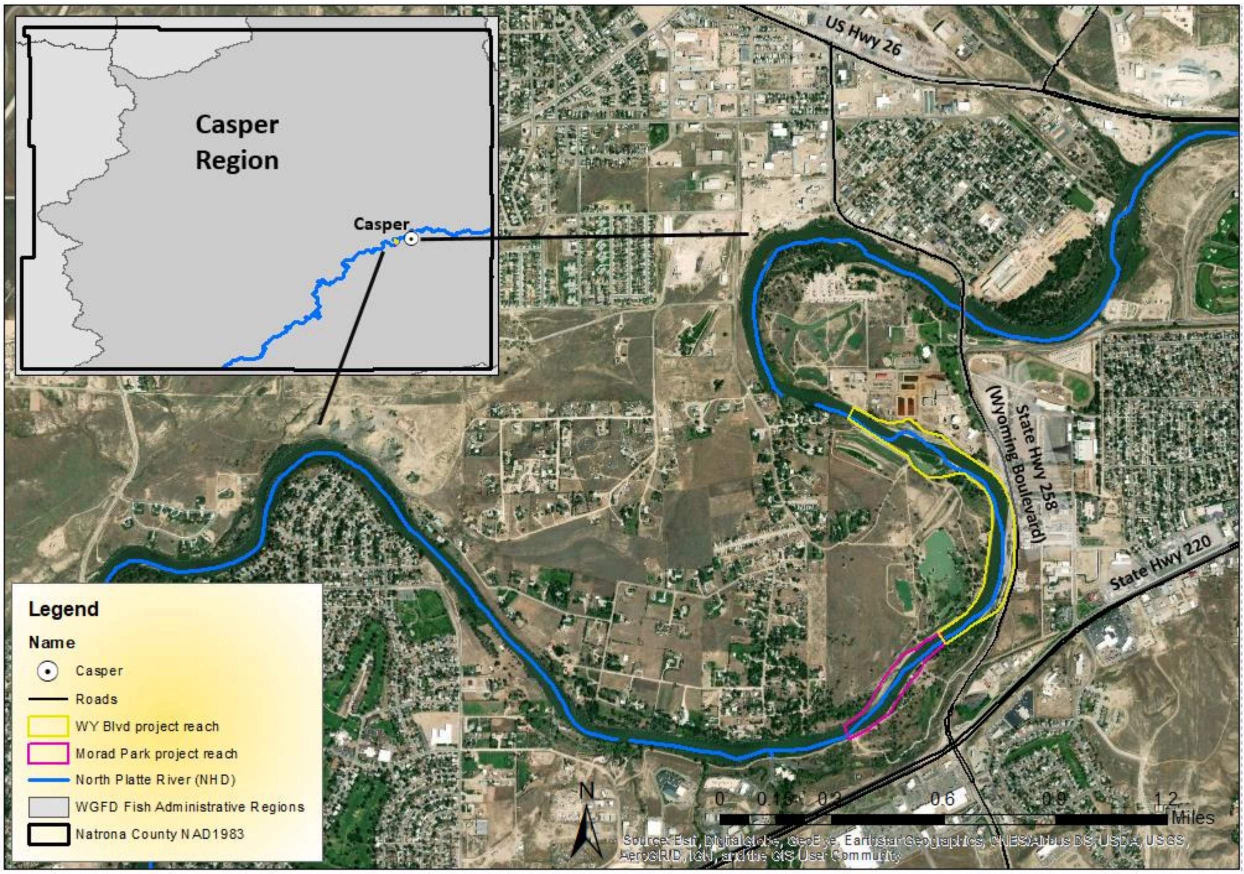

FIGURE 1. Locations of the Morad Park and Wyoming Blvd reaches.

The conceptual goals of restoration in the Wyoming Blvd reach were to

1. Align the channel away from Wyoming Blvd
2. Provide fish habitat
3. Stabilize the relocated channel with structures
4. Narrow and create a single channel in the braided lower section of the reach

To achieve these conceptual goals, the project involved relocation of the stream channel approximately 135 ft from Wyoming Boulevard, creation of a floodplain on the right bank, removal of riprap/concrete from the right bank, removal of mid-channel bars and existing islands, removal of floodplain berms to improve floodplain continuity, installation of in-stream and bank protection structures, creation of riparian wetlands, planting native vegetation, and placement of boulder clusters. Some aspects of the restored sites are monitored to help recognize trends over time (i.e., photo points, in-stream structure ratings, fish populations) while other components have specific target values (i.e., bank erosion risk, geomorphic metrics). Specifically, the monitoring plan outlines three geomorphic goals that are assessed with metrics derived from survey data:

1. Narrow the over-widened river
2. Improve fisheries habitat
3. Stabilize the stream banks

This report provides the results of monitoring and uses the geomorphic goals and associated metrics outlined in the monitoring plan to evaluate the status of conceptual restoration goals for the Wyoming Blvd reach as of 2019, three years post-construction.

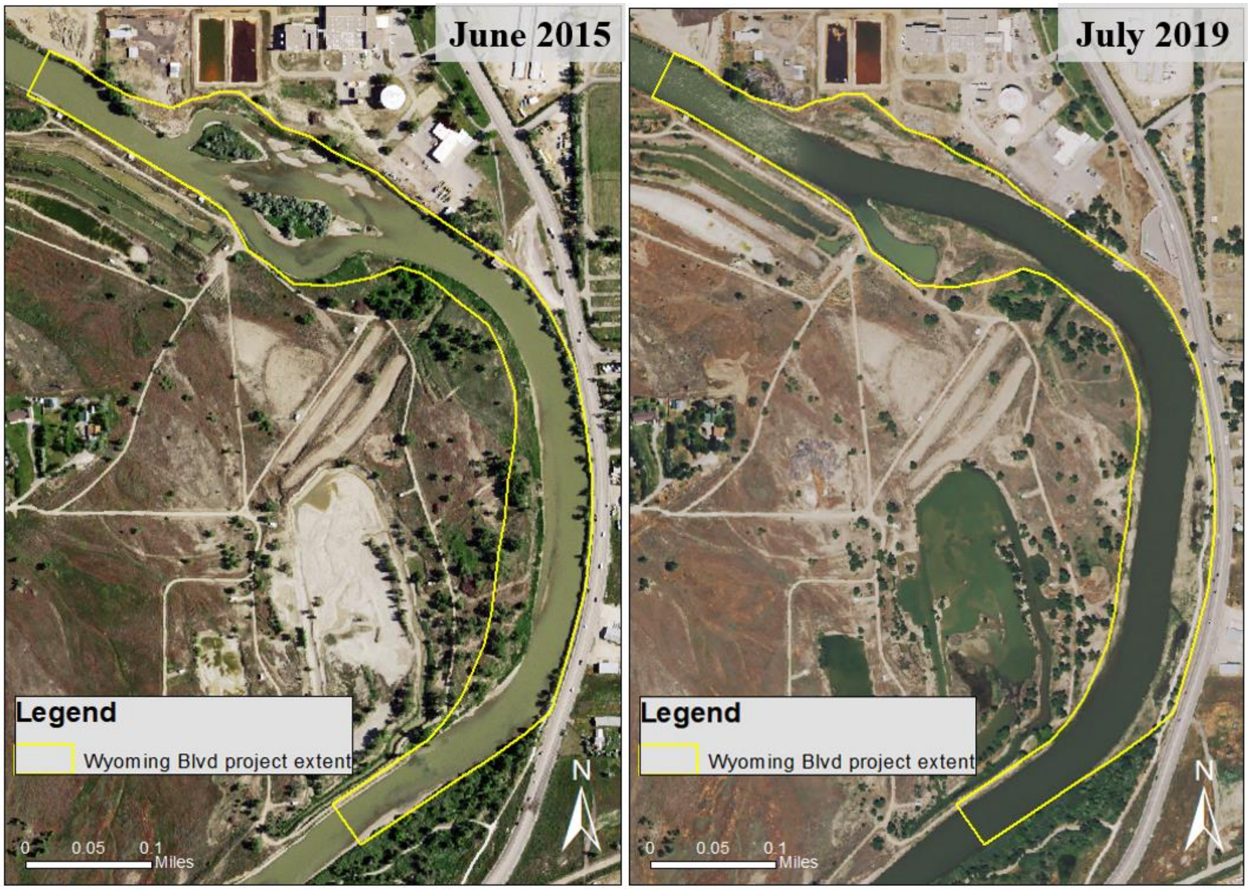

FIGURE 2. National Agricultural Imagery Program (NAIP) images of the Wyoming Blvd project reach before restoration on June 20, 2015 (left) and after restoration on July 19, 2019 (right).

METHODS

The WGFD began collecting monitoring data in 2017, following protocol outlined in the monitoring plan (Table 1; WGFD 2017). Monitoring components include visual assessment in the form of photos and in-stream structure assessments, surveys of riffle and pool cross-sections, surveying the thalweg to create a longitudinal profile of the river, measuring Bank Erosion Hazard Index (BEHI) to estimate risk of bank erosion, and electrofishing to estimate trout abundance and biomass. In 2017, photo points were retaken, but no other monitoring data was collected due to staff turnover. In 2018, photo points were also retaken and instream structures were evaluated, but other data collection was postponed because monitoring in 2018 was focused on the Morad Park reach (WGFD 2018b). In 2019, all monitoring data scheduled in the monitoring plan for that year were collected and analyzed for the Wyoming Blvd reach (Table 1).

TABLE 1. Five-year monitoring plan for the Wyoming Blvd restored reach. An “X” marks planned data collection. Dates indicate when the data for that component were collected.

	Data Collection	As-built	2017	2018	2019	2020	2021
Visual Assessment	Photo stations (summer)		8/3/2017	7/17/2018	8/1/2019	X	X
	Photo stations (fall)	10/04/2016 – 11/15/2016	11/21/2017	11/15/2018	10/22/2019	X	X
	Rapid assessment for in-stream structures		X	11/16/2018	10/21/2019	X	X
Geomorphology	Cross-sections (riffle)	X	X	X	10/21/2019	X	X
	Cross-sections (pool)	X	X	X	10/21/2019		X
	Longitudinal profile		X	11/16/2018	10/8/2019		X
	BEHI & NBS		X	X	10/21/2019		X
	Map Bankfull Line		X	X	10/21/2019	X	X
Fisheries	Single pass electrofishing		X (NC)	10/23/2018 - 10/25/2018	10/1/2019 – 10/3/2019		X

Visual Assessment

The general condition of the channel, structures, and riparian vegetation were assessed visually each year of monitoring to identify obvious problem areas. Visual assessment included both photos and a rapid assessment of the integrity of each structure installed during construction.

Photo point stations were used to document change over time. Stations were spaced closely enough to have overlapping features in successive photographs. Each station location was marked by recording coordinates (Appendix A.1.1) and with an iron bar (with a yellow WGFD-stamped cap) pounded in so that 1-2” were left above the ground surface. Once in summer (July-August) and again in fall (October-December), photos were taken at each location looking upstream, downstream, and across the channel. In fall 2016, Stantec took photos at 14 locations to document construction and as-built conditions (Figure 1). In April 2017, these photo points were revisited by WGFD. The locations used by WGFD for ongoing photo monitoring, beginning in 2017, were located very near most of Stantec’s photo points. One of Stantec’s photo points (S-1 in Figure 3) was retained as a photo point for the Morad Park reach (Morad_05 in Figure 3). Additionally, after construction, WGFD moved the locations of two photo points (WY-2 and WY-9) downstream of where Stantec’s photos were taken. Figure 3 shows the locations of Stantec’s photo points in 2016 and the photo points subsequently monitored by WGFD.

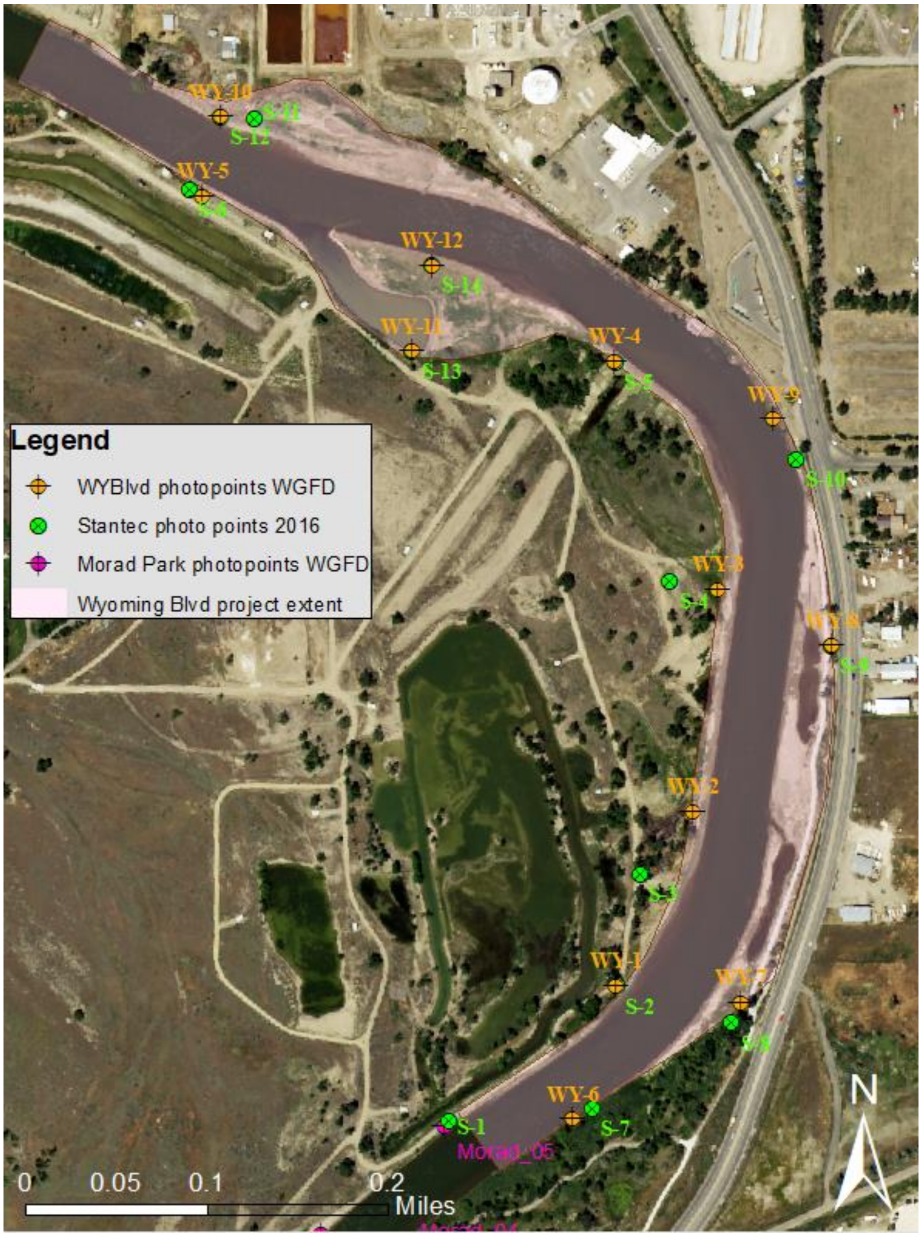

FIGURE 3. Photo monitoring locations for as-built (Stantec 2016) and photos in 2016 and WGFD monitoring photos (2017-2019).

The rapid assessment procedure (Table A.2.1; Miller and Craig Kochel 2013), was used to evaluate the condition of installed structures. Rock and toe wood structures were visually assessed for structural integrity and ranked on a score of 1-4 (1='Intact', 2= "Damaged', 3='Impaired', and 4='Failed'). The extent of unintended erosion or deposition associated with each structure was ranked on a scale of 0-5, with 0 indicating no visible erosion or deposition. For rock vanes, a rating of 0 represents no visible erosion/deposition and a rating of 5 represents either erosion that results in the structure no longer functioning as intended or deposition that buries 90-100% of the structure (Table A.2.1). For toe wood features, an erosion rating of 0 also represents no visible erosion while a rating of 5 indicates that erosion has exposed most of the buried stump (Table A.2.1). Photos were taken of each structure that was visible, although some portions of underwater structures were difficult to see in photos. The structures at the WY Blvd reach included 5 separate toe wood features, 5 rock vanes, 2 rock riffle vanes, 2 sets of wetland outlet cross vanes (a total of 7 cross vanes), and 63 boulders. All these structures were evaluated in both 2018 and 2019, with the exception of the boulders which were only evaluated in 2018.

Geomorphology

The three goals for modifying the geomorphology of the river were to 1) narrow the over-widened river, 2) improve fisheries habitat, and 3) stabilize the stream banks. In 2019, data were collected to evaluate these goals for the WY Blvd project reach.

To evaluate the first geomorphic goal of narrowing the over-widened river specific metrics were calculated including entrenchment ratio, channel incision (bank-height ratio), width-to-depth ratio, and cross-sectional area (Rosgen 1996). Each of these metrics was derived from cross-sections surveyed at riffles. Prior to 2019, no cross-sections had been established in the Wyoming Blvd reach. Thus, in 2019, WGFD biologists used a Trimble S5 robotic total station and Seafloor Hydrolite-TM echosounder to survey ground elevations in the river channel and collect bathymetry data over the approximately 4,760-ft long WY Blvd project reach. Bathymetry data were used to select locations of riffle and pool cross-sections and to determine the thalweg location throughout the reach to create a longitudinal profile. Five cross-sections (three riffles and 2 pools) were surveyed and monumented with rebar and yellow caps.

Elevations of water surface and bankfull were also recorded along the length of the reach. As bankfull indicators were unlikely to have developed clearly in 3 years since construction, we compared our field-identified bankfull elevations with the design bankfull elevations from the 100% design plans (Stantec 2014). We also compared the field-identified bankfull elevations to those associated with an estimated bankfull flow of 4,300 cfs that was listed in the 2016 Morad Park monitoring report (Roberston 2016). Additionally, bankfull flow was estimated from a peak flow analysis using stream flow data from the Bureau of Reclamation (BOR) station NPCW, which is located approximately 4.5 stream miles downstream of the WY Blvd reach (USBOR 2008-2019). Between 2009 and 2019, annual peak flow with a return interval of 1.5-2.4 years was assumed to be the potential channel forming (bankfull) flow. Stream flow within these return intervals ranged from 3,256 cfs to 3,903 cfs.

To evaluate whether fisheries habitat was improved, we used the previously described in-stream structure ratings for the five toe-wood features and also measured maximum pool depth for two excavated pools located near pool cross-sections 6 and 9. The large, deep pool along the right bank where the water treatment intake is located was not selected to monitor pool depth, as it was not modified during the restoration work. A Trimble Geo7X GPS unit was used to obtain spatial data (UTM coordinates with horizontal datum of NAD83 Zone 13N) for the toe wood and rock arms.

To evaluate stream bank stability, we rated Bank Erosion Hazard Index (BEHI) and near-Bank Stress (NBS) (Rosgen 2006) on all banks within the project reach. NBS was determined as a function of thalweg position in relation to the study bank. Bankfull elevation was mapped along both banks throughout the reach to monitor migration of the bankfull channel.

Fisheries

Enhancing the fishery through Casper is one of the primary goals of the North Platte River Restoration project. Setting up a rigorous monitoring protocol to statistically determine if restoration activities yielded measurable fish population changes was not contemplated. In a large river like the North Platte River, long reach lengths and intensive repeated sampling events are required to yield valid abundance estimates. Furthermore, such sampling events would be required multiple times before and after construction, and at sites within and outside of the construction area. Therefore, a less rigorous approach was used to gain general insight into the relative status of fish populations. The sampling methods and results are summarized in this report and more detailed information can be found in the Annual Fisheries Progress Reports on the Work Schedule (WGFD 2015; 2016; 2017b; 2018, 2019). The fish population sampling compared post-restoration differences in trout abundance and size structure relative to an unaltered upstream control reach.

Beginning in 2015, the WGFD began sampling the Morad Park project reach separately from a historical monitoring reach to allow comparisons between the restored sections of the river and the upstream non-restored reaches, which served as a control. From 2015 to 2017, a 2,385-ft reach through Morad Park was electrofished and compared with the historical monitoring reach just upstream (the control reach). Sampling techniques varied from 2015 to 2018 as WGFD experimented with different methods to index the fish population in a small segment of a large river. Sampling methods were revised in 2018 to enable more direct comparisons of trout abundance, species assemblage, and size structure between the restored reaches and a control reach (WGFD 2018). For example, the Morad Park reach was expanded in 2018 to include 5,465 ft of reconstructed river habitat immediately downstream of the WGFD office, ending just upstream of the water intake structure in the WY Blvd reach (Table 2). This expanded sampling reach included all of the Morad Park restored reach and the upstream half of the Wyoming Blvd restored reach. Beginning in 2018, results from fish sampling through the expanded Morad Park reach applied to both the Morad Park and WY Blvd reaches.

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TABLE 2. Upstream and downstream coordinates for restored and control fish sampling reaches (NAD83, UTM zone 13T).

Sampling reach	Years	Upstream		Downstream	
		Easting	Northing	Easting	Northing
Morad Park (extended)	2018-2019	387495	4741889	388114	4743069
Control (Paradise Valley)	2018-2019	385985	4742566	387444	4741875

RESULTS

Visual Assessment

National Agricultural Imagery Program (NAIP) images from 2015 and 2019 illustrate some of the major changes in the stream following restoration (Figure 2). Mid-channel bars and islands in the lower stretch were removed and replaced with a single thread channel. Additionally, the stream channel was moved approximately 130 ft away from SW Wyoming Boulevard and a new floodplain was constructed. Photos from 2019 (Figure 3, Appendix A.4) demonstrate that stream banks throughout the reach have remained stable since construction. The coir fabric used to stabilize soil lifts in the reconstructed banks is still visible and intact in many places. The rebar marking photo points WY-10 and WY-12 could not be located in 2019 but photos were taken from the coordinates for each point and aligned with previous photos.

Along the right bank of the project reach, on the constructed floodplain along SW Wyoming Boulevard, woody and herbaceous vegetation has become well established, with young cottonwoods over 6 ft tall (Figure 5, A.4.7). Restoration was completed in this upper part of the reach in 2015 and unusually high flows occurred May-June 2016, (Figure A.3.1). Peak runoff exceeded 7,100 cfs (Figure A.3.1) and flows remained above bankfull flow for over a month, inundating the floodplain. The time period of floodplain inundation, coupled with the bare soil following construction, created ideal conditions for cottonwood regeneration. Restoration was not completed on the lower part of the reach until fall 2016, so the riparian area did not receive the same benefit from the extended, high runoff of 2016. Willows have established well above all three toe wood structures along the constructed floodplain (Figures 6, A.5.1-A.5.6). Downstream of the water intake structure on the right bank, willows and herbaceous vegetation are sparse (Figures A.4.10, A.5.7). As the coir fabric deteriorates in the future, this area should be monitored for vegetation establishment to ensure long-term stability of the reconstructed banks.

FIGURE 5. A stand of young, healthy cottonwoods on the constructed floodplain between the relocated stream channel and SW Wyoming Boulevard, near photo point WY-7.

Along the left bank of the WY Blvd reach, young willows were observed growing along the water's edge near WY-1 and WY-2, (Figures A.4.1, A.4.2). Many young cottonwoods were also observed on the floodplain on the left bank at photo point WY-3 (Figure A.4.3). Downstream of WY-3 little new woody riparian vegetation growth was observed (Figures A.4.5, A.4.12). Some willows have established on top of toe wood 5 (Figures A.5.9, A.5.10). The left bank between WY-3 and WY-12 is an inner bend and receives less erosive stress from stream flow. However, downstream of WY-12, establishment of willows along the left bank is desirable to help maintain long-term stability of banks that serve as a barrier to the water treatment plant ponds and infrastructure. Vegetation around the oxbow wetland on the left bank is primarily herbaceous (Figure A.4.11).

Rapid assessment ratings for structural integrity and erosion/deposition are provided in Table 3. All structures were identified with the structure type (e.g., toe wood) and were numbered in increasing order from upstream to downstream, to match how they were identified in the design plans (e.g., Toe wood 1; Figure 6). Some structures received a better (lower value) rating in 2019 than 2018 because discussions with the design engineer occurred after structures were rated and these discussions clarified the expected function and condition of the structures.

TABLE 3. Ratings for in-stream structures following the rapid assessment protocol (Miller and Kochel 2013). Bold type and * indicate worsened (increased value) rating between 2018 and 2019.

Structure Description	Structural Integrity Rating (1-4)		Erosion / Deposition Rating (0-5)	
	2018	2019	2018	2019
Toe wood 1	1	1	1	1
Toe wood 2	2	1	1	1
Toe wood 3	2	1	1	1
Toe wood 4	1	1	0	0
Toe wood 5	1	1	0	0
Rock vane 1*	1	1	1	**2**
Rock vane 2*	2	2	3	**4**
Rock vane 3*	1	**2**	2	**4**
Rock vane 4	1	1	0	0
Rock vane 5	1	1	0	0
Riffle vane 1	2	2	2	2
Riffle vane 2	2	2	2	2
Cross vane 37	1	1	0	0
Cross vane 38	1	1	0	0
Cross vane 39 A	1	1	0	0
Cross vane 39 B	1	1	0	0
Cross vane 40	1	1	0	0
Cross vane 41	1	1	0	0
Cross vane 42	1	1	0	0

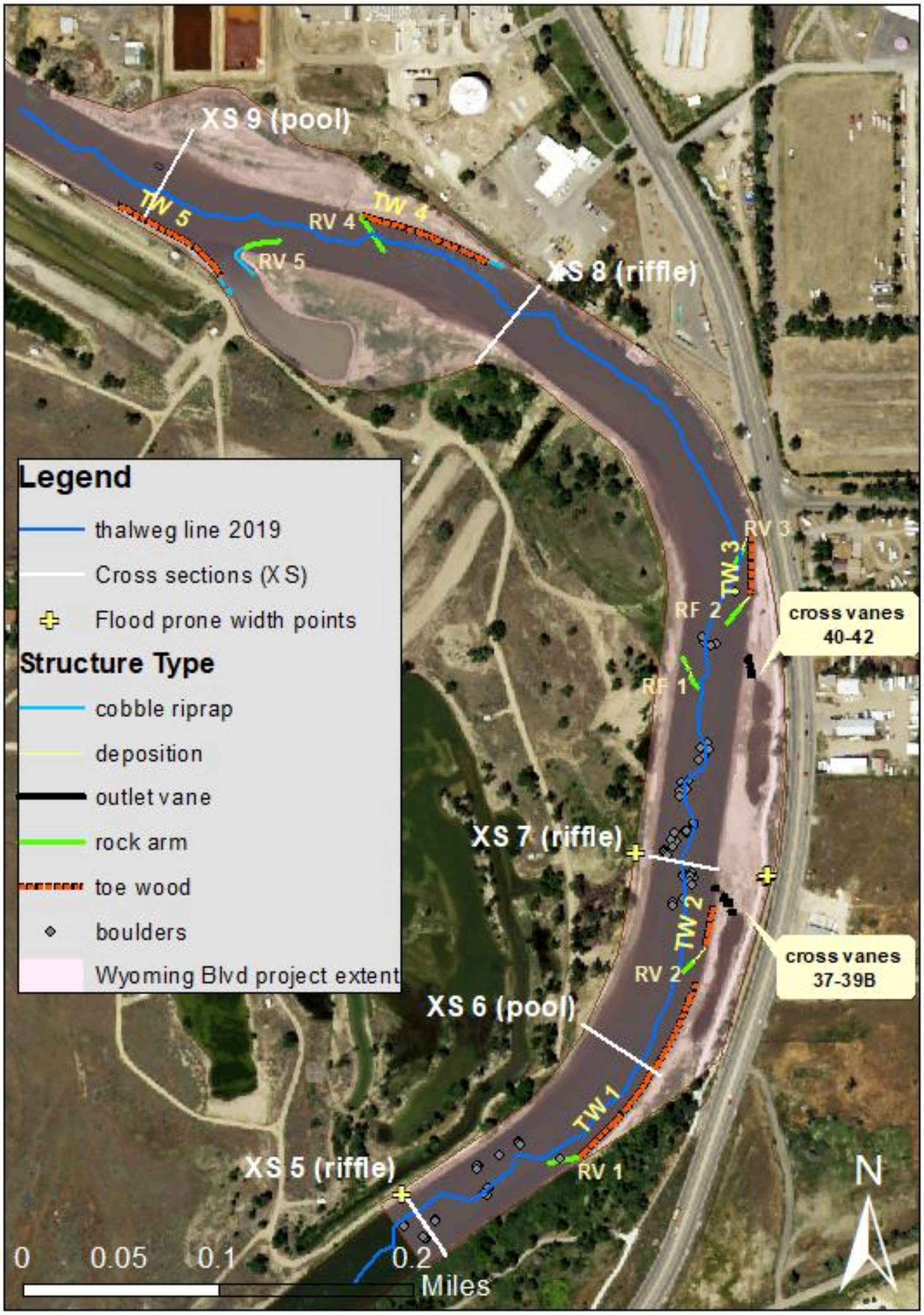

FIGURE 6. Location of in-stream structures, cross-sections, and the thalweg line in 2019. TW represents toe wood, RV represents rock vane, and RF represents riffle vane.

All toe wood structures have two intended functions: 1) to protect the stream bank on outer bends from erosion while woody riparian vegetation establishes and 2) to provide cover and increased habitat diversity for fish by maintaining a scour pool in the stream channel along the structure. Design plans illustrate logs in the toe wood structures completely submerged at base flows and root wads almost completely submerged at base flows (Stantec 2015). Toe wood structures 1, 2, and 3 were constructed in 2015 and the majority of the logs and root wads were elevated above base flow (Figures A.5.1-A.5.6). Along each toe wood structure, the distance between the highest point of the exposed log or root wad and the water surface elevation at base flow was measured. Base flow was estimated at 746 cfs from the USBOR Hydromet station NPCW, located approximately four miles downstream. On average, the tops of the exposed wood in toe wood structure 1, 2, and 3 were 1.7, 2.1, and 1.9 ft, respectively, above base flow. Toe wood structures 4 and 5 were constructed in 2016 by a different crew and the root wads were installed at a lower elevation with the logs partially submerged at base flows (Figures A.5.7-A.5.10). On average, the tops of the logs and root wads in toe wood structure 4 were 1.08 ft above base flow. Elevation of toe wood 5 was not measured, but was similar to toe wood 4. The goal for all toe wood structures is to rank 1-2 on structural integrity and 0-2 on erosion/deposition (WGFD 2017). In 2019, all toe wood structures received a "1" (i.e., "intact") rating for structural integrity as there was no sign that the logs or soil lifts were experiencing any unexpected deterioration (Table 3). Toe wood 1, 2, and 3 all received a "1" for erosion because there was minor localized erosion around some of the logs, but not enough to suggest it will continue. Toe wood 4 and 5 received a "0" for erosion because there was no visible erosion. The elevation of the first three toe wood structures above the water surface at base flows likely contributes to this difference in observed erosion. Detailed observations for each toe wood structure follow:

Toe wood 1 is the longest of the five structures, running approximately 575 ft along the right bank (Figures A.5.1, A.5.2). The river channel in this location was relocated approximately 135 ft west of its former location, immediately adjacent Wyoming Boulevard (Figure 2). Toe wood 1 is important for maintaining stability of the new streambank and floodplain. A few logs protrude further into the channel from the bank, especially toward the downstream end (Figure A.5.1). These logs were not cut at installation and are not indicative of structural instability (T.C. Dinkins, Stantec Design Engineer, personal communication). Willows have established well above the toe wood and contribute to the long-term stability of the new streambank (Figure A.5.2). The elevation difference between the tops of the root wads or logs and the water surface at base flow ranged from 1 to 2.5 ft, with an average of 1.7 ft.

Toe wood 2 is approximately 115 ft long, located just downstream of toe wood 1 and upstream of the first set of wetland outlet cross vanes (Figures A.5.3, A.5.4). Localized bank scour was observed around multiple logs in this structure, resulting in more log length being exposed. Toe wood 2 should continue to be monitored closely for further signs of bank erosion between the vegetation line and the root wads, especially as coir fabric deteriorates. Young willows have established well above the structure. Toe wood 2 is not providing much fish cover or habitat as the root wads were elevated above the water surface elevation at base flows in both 2018 and 2019 and there was no pool being maintained along the structure. The elevation difference between the tops of the root wads or logs and the water surface at base flow ranged from 1.5 to 3.0 ft, with an average of 2.1 ft.

Toe wood 3 is approximately 155 ft long and located downstream of the second wetland outlet where the channel makes a relatively sharp bend northwest (Figures A.5.5, A.5.6). There are some areas along this structure where the gaps between logs is greater (4 to 9 ft) than is typical in the structure (0.5 to 3 ft), which may be due to smaller root wads and logs being used (Figure A.5.6). There is no evidence of bank sloughing around these gaps, but these areas should be monitored as they may be weaker locations in the bank and more susceptible to erosion. Young willow have established well above the toe wood and, overall, the toe wood is intact and functioning as intended. The elevation difference between the tops of the root wads or logs and the water surface at base flow ranged from 1.5 to 2.5 ft, with an average of 1.9 ft.

Toe wood 4 is approximately 358 ft long, located on river right along the upstream end of the water treatment facility (Figures A.5.7, A.5.8). These logs and root wads were installed at lower elevations, are partially submerged at base flows and maintain a scour pool along the structure. The elevation difference between the tops of the root wads or logs and the water surface at base flow ranged from 0.5 to 1.5 ft, with an average of 1.1 ft. Willows have established above the toe wood, but not as densely as above the first three toe wood structures.

Toe wood 5 is approximately 345 ft long, located on the left bank, just downstream of the oxbow wetland (Figures A.5.9, A.5.10). This structure was not in the 100% design plans but was constructed to provide extra protection for the streambank along the water treatment facility wells (T.C. Dinkins, Stantec Design Engineer, personal communication). The river bends right at this location, which likely places additional shear stress on the left bank. Rock vanes 4 and 5 help direct channel flows into the center, rather than this outside bend. Fine sediment deposition was observed just below and between the root wads, likely due to sediment settling out of the slower water downstream of the oxbow wetland. A sediment bar is also forming at the mouth of the oxbow wetland, indicating that the bank is not experiencing high shear stress. The oxbow wetland was intended to be more isolated from the main channel than it currently is, so the deposition is acceptable (T.C. Dinkins, Stantec Design Engineer, personal communication). Some willows have begun to establish above the toe wood, but not as densely as above the first three toe wood structures.

The intended function of the rock vanes is to direct flows toward the center of the channel, away from the bank toe on outer bends, and to form a shelf to improve fish habitat. Overall, the rock vanes all appear to direct flows toward the center of the channel. Several boulders have been buried, some boulders have rolled out of place, and there is a pool associated with each of the vanes. Detailed observation for each rock structure follow:

Rock vane 1 is located upstream of toe wood 1 (Figure A.5.11). In 2018, most of the boulders in the vane were still visible and a pool was maintained in the channel just off the channel end of the vane. In 2019, only the boulders near the bank were visible; the rest were buried. Rock vane 1 received a structural integrity rating of “intact” and a deposition rating of “2” because of deposition over the structure in the channel. Despite the deposition, rock vane 1 appears to function as intended, directing flows away from the toe wood.

Rock vane 2 is located upstream of toe wood 2 (Figure A.5.12). In 2019, only one small boulder could be visually identified. Rock vane 2 received a “damaged” rating for structural integrity and a “4” rating for deposition because over 75% of the structure was buried. A pool was maintained upstream of the structure and toward the middle of the channel. This may be contributing to deposition upstream of rock vane 2. This may not be an ideal structure and location combination, as they tend to become aggraded. The vane was intended to help transition out of a pool and into a riffle and the structure might not have been necessary (T.C. Dinkins, Stantec Design Engineer, personal communication).

Rock vane 3 is located just downstream of toe wood 3 and upstream of a water intake structure (Figure A.5.13). The intended function is to deflect water flow energy away from the downstream bank and further downstream water intake structure. In 2019, none of the boulders in the vane could be located. Thus, rock vane 3 also received a "damaged" rating for structural integrity and a "4" rating for deposition because over 75% of the structure was buried. The downstream bank was not modified during construction but is relatively well-armored with rock and concrete. Thus, the bank and intake structure do not appear at risk of additional erosion due to the potential loss of the function in this rock vane.

Rock vane 4 is located just downstream of toe wood 4 and was not in the 100% design plans (Figures A.5.14, A.5.15). Rock vane 4 spans over half of the channel width at base flow. Two boulders in the vane (the 21st and 22nd from the bank) rolled downstream 2-3 ft. A deep, well-defined pool is maintained downstream of the structure. Thus, rock vane 4 received an "intact" rating for structural integrity, as the shifted boulders do not comprise 10% of the structure, and a "0" rating for erosion/deposition, as none was observed.

Rock vane 5 is located just upstream of toe wood 5 and upstream of the mouth of the oxbow wetland (A.5.16, A.5.17). Rock vane 5 was also not in the 100% design plans but was added in conjunction with toe wood 5 to protect infrastructure on the left bank. Most boulders in this vane were visible and in place in 2019 so it received an "intact" rating for structural integrity and a "0" rating for erosion/deposition as none was observed.

The main intent of the two riffle vanes was to add habitat diversity. In riffle vane 1, many boulders were buried near the bank but those toward the center of the channel protrude into the water column. This pattern of sediment deposition over the structure near the banks is expected. In riffle vane 2, two boulders had rolled and one may have been buried or sunk. Both riffle vanes received a "damaged" rating for structural integrity because of rolled boulders and a "2" for deposition because of boulders that had been buried. No pictures were taken as the structures were not visible underwater.

Two wetlands were constructed on the new floodplain along Wyoming Boulevard (Figure 6). The two constructed wetlands on the floodplain along Wyoming Boulevard contained water through the summer and into fall 2019, providing increased habitat diversity with different vegetation zones associated with the soil moisture gradient (Figures A.4.8, A.4.18, A.4.19). Both wetlands have outlets with 3-4 cross vanes that function as grade control (Figures A.5.20 – A.5.25). All cross vanes at wetland outlets received "intact" ratings for structural integrity and a "0" for erosion/deposition as none was observed.

Throughout the Wyoming Blvd reach, individual boulders and boulder clusters were installed to increase structural diversity of the stream and provide additional fish habitat. The boulder locations in the design plans were approximate and included 129 individual boulders, arranged in one of three cluster types (Stantec 2014). Design plans indicated boulder clusters to be placed under direction of the onsite engineer and although the design plans show 49 boulders downstream of toe wood structure 3, none were installed in that stretch (T.C. Dinkins, Stantec Design Engineer, personal communication). In 2018, the coordinates of each visible boulder were recorded and mapped (Figure 6), a total of 62 individual boulders. The boulders had varying degrees of deposition and scour and increased habitat diversity for fish.

Geomorphology

During high flows in 2019, bathymetry data of the WY Blvd project reach were collected and used to identify pools and riffles (Figure A.6.1). A longitudinal profile of the reach was plotted from these data (Figure A.6.2) and cross-sections of three riffles were surveyed (cross-sections 5, 7, and 8; Figures A.6.3-A.6.5) in addition to cross-sections of two of the five distinct pools (cross-sections 6 and 9; Figures A.6.6-A.6.7).

Across the five cross-sections, bankfull elevation based on bankfull indicators, design plans, and estimated bankfull flow differed by a maximum of 0.82 ft in elevation, and usually much less (Figures A.6.3-A.6.5). The design bankfull elevation and the best bankfull elevation identified in the field are both plotted on the cross-sectional profiles (Figures A.6.3-A.6.7).

Geomorphology Goal 1 – Narrow Over-Widened Channel.

Entrenchment ratio was calculated at two of the three riffle cross-sections because it requires identification of flood-prone width. In 2019, flood-prone width was identified at riffle cross-section 7, but not at the other two riffle cross-sections. In 2017, flood-prone width was identified and recorded at cross-section 5, but in 2019 willows were too dense to identify it accurately. As the cross-section 5 profile has changed very little since 2016 (Figure A.6.3), the flood-prone width from 2016 was also used in 2019. At cross-section 8, flood-prone width was not identified because the floodplain was highly developed (road embankments, water treatment ponds, other infrastructure), rendering flood-prone width less meaningful. The entrenchment ratio at cross-section 5 was calculated as 3.1 (Table 4), essentially the same as in 2016 (3.1). Entrenchment ratio at cross-section 7 was 2.0 (Table 4). Entrenchment ratio at both cross-sections was higher than pre-project, although at cross-section 7, it falls slightly below the minimum ratio of 2.2.

Channel incision was quantified using the bankfull height ratio, with a desired value between 1.0 and 1.2. Bankfull height ratio was 1.0 at all three riffle cross-sections (Table 4).

The width-to-depth ratio was calculated for all three riffle cross-sections as bankfull width divided by mean bankfull depth, with a desired value between 35 and 42. Width-to-depth ratios were all within the desired range, with the exception of cross-section 8, which had a slightly higher value of 43.46 (Table 4). At cross-section 5, width-to-depth ratio remained essentially the same between 2016 and 2019.

Cross-sectional area of riffles was expected to vary by not more than 10% between years and by not more than 15% across all cross-sections (WGFD 2017). The only cross-section that was surveyed in multiple years was cross-section 5. Between 2016 and 2019, cross-sectional area at cross-section 5 varied very little (0.65%; Table 4). In 2019, cross-sectional area across all three riffles varied between 6% and 14%, with an average of 9%. The greatest difference (14%) was between cross-sections 5 and 7. The monitoring plan also indicates that bankfull cross-sectional area should be reduce to approximately 950 square ft. The cross-sectional areas of riffles are all below this value, but the change in cross-sectional area over time is the more important aspect of cross-sectional area to monitor.

TABLE 4. – Geomorphology summary data at the WY Blvd reach pre-2016 and in 2019.

Monitoring parameter	Pre-project (pre-2016)	2016	2019	Criterion
Entrenchment ratio	Average=1.6	XS5 = 3.1	XS5 = 3.1 XS7 = 2.0 XS8 = NA	Minimum ratio >2.2; preferred ≥3.0
Channel incision ratio	1.1 to 2.0	XS5 = 1.0	All XS = 1.0	Average bank-height ratio value 1.0-1.2
Width to depth ratio	52 to >100	XS5 = 39.0	Average = 40.7 XS5 = 38.9 XS7 = 39.8 XS8 = 43.5	Between 35 and 42
Cross-sectional area (ft^2)	850 to 1300	XS5 = 925	XS5 = 919 XS7 = 802 XS8 = 852 XS6 = 1126 XS9 = 1240	About 950 sq. ft. Value for riffle cross-section should not vary by more than 10% year to year or by more than 15% across all sites.

Geomorphology Goal 2 – Improve Fisheries Habitat.

In 2019, five distinct pools were observed within the Wyoming Blvd project reach (Table 5, Figure A.6.2). A pool along the water intake structure was 16.6 ft deep at bankfull (pool 3 in Figure A.6.2) and was excluded from assessment of improvement in fisheries habitat as the stream in this area was not altered by the restoration work. The other four constructed pools ranged in depth at bankfull from 8.8 ft to 11.2 ft (Table 5). All pools met the criterion that they remain at least 75% of project design depth, which is 9.3 ft in the Wyoming Blvd reach (Table 5).

Pool 1 and pool 5 were selected for cross-section surveys. Cross-section 6 captured pool 1 (Figure A.6.6) and cross-section 9 was intended to capture pool 5 (Figure A.6.7). On the longitudinal profile, it appears that cross-section 9 was surveyed slightly upstream from the location of pool 5. However, the cross-section profile shows that the pool depth at the cross-section (11.2 ft) was deeper than the pool depth on the longitudinal profile (pool 5, 10.5 ft; Figure A.6.2). The difference is only 0.7 ft and the discrepancy may be due to missing the exact location of the deepest point of the pool when bathymetry data was collected. Elevation data from the cross-section surveys are more accurate than elevation data recorded during bathymetry mapping when the boat from which recordings were made was moving more quickly and more likely to be influenced by variation in pitch.

TABLE 5. – Summary of data collected at the Wyoming Blvd project reach in 2019.

Monitoring parameter	Design Depth from bankfull (ft)	2019 Depth from bankfull (ft)	% of design depth	Criterion
Maximum pool depths from bankfull elevation	9.3	Pool 1 (XSEC 6): 9.1 Pool 2: 8.8 Pool 3: 16.6 Pool 4: 9.54 Pool 5: 10.5 XSEC 9: 11.23	98% 95% NA 103% 112% 121%	Deepest point in each pool should remain at least 75% of project design depth (6.95-11.65 ft).

Geomorphology Goal 3 – Stabilize Streambanks.

Visual assessment of the streambanks revealed no significant erosion. Geotextile fabric continues to stabilize much of the bank. Toe wood structures should be monitored for signs of slumping and erosion, especially at the upstream end of toe wood 2 and in places where root wads appear missing in toe wood 3. Some willows have established above toe wood 4 and 5 but they are relatively sparse, especially compared to the three upstream toe wood structures, which were built one year earlier.

Bankfull elevation was surveyed on both banks along the entire project length and mapped (Figure 7). As this was the first time the bankfull line was mapped, this data serves as a baseline for comparison in future to track potential areas of channel migration.

BEHI and NBS ratings were mapped (Figures 8-9) and summarized in Table 6. The goal was for BEHI and NBS to be moderate, low, or very low on all banks within the project reach. In 2019, BEHI was low or very low on 90% of the bank length and moderate on 10% of the bank length (Table 6). No banks received a BEHI rating greater than moderate in 2019. The biggest difference in 2019, was the greater percentage (70% vs 43%) of the bank length with a "low" rating and a smaller percentage (20% vs. 43%) with a "very low" rating, compared to pre-construction BEHI values. This is likely not indicative of a trend in bank erosion risk, but rather due to differences in the individual observers who rated the banks in each year. The bank on river right that received a moderate BEHI rating was not modified during the restoration project because it supported important infrastructure that was left undisturbed. An oxbow wetland was created at the downstream end of the project reach and, because this wetland is connected to the main channel even at base flows, we rated the banks for BEHI as well. The oxbow wetland stream banks were not included in Table 6 because it would confound evaluation of erosion risk of stream banks along the main channel. Of the oxbow wetland banks, 52% received a low or very low BEHI rating and 48% received a moderate rating. The bank in the oxbow wetland with the moderate rating was not modified during restoration because it supports a road and serves as a barrier to water treatment plant ponds.

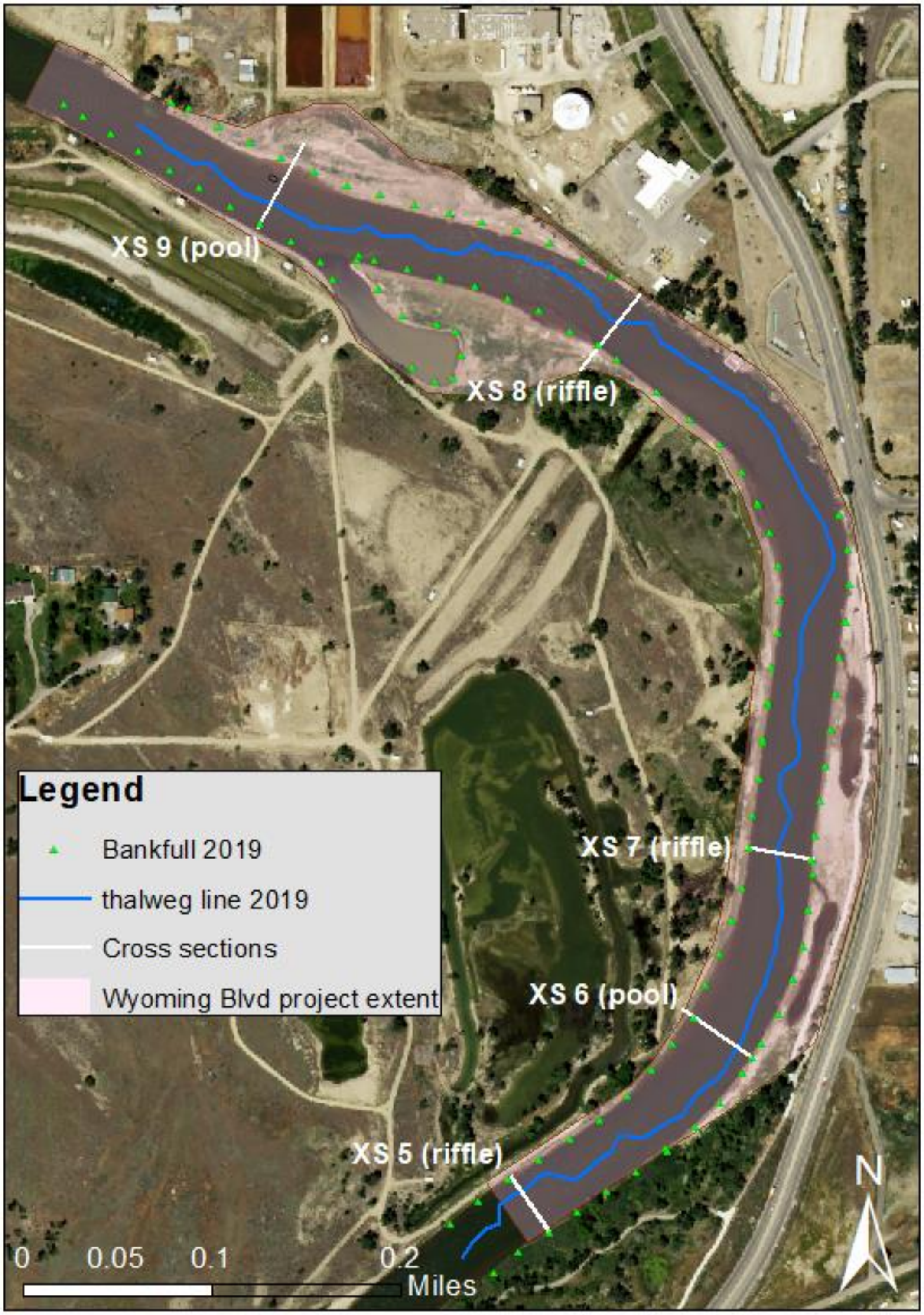

FIGURE 7. Bankfull elevations along the Wyoming Blvd project reach.

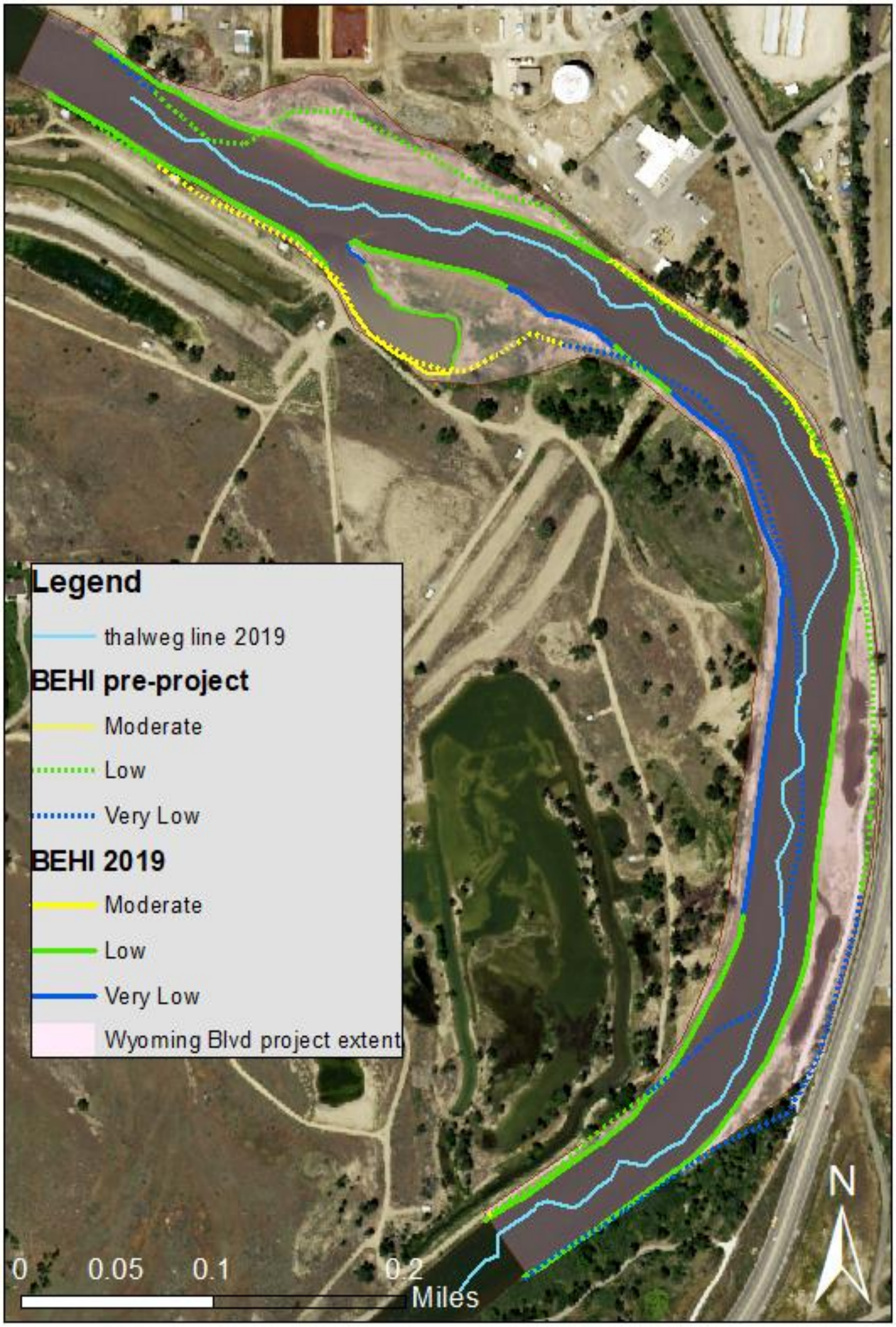

FIGURE 8. Bank Erosion Hazard Index (BEHI) ratings for the banks in the Wyoming Blvd project reach before restoration (dotted) and after restoration (solid lines).

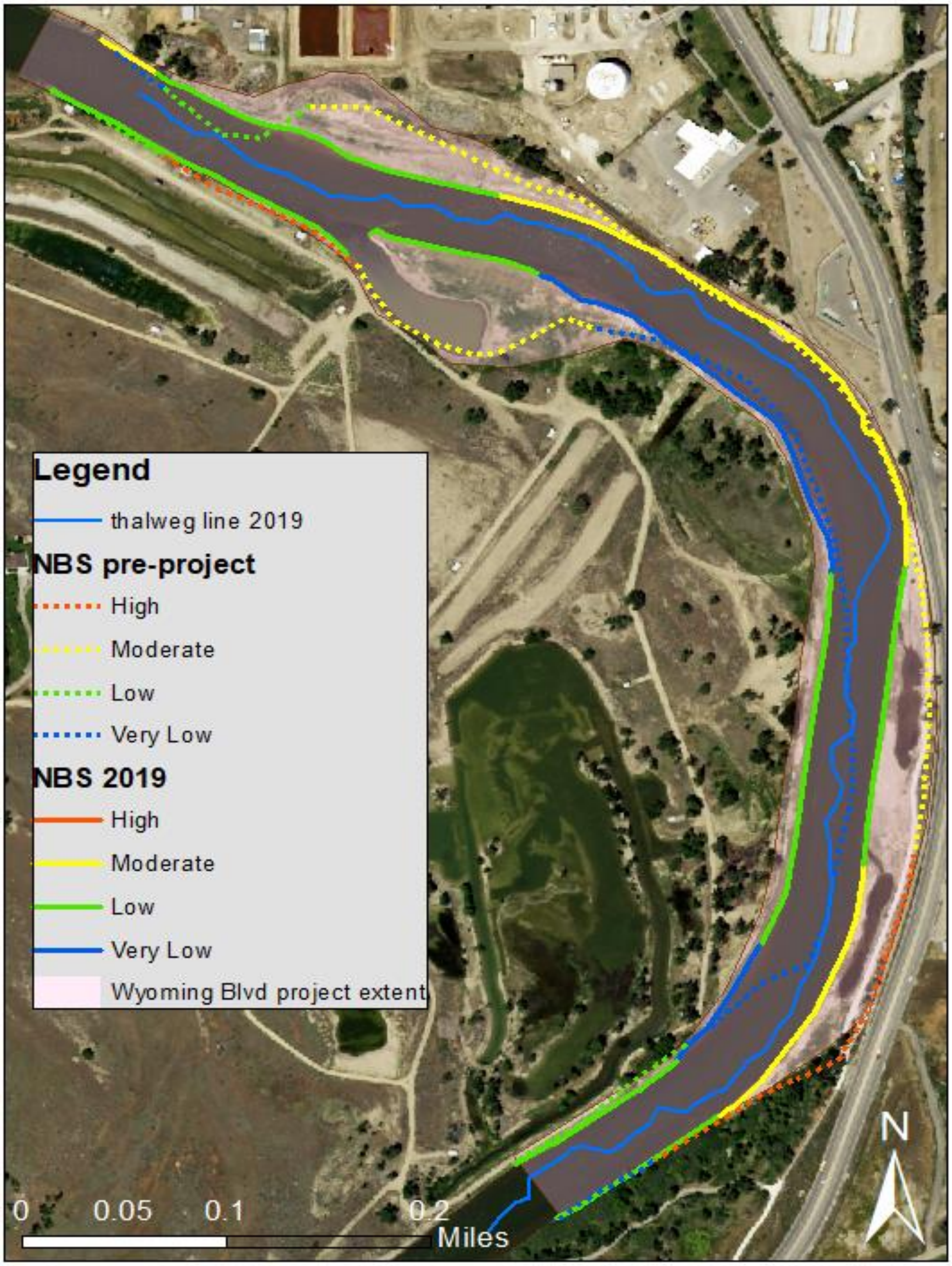

FIGURE 9. Near-Bank Stress (NBS) ratings for the banks in the Wyoming Blvd project reach before restoration (dotted) and after restoration (solid lines).

In 2019, NBS ratings were low or very low on 73% of the banks (Table 6). Moderate NBS ratings were assigned to two bank segments, both on outside bends along Wyoming Boulevard (Figure 9). However, neither of these banks are concerning. At the upstream bank, where the new floodplain was created, willows and cottonwoods have established well and helped stabilize the bank. Additionally, high flows can dissipate across the constructed floodplain, which reduces stress on the bank. The second segment that received a moderate NBS rating is downstream of the constructed floodplain, where the stream was modified little during restoration.

TABLE 6. Ratings for BEHI and NBS rating in 2019 and prior to construction.

	BEHI		NBS	
Rating	Pre-project	2019	Pre-project	2019
Very Low	43%	20%	31%	17%
Low	43%	70%	13%	56%
Moderate	14%	10%	38%	28%
High	0%	0%	18%	0%
Very High	0%	0%	0%	0%

Fisheries

Fish sampling results are summarized in this report and additional details can be found in the Annual Fisheries Progress Reports on the Work Schedule (WGFD 2015; 2016; 2017b; 2018, 2019). Electrofishing occurred October 23-25, 2018 in the expanded Morad Park and control reaches using one jet boat with two netters to generate separate three-pass mark-recapture population estimates from each reach. Population estimates were generated for both RBT and BNT. In 2018, there was no evidence of significant differences in abundance or biomass of trout between the Morad Park reach and the upstream control reach (Figures 10-11). There were also no significant differences in abundance or biomass of RBT or BNT between the two reaches (Figures 12-13). There were no significant differences in overall size structure in the RBT population between the two reaches. There were differences in size structure in the BNT population but they were likely an artifact of low sample size.

Electrofishing occurred October 1-3, 2019 according to the same methodology, except two jet boats and two netters each were used. Population estimates were generated only for RBT due to low sample size and a lack of recaptures for other trout species. Similar to 2018, comparisons of the 2019 trout estimates provided no evidence of a significant difference in abundance or biomass between the Morad Park and control reaches (Figures 12-13). Cohort representation in the reach-specific trout populations was nearly identical with the exception of significantly fewer age-3 RBT in the restored section of Morad Park relative to the upstream control reach. There were no significant differences in the overall size structure of the RBT population between the two reaches.

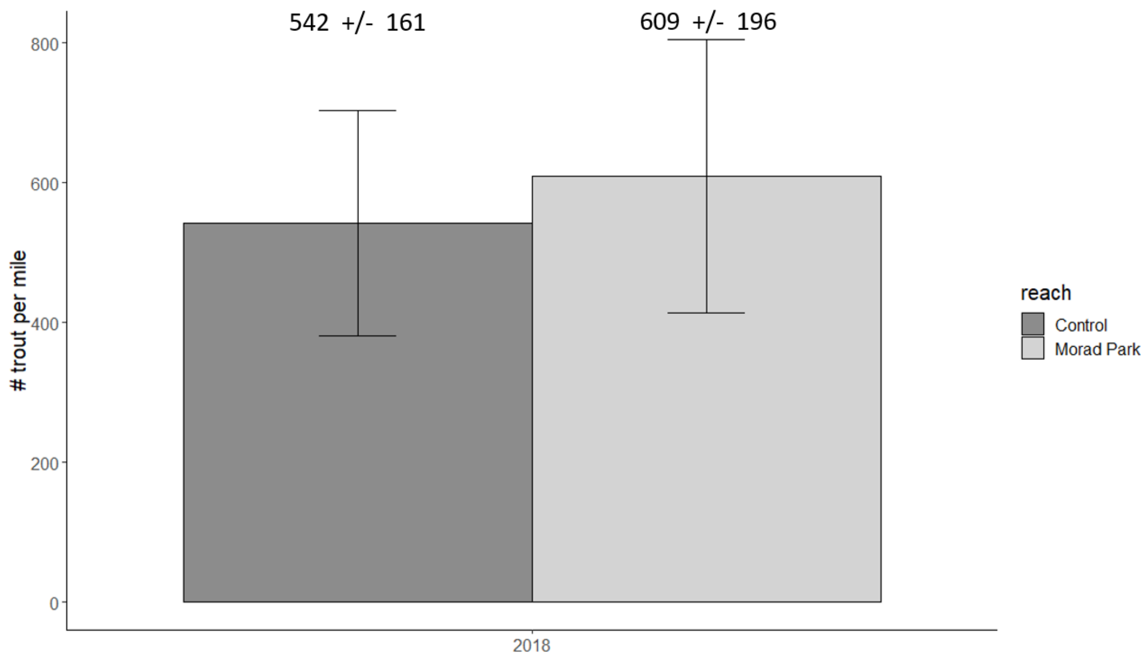

FIGURE 10. – Estimated number of RBT (≥8 inches) per mile (± SE) from a three-pass mark-recapture population estimate for fish captured in the restored Morad Park reach and the unrestored upstream control reach of the North Platte River in 2018.

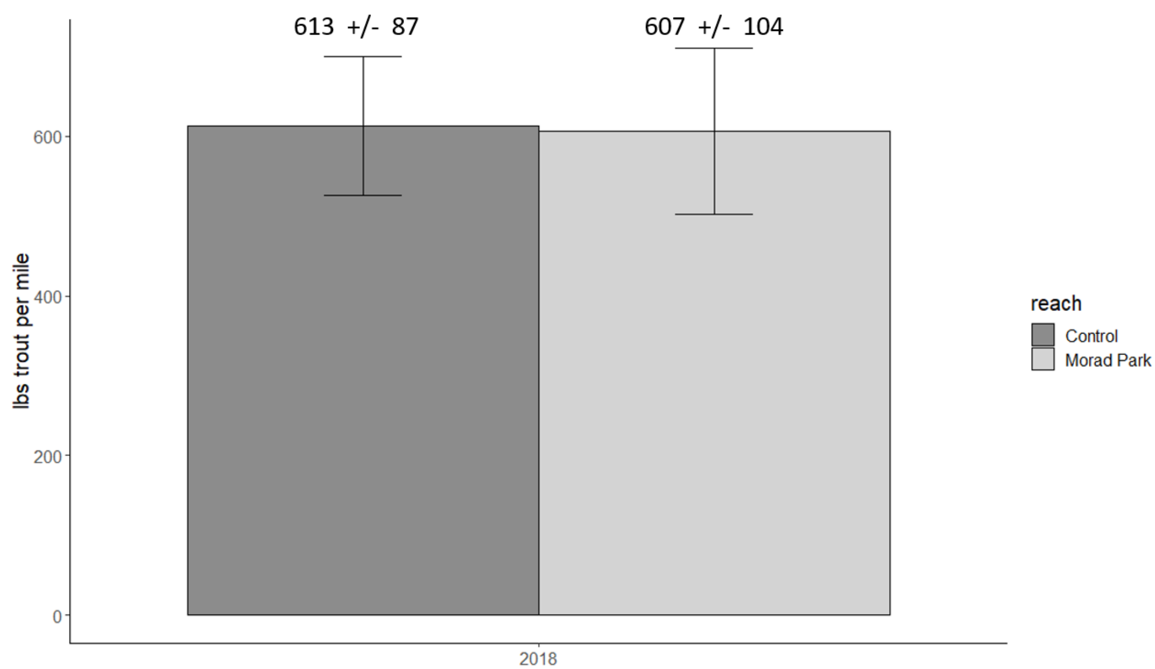

FIGURE 11. – Estimated lbs of RBT (≥8 inches) per mile (± SE) from a three-pass mark-recapture population estimate for fish captured in the restored Morad Park reach and the unrestored upstream control reach of the North Platte River in 2018.

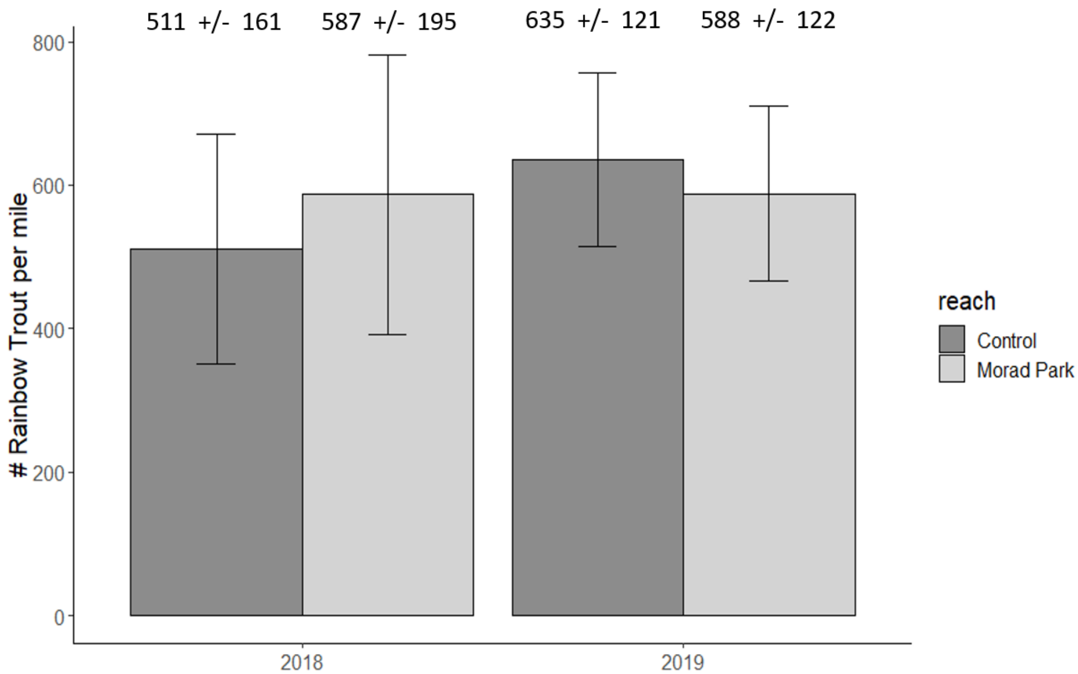

FIGURE 12. – Estimated number of RBT (≥8 inches) per mile (± SE) from a three-pass mark-recapture population estimate for fish captured in the restored Morad Park reach and the unrestored upstream control reach of the North Platte River in 2018 and 2019.

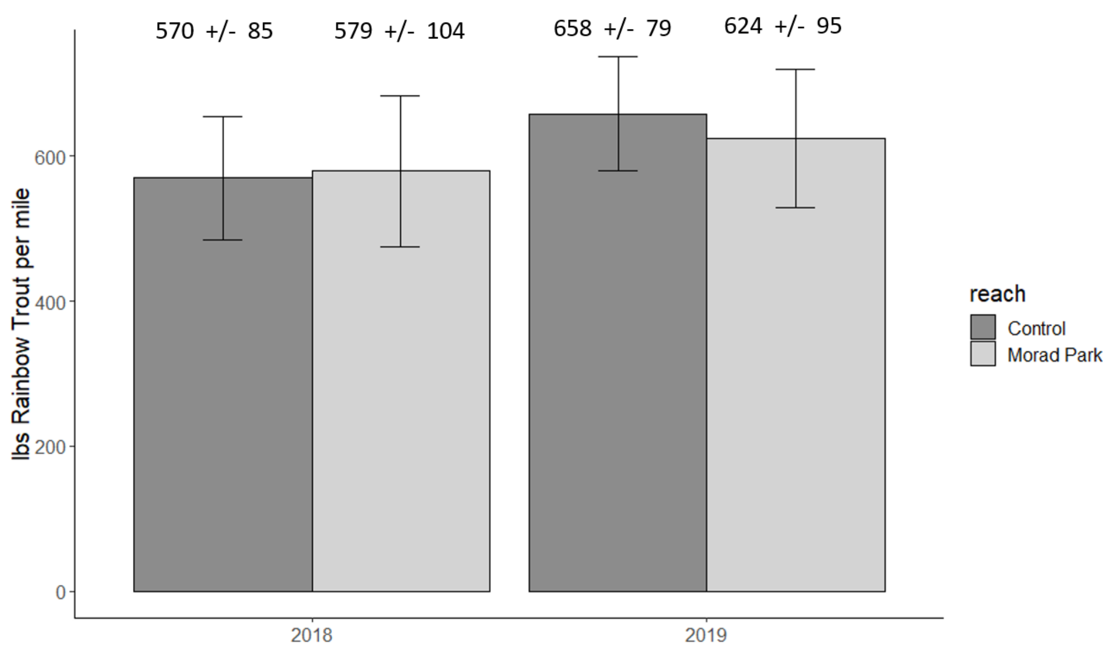

FIGURE 13. – Estimated lbs of RBT (≥8 inches) per mile (± SE) from a three-pass mark-recapture population estimate for fish captured in the restored Morad Park reach and the unrestored upstream control reach of the North Platte River in 2018 and 2019.

DISCUSSION

There are three focal areas for restoration efforts within the North Platte River Master Plan: improvement and stability of the stream channel (geomorphology), enhancement of fisheries, and restoration of native riparian vegetation. Each of these focal areas have been addressed in the Wyoming Blvd reach.

In the monitoring plan, there were three specific goals associated with modification of the geomorphic characteristics of the river. The first goal was to narrow the over-widened river channel and success was evaluated using entrenchment ratio, bankfull height ratio (incision), width-to-depth ratio, and bankfull cross-sectional area. Prior to construction, the river was entrenched, moderately to deeply incised, and had a high width-to-depth ratio typical of a channel that has difficulty moving its sediment load. After construction, the flood prone area had increased, which allows high flows to dissipate and reduce shear stress on banks. The increase in entrenchment ratio from an average of 1.6 to a range of 2.0 to 3.1 represents this decrease in entrenchment. The channel was also narrowed, which improved the river's ability to transport sediment and maintain a deeper, more stable channel. This is evident in the decrease in width-to-depth ratio from a previous range of 52 to 100, down to an average of 41 in 2019. Although the width-to-depth ratio at cross-section 8 (43) was slightly higher than the desired criterion (42), it is only slightly outside the desired range and still significantly lower than the ratios prior to restoration. The degree of incision has decreased as well, as bank-height ratio is close to 1 along most of the reconstructed banks. However, as bankfull features are still not well-defined, incision will be more confidently evaluated in the future. Finally, variation in cross-sectional area across all three riffles was low and under the criteria of 15%. Variation in cross-sectional area between years will be evaluated in 2021 after all cross-sections have been surveyed at least twice.

The second geomorphic goal was to improve fisheries habitat. Prior to construction, in the upper part of the reach the channel bed was wide and shallow with no distinct pools. Some deep pools existed along Wyoming Blvd but their location was problematic on an outside bend with high near-bank stress where infrastructure was at risk. Additionally, in the lower part of the reach, the channel was overly wide and had a shallow bed. In contrast, in 2019, even after realigning the channel away from Wyoming Blvd, four large, deep pools were observed throughout the reach (8.8 – 11.2 ft deep). Three of the pools were associated with toe wood structures and the deepest pool (16.6 ft) was located along water treatment infrastructure where the stream was largely undisturbed in the restoration work. All three constructed pools along toe wood structures met the depth criterion of at least 75% of design depth (9.3 ft). All five toe wood structures were largely intact and had experienced little to no erosion by 2019. However, the toe wood itself does not provide much cover for fish at base flows as the uppermost three structures were constructed above the elevation of base flows and the lower two structures have experienced some sediment deposition so that the water at base flows is very shallow. Additionally, individual boulders and boulder clusters improve habitat diversity throughout the upper half of the reach, although to varying degrees as some boulders appeared to have sunk or been buried by sediment.

The third geomorphic goal was to stabilize stream banks. Excessive bank erosion was not evident in the Wyoming Blvd reach. Toe wood was largely intact and functioning to protect constructed banks. At toe wood 2 and 3 the bank should continue to be closely monitored for signs of slumping and erosion in locations where root wads appear missing or have larger gaps.

Bank stability was evaluated in more detail using BEHI and NBS ratings. All banks met the objective of having very low to moderate BEHI and NBS ratings. An outside bend in the middle-downstream part of the reach was rated as moderate for BEHI, although before construction it was rated as low. As the bank in this part of the reach were mostly unaltered by the restoration, this discrepancy between years is likely due to slight differences in the ratings applied by different observers. The decreased risk of bank erosion has been achieved by improved access of bankfull flows to the floodplain to dissipate energy, establishment of willows along the toe wood structures and constructed banks, sloped bank angle, and increased bank cover provided by vegetation and coir fabric. The thalweg still runs close to the bank nearest Wyoming Blvd and also near the bank downstream of the constructed floodplain where little work was done. Both these banks were rated moderate for NBS in 2019 but no banks were rated high.

In 2019, all banks were evaluated for BEHI and NBS in order to compare them with pre-project data that were also acquired for all banks. However, BEHI and NBS are intended to be evaluated only on banks that are actively eroding or have strong potential to erode (Rosgen 2006). Thus, in the final year of monitoring, only those banks will be evaluated. The monitoring plan states that the objective is to have no banks with a BEHI/NBS rating higher than moderate. However, the metrics Dominant BEHI/NBS and Percent Bank Erosion can be calculated from this data as described in the Wyoming Stream Quantification Tool (WSQT) and would help to better characterize the magnitude and extent of bank erosion. Dominant BEHI/NBS can be calculated retroactively from pre-project data for comparison.

Since completion of construction at the Wyoming Blvd reach in 2015 and 2016, the North Platte River through Casper experienced two years with high flow events. Construction was completed in fall of 2015 for the upper part of the reach and, in June 2016, runoff flows exceeded 7,100 cfs (Figure A.3.1). Flows in 2016 remained above bankfull flow and inundated the floodplain for over one month. In June 2017, flows exceeded 4,600 cfs and remained above bankfull for approximately two weeks. After these high flow events that had the potential to change geomorphic conditions of the site, there is no evidence of channel migration, banks appear stable, and most in-stream structures largely continue to function with excess deposition over rock vanes being the only potential concern.

All five toe wood structures remain intact and function primarily to protect the stream bank from erosion while woody riparian vegetation establishes. The in-stream ratings for structural integrity and erosion/deposition indicated no change between 2018 and 2019. Toe wood structures 1-3 were installed at a higher elevation than desired and are almost completely exposed at base flows whereas toe wood structures 4 and 5 were installed at lower elevations and are only partially exposed during base flows. Pools are maintained along each toe wood structure which improve habitat diversity for fish, but the root wads themselves likely do not significantly improve cover for fish.

Rock vanes and riffle vanes largely continue to function to direct flows toward the channel center. However, several of the vanes had “damaged” structural integrity ratings and higher erosion/deposition ratings than desired. In several of the rock vanes, boulders had been buried and some individual boulders had rolled out of place. These structures should continue to be monitored to determine if the deposition is significantly affecting their function.

Vegetation restoration is an important factor in the long-term stability of the restored channel and streambanks. The monitoring plan does not include any data collection to monitor vegetation, except for photo points. Cottonwoods and willows have established very well along the constructed wetland along Wyoming Blvd and willows have established well above toe wood structures 1-3 and 5. Willows above toe wood 4 are smaller and sparser. As the coir fabric deteriorates in the future, this area should be monitored for vegetation establishment to ensure long-term stability of the reconstructed banks. Wetland vegetation has established well in the two wetlands that were constructed on the floodplain along Wyoming Blvd. They both contained water throughout the summer and into the fall of 2019, providing increased habitat diversity. The oxbow wetland at the lower end of the project reach had little riparian or wetland vegetation along its banks, especially compared to the herbaceous wetland vegetation in the similar, but smaller and shallower, wetland in the upstream Morad Park reach (Figure 11). In 2020, in the Morad Park oxbow wetland, numerous adult Northern Leopard Frogs (*Lithobates pipiens*) and both metamorphs and adult Rocky Mountain (Woodhouse's) Toads (*Anaxyrus woodhousii*) were observed (Figure 12). No amphibians were observed in the oxbow wetland in the Wyoming Blvd reach.

FIGURE 14. Oxbow wetland in the Wyoming Blvd reach (left) and the Morad Park reach (right) in 2020.

FIGURE 15. Rocky Mountain Toads (left, middle) and Northern Leopard Frogs (right) observed in the oxbow wetland in Morad Park in 2020.

In both 2018 and 2019, abundance and biomass of trout did not differ between the Morad Park reach and the control reach. In both years, cohort representation in the reach-specific trout populations was nearly identical except for significantly fewer age-3 RBT were caught in the Morad Park reach relative to the control reach. The North Platte River is currently below its carrying capacity for trout and they may be more homogenously distributed throughout the river than they would be if their overall populations were higher. These lower population levels may be part of the reason that fish sampling has not revealed differences between the Morad Park reach and the control reach. Variation in trout abundance from year to year can be due to a range of factors that influence population dynamics. Thus, while enhancing fisheries is one of the main goals of these stream restoration projects, the multiple factors that affect fish populations throughout the North Platte River make it challenging to evaluate the isolated effect of habitat changes in a specific reach on fish populations. In future years, trout populations will continue to be monitored using standardized biennial sampling and the Morad Park reach will be included with the historical sampling reach, the Robertson Road reach. The Morad Park/Wyoming Blvd project reach will no longer be sampled separately as there is not enough pre-construction data on fish populations for this small reach of the river to make meaningful observations about the effect of changes in habitat on fish populations.

Recommendations

- All monitoring data should be collected again in 2021 in conjunction with a final year of monitoring data collection in the upstream Morad Park project reach. A final monitoring report for the continuous restored segment of the river (Morad Park reach and Wyoming Blvd reach) should be prepared based on the 2021 data.

- Although all banks were evaluated for BEHI/NBS both pre-project and in 2019, in the final year of monitoring (2021), BEHI/NBS will only be evaluated for banks that are actively eroding or that have the have strong potential to erode (i.e., outside meander bends). This follows the guidance described in the Wyoming Stream Quantification Tool (WSQT; USACE 2018). The metrics Dominant BEHI/NBS and Percent Bank Erosion will be calculated as described in the WSQT to better characterize the magnitude and extent of bank erosion. Additionally, to ensure continuity BEHI/NBS ratings should be conducted by both the Aquatic Habitat Biologists in Lander and Casper in 2020 to ensure continuity in BEHI/NBS ratings. Past photos of stream banks should also be used to inform BEHI ratings.

- As coir fabric deteriorates over the next couple years, banks will become more exposed to erosive forces of the stream flow, especially where riparian vegetation has not established. The lower half of the Wyoming Blvd reach should be closely monitored to determine if additional plantings are needed to maintain bank stability. The loss of coir fabric will also likely result in lower BEHI ratings, as coir fabric was counted as surface protection in BEHI ratings in 2019.

- As bankfull features continue to develop, bankfull elevation and the associated metrics (flood prone width, bank-height ratio, entrenchment ratio, BEHI, etc.) should be re-evaluated to better assess the geomorphic goals for the restored reaches.

- Mapping the bankfull line was included in the monitoring plan to help track any potential channel migration. The bankfull line was mapped in 2019 but it is unlikely that collecting this data again in the near future will provide much additional information about the project reach that isn't already captured through visual assessment, photo points, cross-section surveys, and structure assessments. Accordingly, it is not worth the effort to map the bankfull line again in 2021. The movement in the bankfull line will be a more useful long-term characteristic to monitor 10-20 years post-construction.

- The ratings from the rapid assessments of in-stream structures need to be interpreted in context of descriptions and photos of the structures. The rating system for structural integrity does not differentiate between physical integrity and intended function. Currently, the "Intact" rating is defined as "No visible damage; fully operational in terms of integrity For example, a structure may not be visibly physically damaged but also may not fully function as intended due to non-structural reasons. Additionally, the rating system for erosion/deposition does not allow for rating both erosion and deposition for the same structure. To improve clarity of future structure assessments, we recommend the following:
    - Rate erosion and deposition separately for each structure.
    - Add an additional rating for structural integrity, "1B" that recognizes a structure is intact with no visible damage but that may not be functioning for reasons other than structural integrity.

- In addition to the structural and erosion/deposition rapid assessment ratings of toe wood structures, past photos of the structures from 2018 and 2019 should be used to evaluate any changes during future monitoring. Particularly, these photos will be useful to monitor potential ongoing erosion of toe wood 2 and any potential changes in toe wood 3 where wider spacing between logs was observed.

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APPENDIX A.1. COORDINATES OF PHOTO POINTS

TABLE A.1.1. Photo point coordinates.

Original Stantec photo point name (2016)	Current WGFD photo point name (2017)	CRS: NAD1983 UTM Zone 13N				Notes
		Stantec coordinates		WGFD coordinates		
		2016 Easting	2016 Northing	2018 Easting	2018 Northing	
WYBLVD_01	NA	387980	4742330	NA	NA	Discontinued - redundant with Morad Park 5
WYBLVD_02	WY-1	388133	4742450	388132	4742449	Stantec photo points were re-numbered starting with WYBLVD-02 as WYBLVD-01
WYBLVD_03	WY-02	388157	4742550	388204	4742602	re-numbering; also moved closer to stream channel in 2017
WYBLVD_04	WY-3	388191	4742810	388232	4742799	re-numbering; also moved closer to stream channel in 2017
WYBLVD_05	WY-4	388147	4743000	388146	4743004	re-numbering
WYBLVD_06	WY-5	387773	4743170	387783	4743161	re-numbering
WYBLVD_07	WY-6	388108	4742340	388090	4742332	re-numbering
WYBLVD_08	WY-7	388235	4742410	388242	4742431	re-numbering
WYBLVD_09	WY-8	388332	4742750	388331	4742746	re-numbering; also moved closer to stream in 2017
WYBLVD_10	WY-09	388306	4742910	388285	4742949	re-numbering; also moved further downstream in 2017 - not sure why
WYBLVD_11	NA	387833	4743230	NA	NA	Discontinued - redundant with new WYBLVD-10
WYBLVD_12	WY-11	387967	4743020	387966	4743018	re-numbering

WYBLVD_13	WY-10	387803	4743230	387802	4743231	re-numbering; coordinates not in Trimble.
WYBLVD_14	WY-12	387987	4743090	387986	4743094	re-numbering

APPENDIX A.2. – STRUCTURE RAPID ASSESSMENT DATA

TABLE A.2.1 – Rapid assessment ratings for in-stream structures (Miller and Kochel 2013).

Ranking	Description
(A) Rankings used to classify in-stream rock or log structures for structural integrity	
Intact (1)	No visible damage; fully operational in terms of integrity
Damaged (2)	Structure functions as intended, but at least 10 % of structure visibly damaged; usually involved movement of one or more boulders
Impaired (3)	Structural components in general location of original structure, but feature no longer functions as intended; 25–75 % of structure remaining
Failed (4)	Significant parts (>75 %) have been removed from site; severely fragmented; incapable of achieving intended objective

Rating	Description	
	Erosion	Deposition
(B) Ranking system used to categorize structures for unintended erosion or deposition		
0	None visible	None visible
1	Minor localized erosion along margins of feature; structure maintains continuity with bank and bed; undermining of footings	Minor deposition over center of structure; pool remains well-defined
2	Localized erosion visible, which is likely to continue. Eroded area likely to influence flow	Deposition along 25–50 % of structure in channel; pool poorly developed and/or partially filled
3	Structure remains in contact with bank, but erosion has occurred along entire zone of contact with bank. Unintended erosion of channel bed must exceed 50 cm and be clearly related to the structure	Deposition occurs long 50–75 % of structure's length in channel; pool very weakly defined or filled
4	Structure partially detached from bank; complete detachment eminent; feature no longer functions as intended	Sediments bury 75–90 % of structure in channel; no pool present
5	Structure completely detached from bank; no longer performs function intended	Sediments bury 90–100 % of structure in channel; no pool present

Structure	Description
(C) Ranking system used to evaluate the performance of rootwads	
0	No visible erosion
1	Rootwads intact, but minor localized erosion visible around <25 % of root mass
2	Erosion visible around 25–90 % of root mass; stump remains buried, or as presumed to be at time of construction
3	Erosion around entire rootwad; stump locally exposed
4	Erosion around entire rootwad, exposing stump; rootwad no longer located along bank, but extends into channel and effects local flow field
5	Erosion has exposed most of buried stump; rootwad located in channel and affects flow field

APPENDIX A.3. – STREAM FLOW DATA

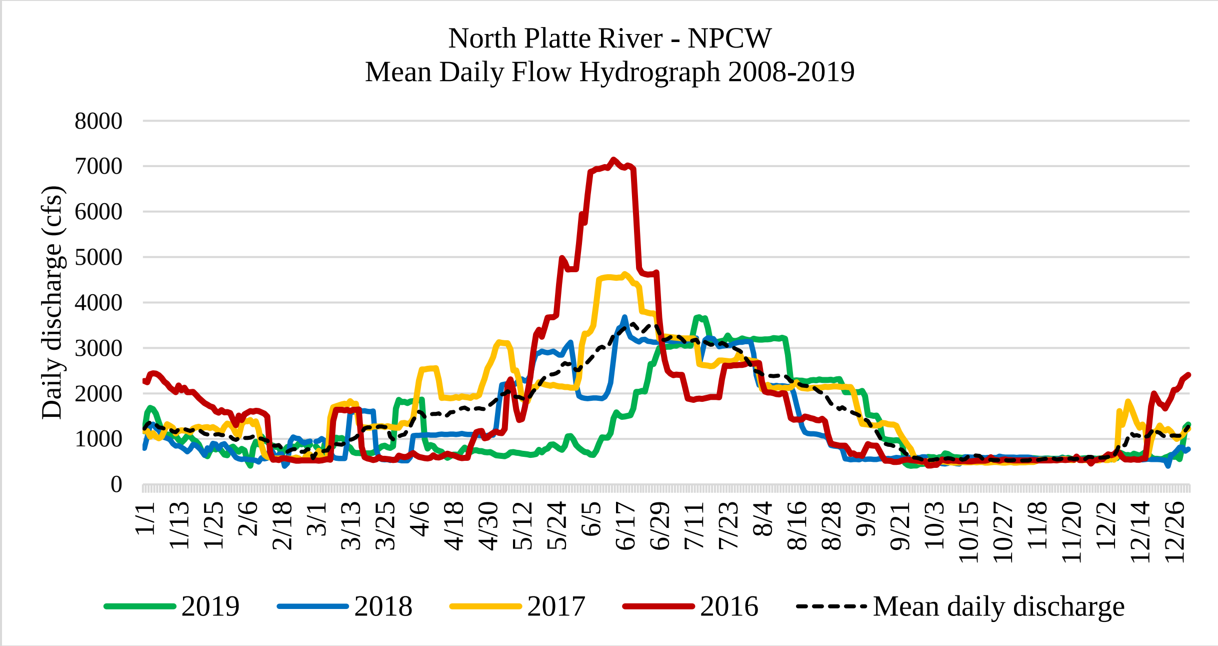

FIGURE A.3.1. Mean daily flow at the Bureau of Reclamation (BOR) station NPCW. The mean daily average uses flow data from 2008-2019.

APPENDIX A.4. MONITORING PHOTOS

Three sets of photos are provided in Figures A.4.1 – A.4.12 for each photo point. The top row of photos shows as-built conditions from fall 2016. The middle row of photos shows the same location in fall 2019, three years post-restoration. The bottom row shows the same locations in summer 2019.

FIGURE A.4.1. Views from photo point WY-1 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.2. Views from photo point WY-2 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.3. Views from photo point WY-3 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.4. Views from photo point WY-4 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.5. Views from photo point WY-5 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.6. Views from photo point WY-6 looking upstream (left), across (middle), and downstream (right).

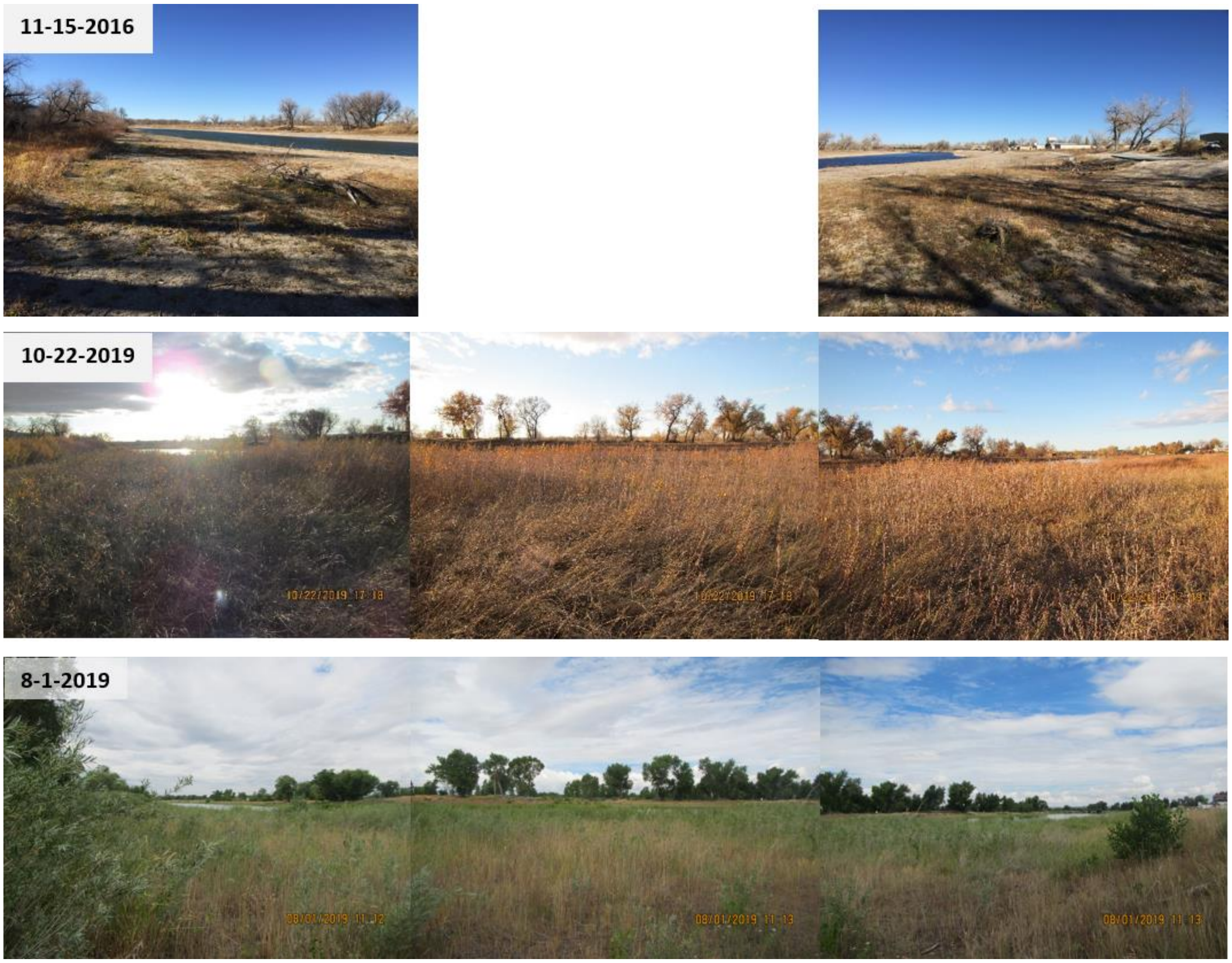

FIGURE A.4.7. Views from photo point WY-7 looking upstream (left), across (middle), and downstream (right).

FIGURE A.4.8. Views from photo point WY-8 looking upstream (left), across (middle), and downstream (right).

FIGURE A.4.9. Views from photo point WY-9 looking upstream (left), across (middle), and downstream (right).

FIGURE A.4.10. Views from photo point WY-10 looking upstream (left), across (middle), and downstream (right). The top row of photos were taken prior to restoration. No photos of the as-built condition of the site were found.

FIGURE A.4.11. Views from photo point WY-11 looking downstream (left), across (middle), and upstream (right).

FIGURE A.4.12. Views from photo point WY-12 looking downstream (left), across (middle), and upstream (right).

APPENDIX A.5. PHOTOS OF INSTREAM STRUCTURES

FIGURE A.5.1. Site 2 & 3 - Wyoming Blvd, standing near upstream end of toe wood 1, looking downstream.

FIGURE A.5.2. Site 2 & 3 - Wyoming Blvd, standing at downstream end of toe wood 1, looking upstream. Willows have established well above the structure, contributing to long-term bank stability.

FIGURE A.5.3. Site 2 & 3 - Wyoming Blvd, standing upstream of toe wood 2, looking downstream.

FIGURE A.5.4. Site 2 & 3 - Wyoming Blvd, standing at downstream end of toe wood 2, looking downstream.

FIGURE A.5.5. Site 2 & 3 - Wyoming Blvd, at middle of toe wood 3 in-stream, looking at upstream half of toe wood 3.

FIGURE A.5.6. Site 2 & 3 - Wyoming Blvd, at the middle of toe wood 3 in-stream, looking at downstream half of toe wood 3.

FIGURE A.5.7. Site 2 & 3 - Wyoming Blvd, standing at middle of toe wood 4, looking upstream at upper half of toe wood 4.

FIGURE A.5.8. Site 2 & 3 - Wyoming Blvd, standing downstream of toe wood 4, looking upstream at toe wood 4.

FIGURE A.5.9. Site 2 & 3 - Wyoming Blvd, standing near upstream end of toe wood 5, looking downstream.

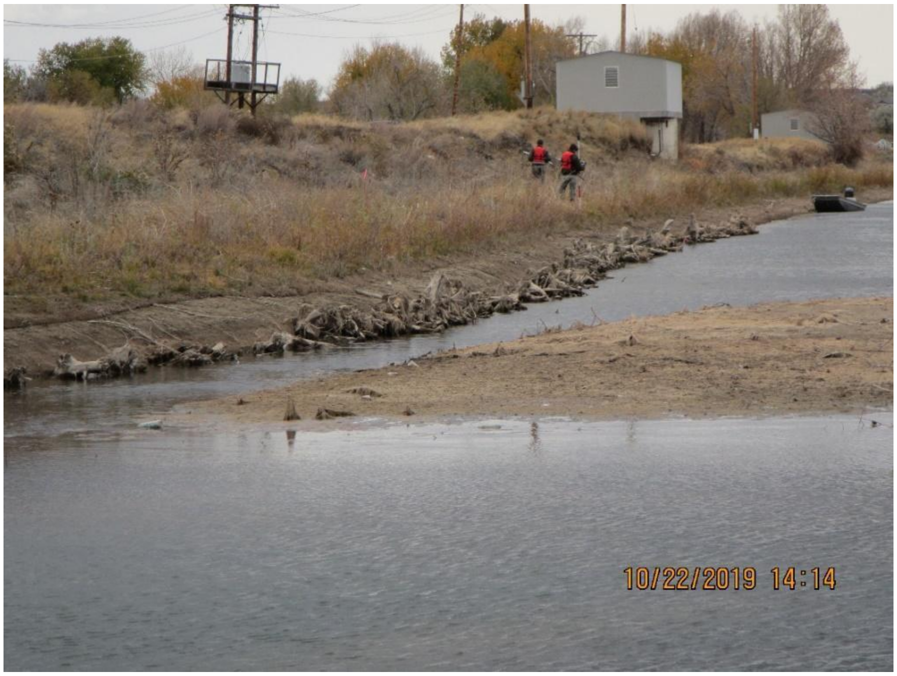

FIGURE A.5.10. Site 2 & 3 - Wyoming Blvd, standing in-stream, near upstream end of toe wood 5, looking downstream at lower half of toe wood 5.

FIGURE A.5.11. Site 2 & 3 - Wyoming Blvd, standing downstream of rock vane 1 on river right, looking upstream.

FIGURE A.5.12. Site 2 & 3 - Wyoming Blvd, standing just upstream of rock vane 2 on river right, looking downstream at rock vane 2 (rocks not visible in photo).

FIGURE A.5.13. Site 2 & 3 - Wyoming Blvd, standing just downstream of rock vane 3 on river right, looking upstream at rock vane 2. The two individuals are standing on the first and last visible boulders of rock vane 3. This photo is from October 2018, as the boulders could not be located in 2019.

FIGURE A.5.14. Site 2 & 3 - Wyoming Blvd, standing at rock vane 4 on river right, looking slightly upstream, in direction of rock vane 4. Boulders in the vane are visible near the bank.

FIGURE A.5.15. Site 2 & 3 - Wyoming Blvd, standing just upstream of rock vane 4 on river right, looking slightly downstream, in direction of rock vane 4. The vane's influence on streamflow is visible at these flows past the channel center.

FIGURE A.5.16. Site 2 & 3 - Wyoming Blvd, standing upstream of rock vane 5 on river left, looking downstream, in at rock vane 5.

FIGURE A.5.17. Site 2 & 3 - Wyoming Blvd, standing at rock vane 5 on river left, looking across.

FIGURE A.5.18. Site 2 & 3 - Wyoming Blvd, at middle of upstream wetland along Wyoming Boulevard, looking upstream.

FIGURE A.5.19. Site 2 & 3 - Wyoming Blvd, at middle of upstream wetland along Wyoming Boulevard, looking downstream.

FIGURE A.5.20. Site 2 & 3 - Wyoming Blvd, at upstream set of wetland cross vanes, looking at cross vane 37.

FIGURE A.5.21. Site 2 & 3 - Wyoming Blvd, at upstream set of wetland cross vanes, looking at cross vane 38.

FIGURE A.5.22. Site 2 & 3 - Wyoming Blvd, at upstream set of wetland cross vanes, looking at cross vanes 39A (middle) and 39B (closest). Cross vane 38 is also visible (furthest).

FIGURE A.5.23. Site 2 & 3 - Wyoming Blvd, at downstream set of wetland cross vanes, looking up at cross vanes 40,41, and 42.

FIGURE A.5.24. Site 2 & 3 - Wyoming Blvd, at downstream set of wetland cross vanes, looking up at cross vane 40.

FIGURE A.5.25. Site 2 & 3 - Wyoming Blvd, at downstream set of wetland cross vanes, looking up at cross vane 41.

APPENDIX A.6. LONGITUDINAL PROFILE AND CROSS-SECTIONS

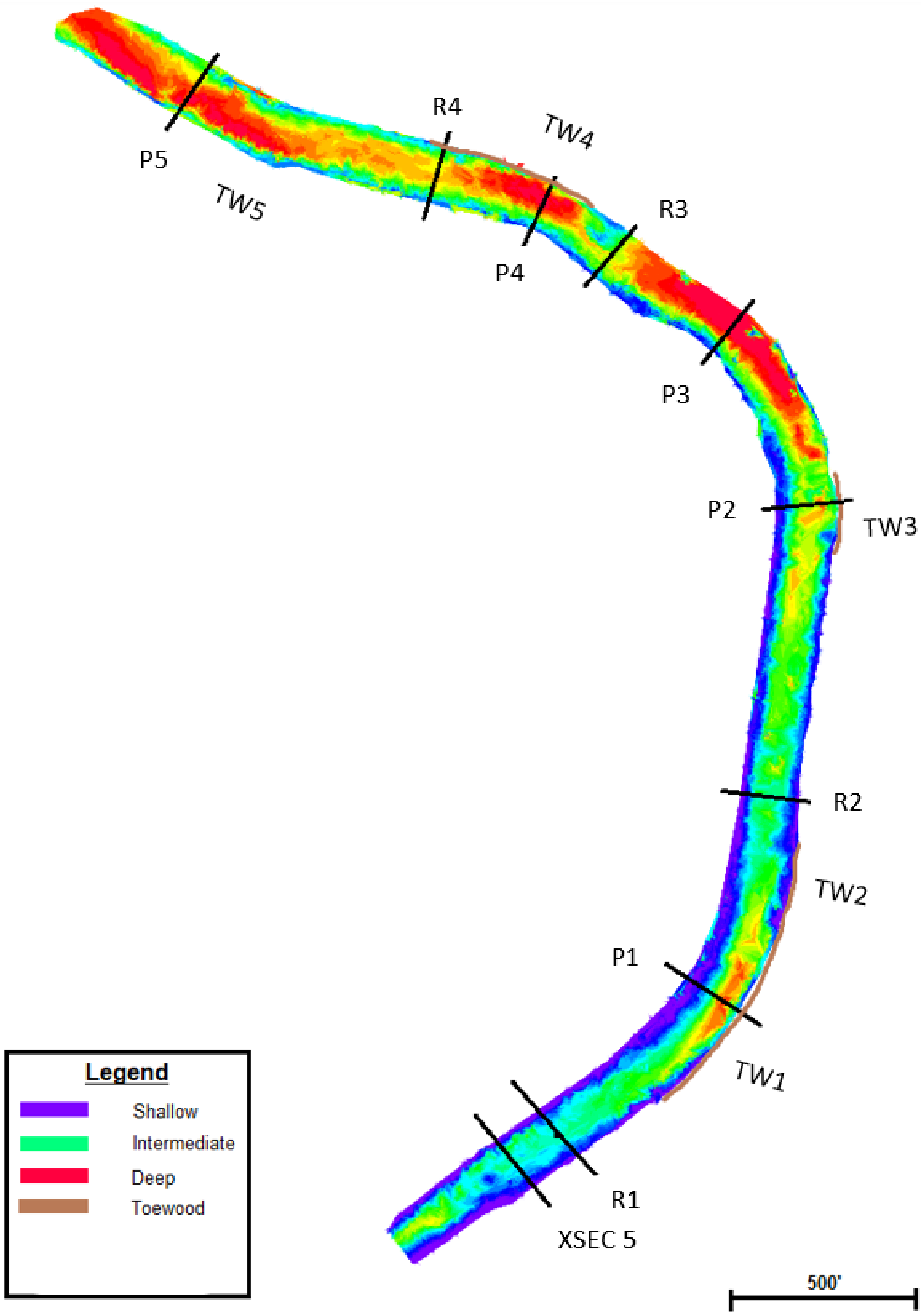

FIGURE A.6.1. – Bathymetry data of the Wyoming Blvd project reach. R represents riffles and P represents pools that were identified as potential locations for surveying cross-section profiles. TW represents toe wood features.

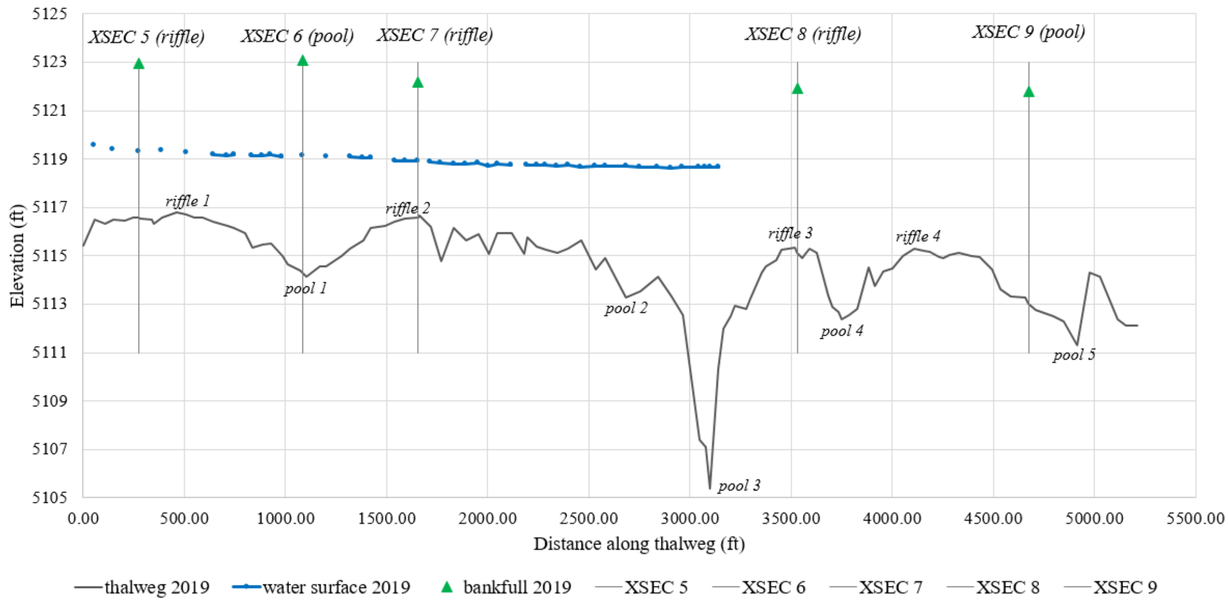

FIGURE A.6.2. – The longitudinal profile of the Wyoming Blvd project reach in October 2019, identified pools and riffles, and the locations of the five surveyed cross-sections.

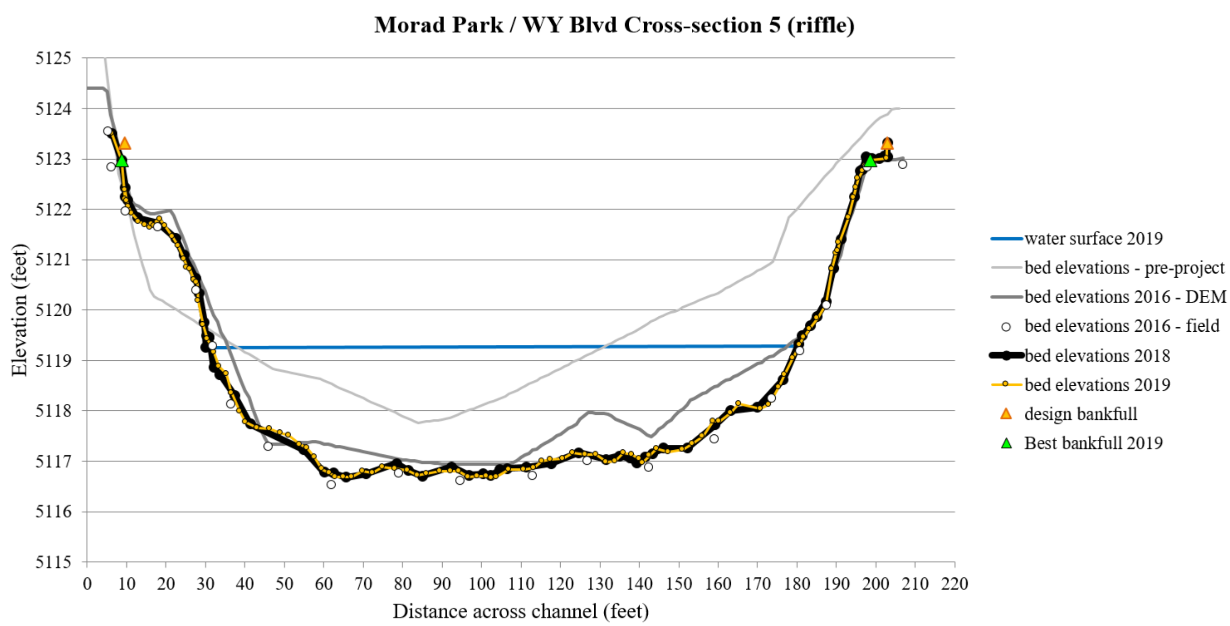

FIGURE A.6.3. – Profile of river bed and bank elevations at cross-section 5 in 2016 - 2019 and before construction.

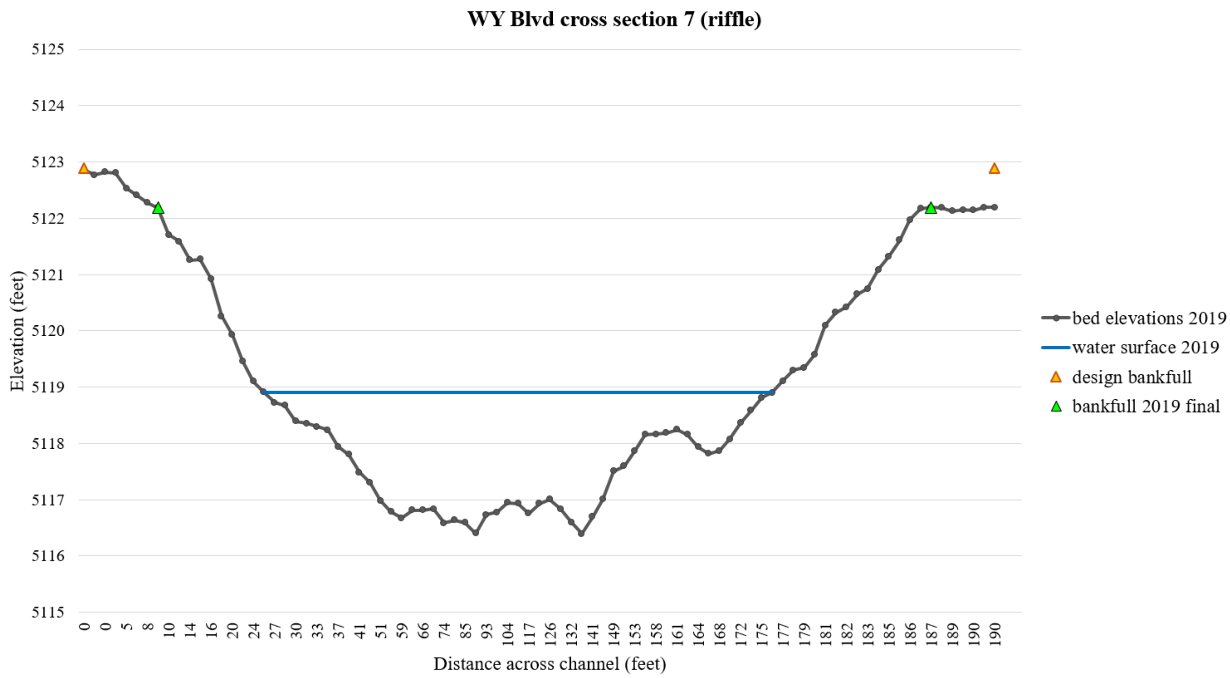

FIGURE A.6.4. – Profile of river bed and bank elevations at cross-section 7 in 2019.

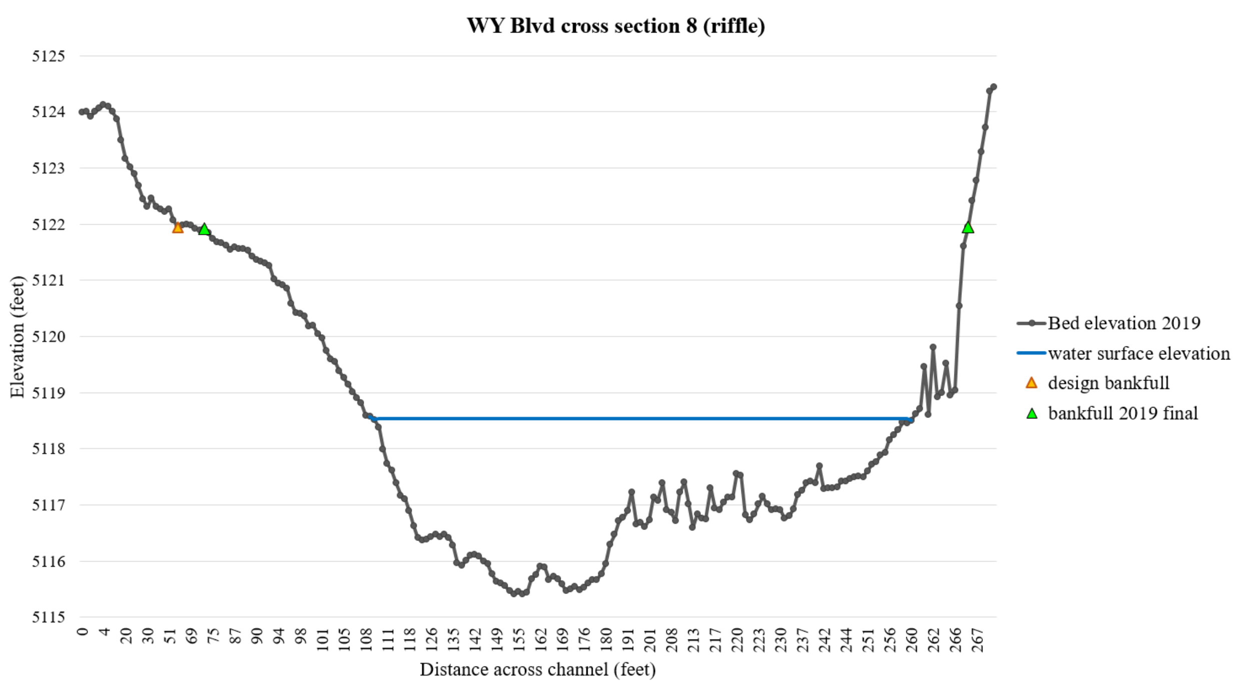

FIGURE A.6.5. – Profile of river bed and bank elevations at cross-section 8 in 2019.

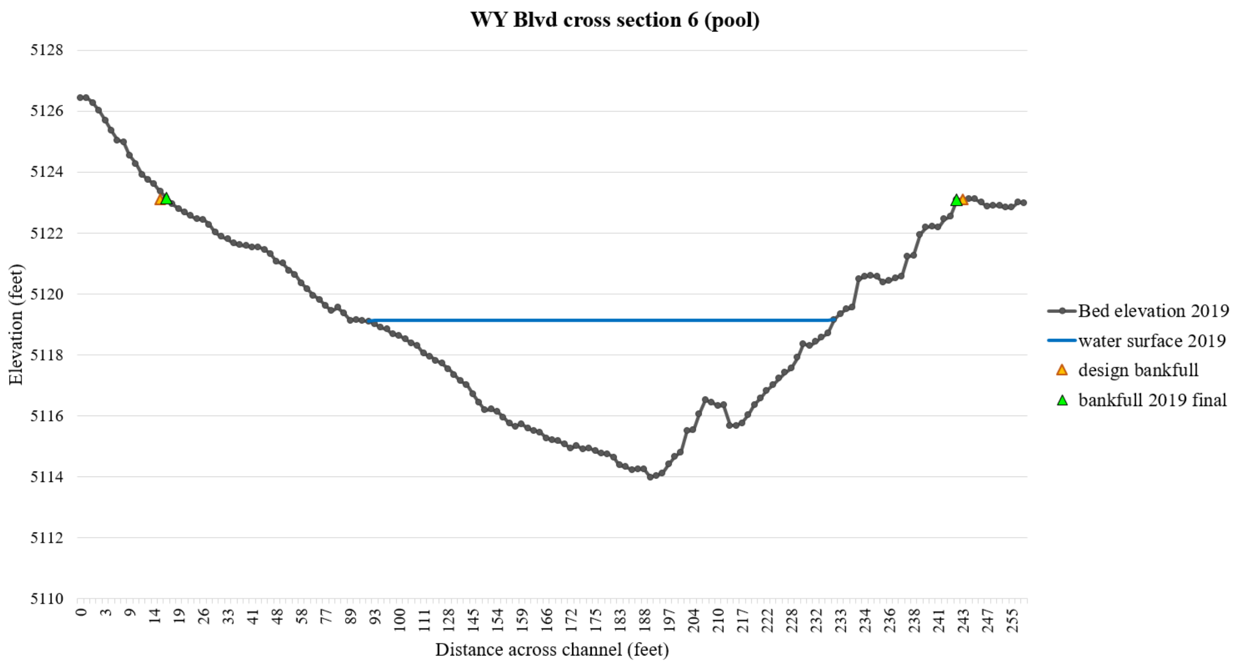

FIGURE A.6.6. – Profile of river bed and bank elevations at cross-section 6 in 2019.

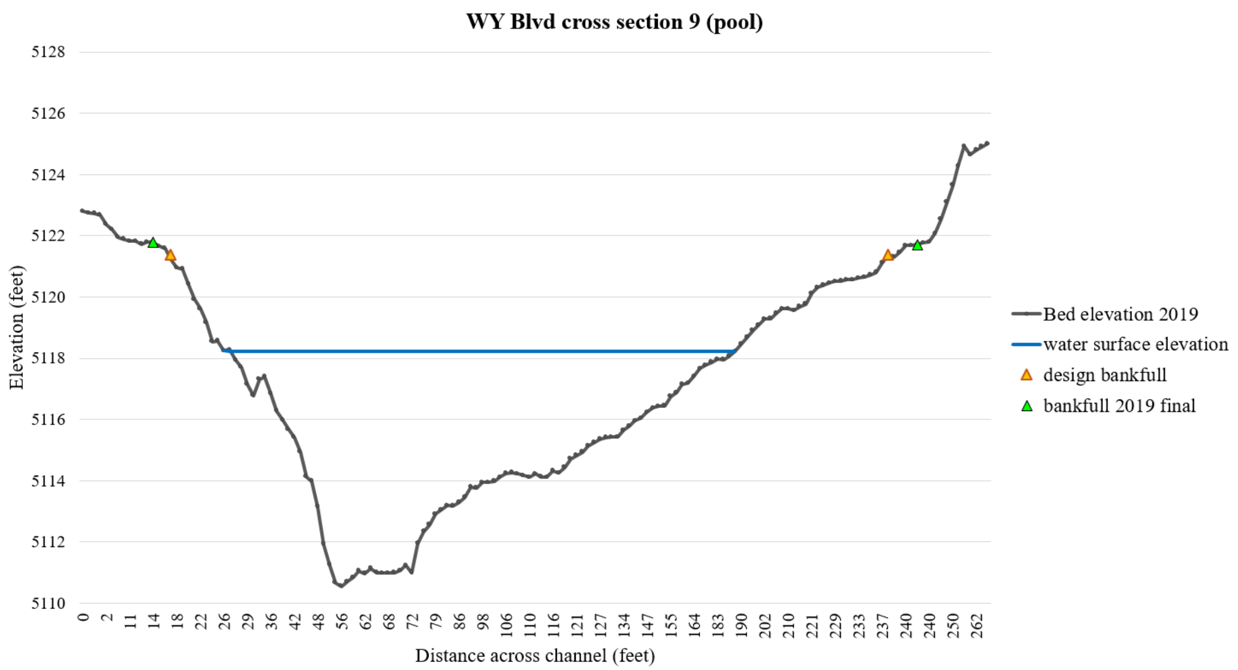

FIGURE A.6.7. – Profile of river bed and bank elevations at cross-section 9 in 2019.