PURGATOIRE RIVER ASSESSMENT REPORT: PART 1

RIVER HABITAT, HYDROLOGY/HYDRAULICS AND FISHERY BIOLOGY ASSESSMENT

2019-2020

Prepared By:

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EXECUTIVE SUMMARY

In 2011, Fin-Up Habitat Consultants completed the report *Assessment of Current River Condition & Fisheries Enhancement* for the Purgatoire River as it flows from Trinidad Dam to the Highway 350/160 bypass. That assessment recognized the potential to create a seasonal "put and take" fishery within the city limits of Trinidad by creating velocity shelter, in-channel holding cover, and additional useable habitat for stocked trout during the high summer flow season (April through October). Habitat work would also enhance recreational angling opportunities (access and facilities) and improve bank stability. The report concluded that low winter flows precluded establishment of a year-round, self-sustained fishery. Instream and riparian habitat was subsequently improved in 1.5 miles of river from 2012-2017.

In 2019-2020, this River Assessment effort was conducted to determine the effectiveness of those habitat improvements and overall current river conditions; determine how best to manage winter flows to create a self-sustained fishery; and conduct a fishery biology assessment. Assessment results were analyzed and recommendations made for future work.

Effectiveness of Habitat Enhancement Efforts & River Condition Assessment
The efficacy of previous habitat enhancement efforts was assessed through habitat mapping (Reach 5 only) and geomorphic and photo-point surveys. Velocity shelter, cover, and useable habitat were found to have improved in all three river reaches (3-5), and river form (narrower and more sinuous) and function (sediment transport) improved as well. Habitat diversity improved in all meso-habitats (pool, riffle, and glide) creating the physical habitat necessary to survive and grow trout throughout the year; but natural reproduction, necessary for a self-sustained trout fishery, is absent.

Flows for Fish Assessment
This effort focused on determining how to best manage winter flows to create a self-sustained fishery. R2 Cross (Espegren 1996) was used to determine the appropriate minimum instream flow necessary to sustain a trout fishery through natural trout reproduction. A winter flow (October 16-March 31) of 20.6 cfs (approximately 6922 acre-feet) would be required, measured at the Trinidad gauge. A lesser flow may be appropriate, with significant and large-scale channel modification, but is not recommended.

Fishery Biology Assessment
A rivers fish population is a product of its habitat and potential human influence on this habitat; determining species present and their ability to survive, grow, and reproduce. Fishery management attempts to identify and correct the factors that limit, in this case, trout viability in the Purgatoire River within the Project Area. This Fishery Biology Assessment was conducted to determine if management actions could be implemented to solve habitat bottlenecks with the goal of creating the best trout fishery possible.

Velocity shelter, cover, and useable habitat have significantly improved in restored reaches. Trout are surviving to successive age-classes and growth is good, but numbers remain low and they are not reproducing, in spite of liberal stocking. Several native, nongame species are also present, typical of a fishery transitioning to warm water habitat.

Flows for Fish Recommendations

Life history requirements for brown and rainbow were overlaid with flow management targets to develop an annual flow operation recommendation. Maintaining an appropriate winter minimum flow is necessary to enhance trout survival and growth but is critical to establishing a self-sustained trout fishery. This is the highest priority management action necessary to profoundly improve the fishery. Incubating eggs are extremely susceptible to dewatering and desiccation under current winter flow operations. The presence of adult trout, but complete absence of juvenile trout, is premia fascia evidence of poor incubation habitat for both trout species. A minimum winter (October 16-March 31, non-irrigation season) flow of 20.6 cfs is needed to fulfill trout egg incubation requirements. Additionally, an abrupt and dramatic flow increase in April-May renders newly emerged brown and rainbow trout fry vulnerable to "blow out" from elevated flow.

It is important to make flow changes gradually throughout the year. High and fluctuating summer flows are of concern, for example. Flows well above baseline occur throughout the irrigation season from May-October, often accompanied by dramatic daily change. Flows of this nature can be extremely impactful to newly emerged fry but also can have profound impact on juvenile to adult trout physiology, life function and behavior. Other aquatic biota (e.g. macroinvertebrates) is similarly impacted as is channel stability (e.g. bank erosion). The entire aquatic ecosystem is vulnerable to such extreme and variable flow events. Attempts should be made to moderate high flow releases throughout the year. A reasonable ramping policy should be developed that allows water managers to meet downstream obligations while protecting aquatic life and their habitat. To this end, flow changes should not exceed 25% per day. This pertains to any anthropogenic flow change, either up or down, throughout the year.

Habitat Enhancement Recommendations

The Purgatoire River naturally warms as it progresses to the plains below Trinidad Reservoir. Trout seek out deeper, colder water refugia during these circumstances. Habitat work to create summer refugia (also of benefit in the winter) should be considered, recognizing that flow management is of highest priority. It is also paramount to maintain current riparian and floodplain function, enhancing overall river health and cooling through overhead cover and shading. Any actions that degrade overhead cover should be avoided and efforts to enhance it (e.g. bank stabilization, invasive species removal, native species planting, jetty jack remediation) should be encouraged.

Additional Recommendations

Other recommended actions include the following. The Picketwire Ditch diversion dam should be modified to allow for upstream fish movement. Cooperate with private landowners to enhance instream and riparian habitat in Reach 6 and secondarily discuss public access opportunities. There is considerable bank erosion and channel thread movement in reaches 1 and 2 as well. Habitat actions to correct these issues should be considered. Institute Project Area river enhancement efforts if fish population objectives are not met by the Winter Flow Program (e.g. "channel within a channel" modifications).

The fishery in the Purgatoire River within the Project Area should be managed to create a self-sustained brown trout fishery. Fingerling brown trout should be planted to accomplish this goal. Catchable (10 inch plus) rainbow trout should also be stocked to create a "put and take" and diverse trout fishery. Biennial fish surveys are recommended to assess trout survival, growth, and reproduction relative to flow management changes and stocking protocol.

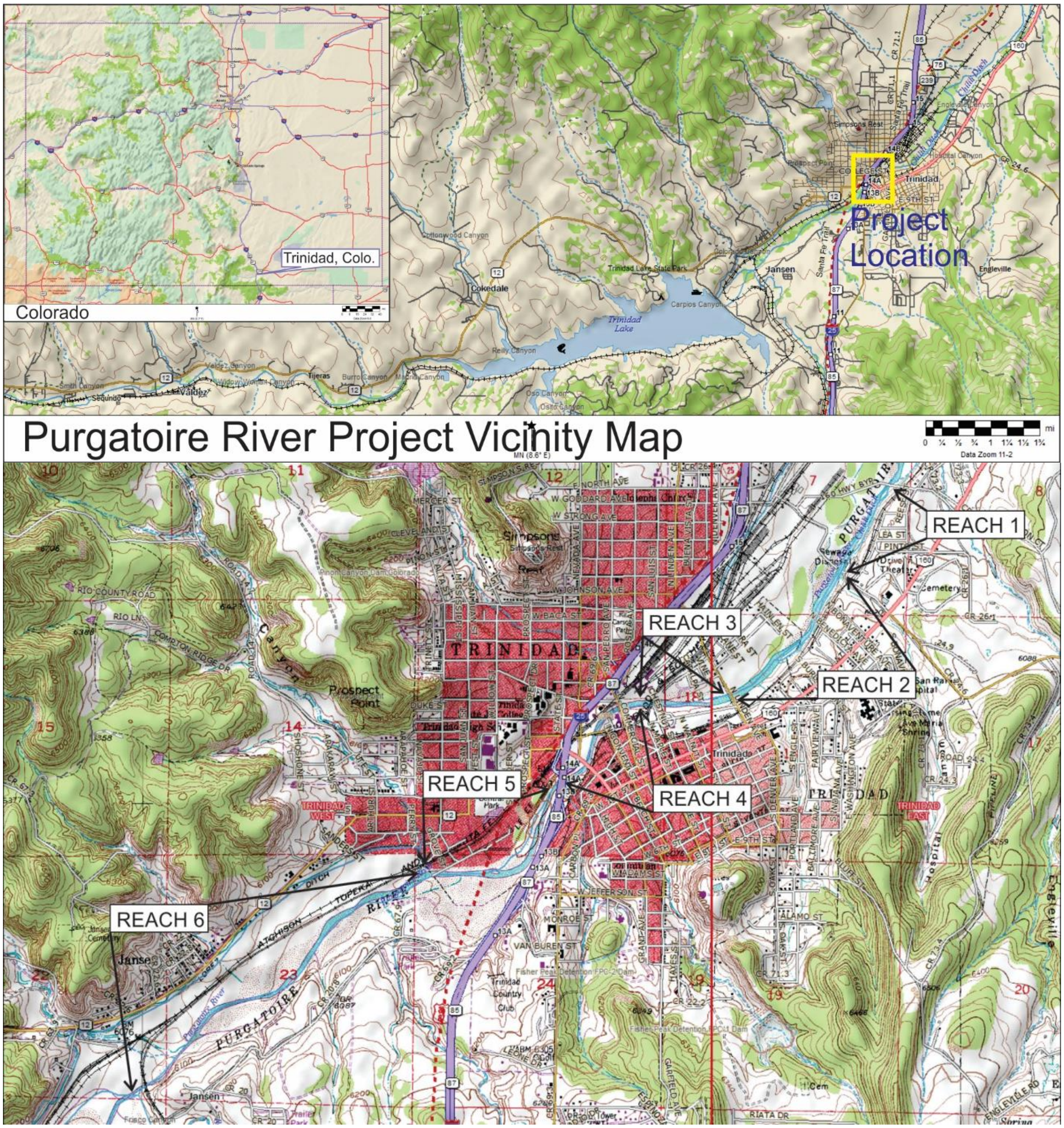
Effectiveness of Habitat Enhancement Efforts & River Condition Assessment

Introduction

In 2011, Fin-Up Habitat Consultants completed the report *Assessment of Current River Condition & Fisheries Enhancement* for the Purgatoire River as it flows from Trinidad Dam to the Highway 350/160 bypass, which represents the 4.5 miles of river in the project area. This Assessment recognized the potential to create a seasonal "put and take" fishery within the city limits of Trinidad by creating velocity shelter, in-channel holding cover, and additional useable habitat for stocked trout during the high summer flow season (April through October). The report concluded that low winter flows precluded establishment of a year-round, self-sustained fishery. A project would also enhance recreational angling opportunities (access and facilities) and improve bank stability as stated in the 2017, Fin-Up Habitat Consultants Final Report entitled *Trinidad/Purgatoire River, Reach 5 – Boulevard Addition, Aquatic Habitat Enhancement Project*.

Since the development of the plan, in-stream habitat structures, including cross-vanes, J-hooks, and boulder clusters, have been installed by Chaparral Construction in approximately 1.5 miles of river (Reaches 3-5). Reach 4 was completed in 2012, Reach 3 in 2014, and Reach 5 in 2017. See Figure 1 for description of Project Reaches. Background and project details for each reach are summarized in the report *Trinidad/Purgatoire River, Reach 5 – Boulevard Addition, Aquatic Habitat Enhancement Project*. In May 2017, river flow reached 2040 cfs, the highest discharge in the project area since Trinidad Dam was constructed. To study the effects of the in-stream structures and flood waters on the river, extensive monitoring was used to evaluate the effectiveness of these structures on improving fish habitat, stabilization of the stream channel, and overall condition of the river. This analysis will also guide future stream management efforts.

Figure 1. Purgatoire River Reach Location Map



Method/Procedure

Detailed monitoring assessments were used to compare habitat conditions prior to and after habitat improvement. Cross-sectional and longitudinal profiles, and pebble counts were completed in the habitat improved reaches (3-5), and photo-point surveys (both baseline and As-Built) were completed in all six river reaches. A detailed topographic survey using survey grade GPS (habitat mapping) was conducted in Reach 5 in 2017 and replicated in 2019. This detailed total station methodology was used to quantify instream habitat features, representing habitat changes elsewhere in the river (Reaches 3-4). Biological data (fish population, fish stocking, water temperature) was also evaluated and will be used to correlate physical habitat to fishery dynamics/life history, and flow related effects on the aquatic ecosystem.

Results and Discussion

Habitat mapping (Reach 5 only), geomorphic, and photo-point surveys were used to determine the efficacy of habitat enhancement efforts (Appendix 1) relative to project goals outlined in the above Introduction.

Aquatic habitat (Basin-Wide Habitat Stream Inventory – BWSHI) was measured and quantified in Reach 5 of the Purgatoire River utilizing the USFS/CPW Winters Protocol (Winters and Gallagher, 1997). All meso-habitat forms (pool, riffle, and glide) were measured and mapped using ArcGIS, and assessed for wetted perimeter, usable area, cover, and bank stability/condition. Reach 5 was first surveyed in May 2015, prior to the habitat improvement project. The survey was repeated two years following the completion of the habitat project in April 2019.

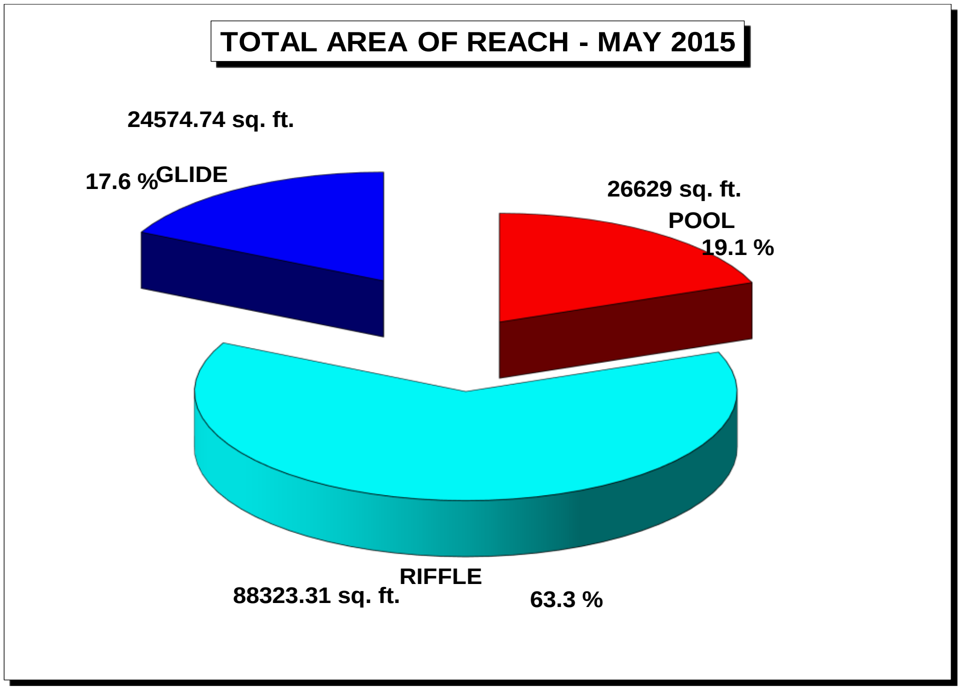
Reach 5 is characterized by a relatively straight channel through depositional material composed mostly of larger gravels, cobble, and small boulders. The reach exhibits a relatively low gradient, and a broad valley bottom with extensive riparian floodplain containing large mature cottonwood galleries. Local sediment sources are typically from failing stream banks along the reach, as well as from Raton Creek upstream of the reach.

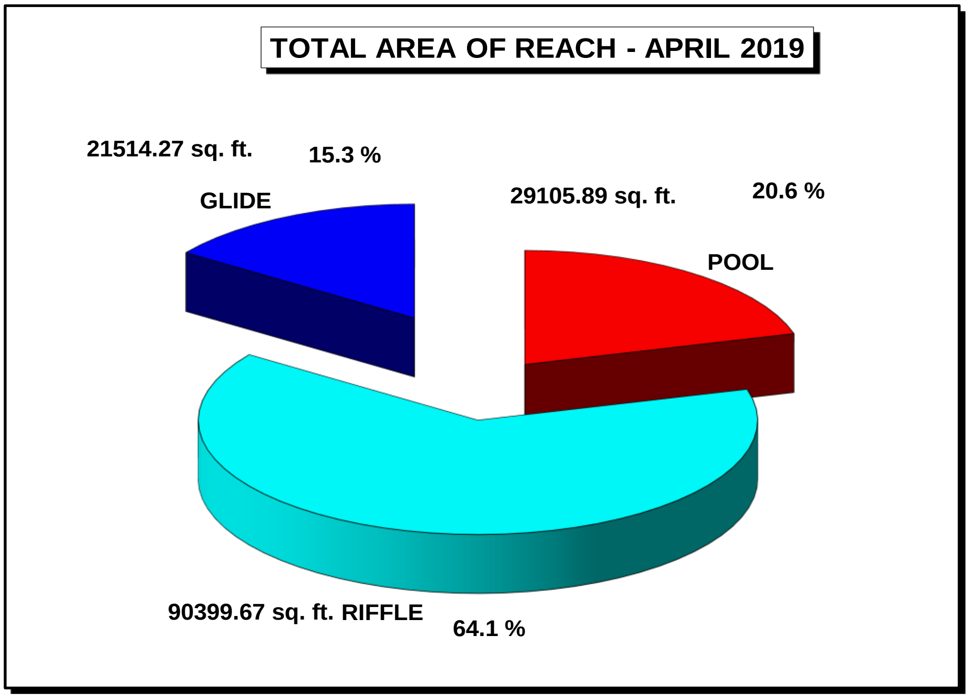
Typical habitat within the Purgatoire River study reach.

In 2019, we observed 34 individual meso-habitats measured in the reach (10 pools, 18 riffles and 6 glides), along a length of 4,208 feet of stream, and comprising a total wetted area of 141,020 ft^2 (see Table 1 for Meso-Habitat Types). Maps of the surveyed habitats are presented on the following pages. The total area of the reach in 2019 consisted of 64% riffles and 21% pools, with the remaining 15% consisting of glide habitat (Figure 2). The relative frequency of meso-habitat was generally unchanged from the 2015 survey (63% riffle, 19% pool, 18% glide). The average wetted width of the stream was 31.6 feet throughout the reach.

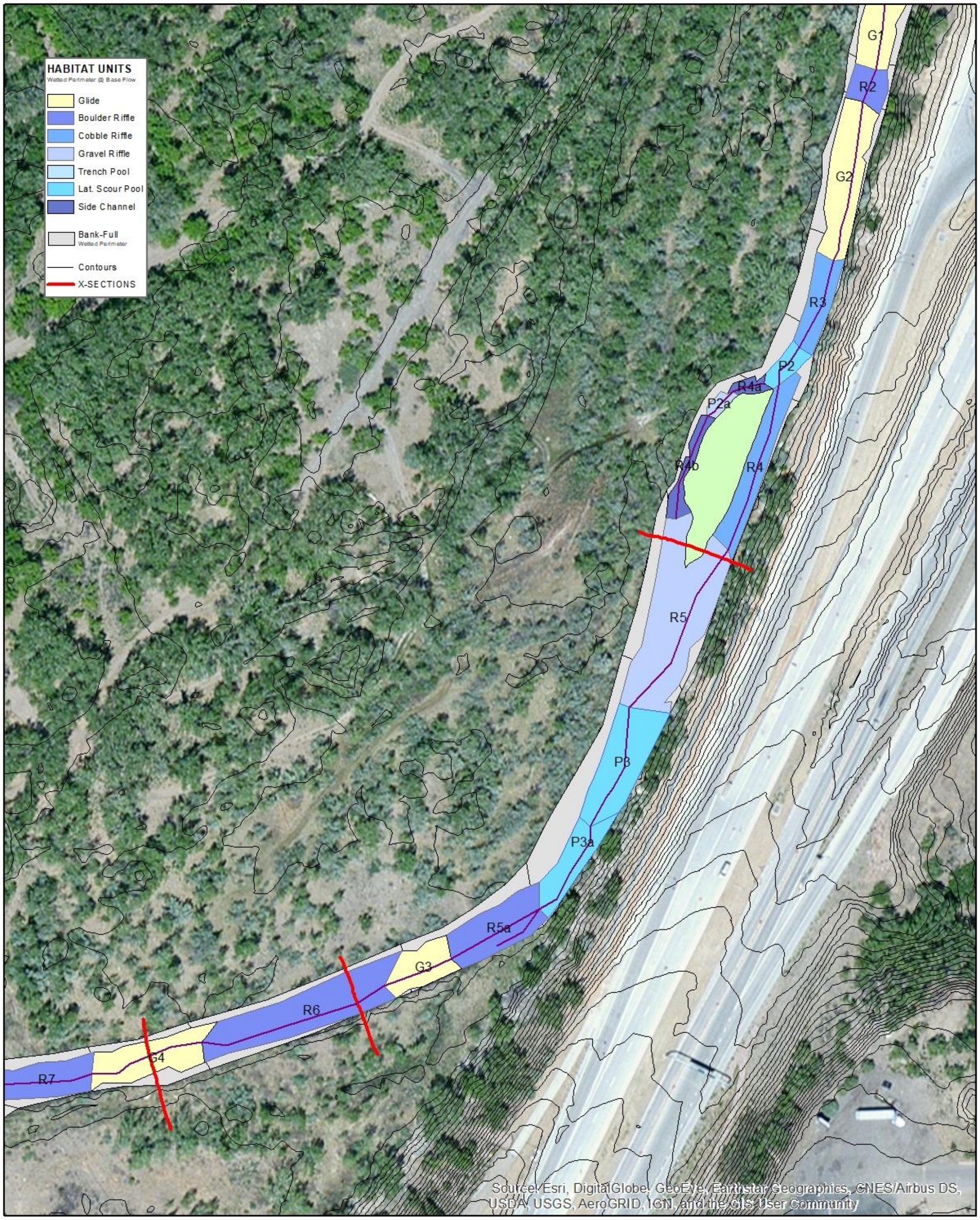
Stream banks were generally stable and vegetated throughout the reach, consisting mostly of alder, sedge, and a few willows. There were 359 feet of actively eroding stream banks contributing sediment directly into the stream. This accounted for approximately 4% of the total length of banks in the reach. The linear footage of eroding banks in the reach was considerably less than what was observed in 2015, when 1,812 ft of eroding banks (21% of the river bank length) were measured.

Figure 2. Distribution of Pool, Riffle and Glide habitats in the study reach on Purgatoire River.

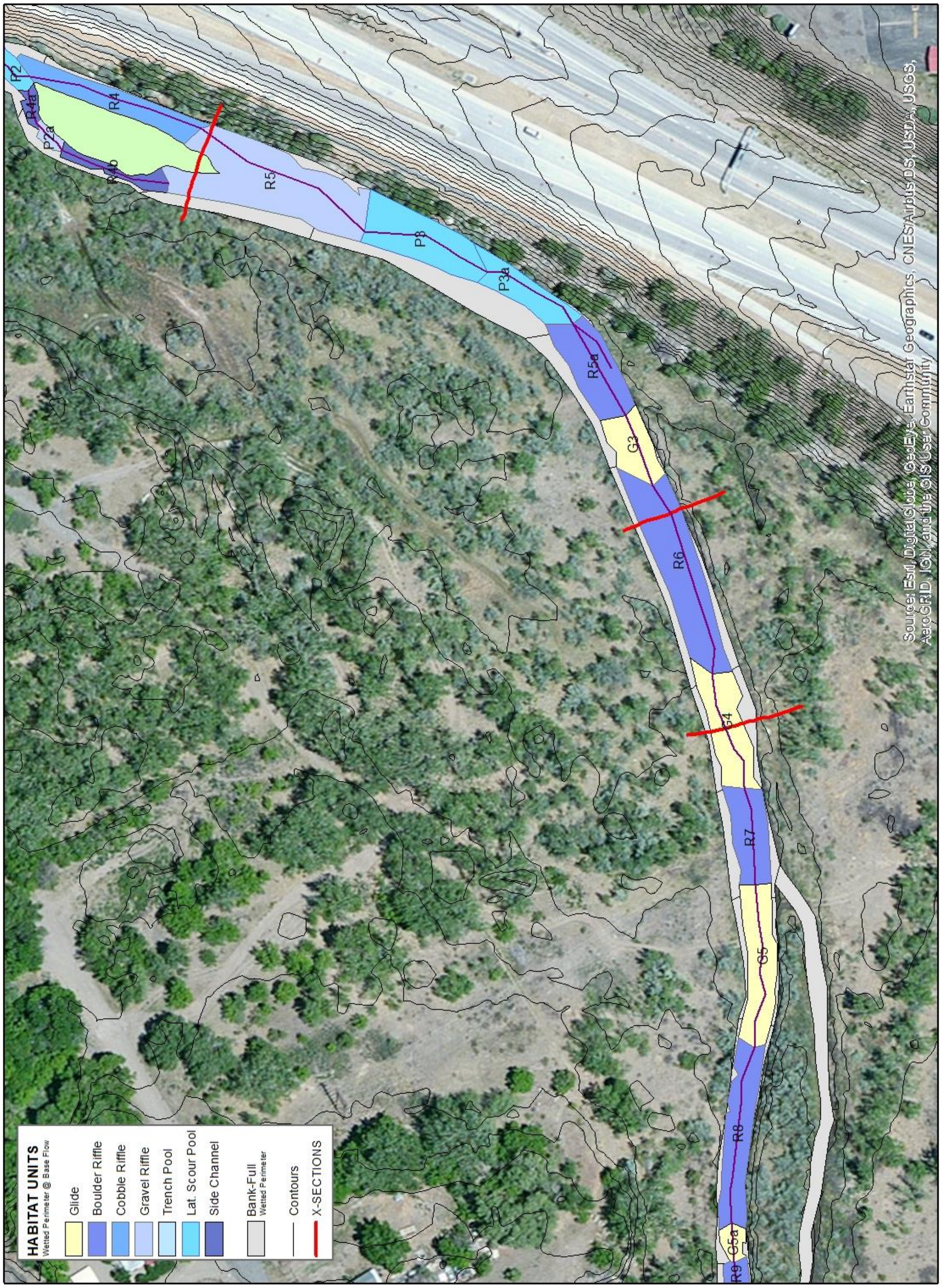




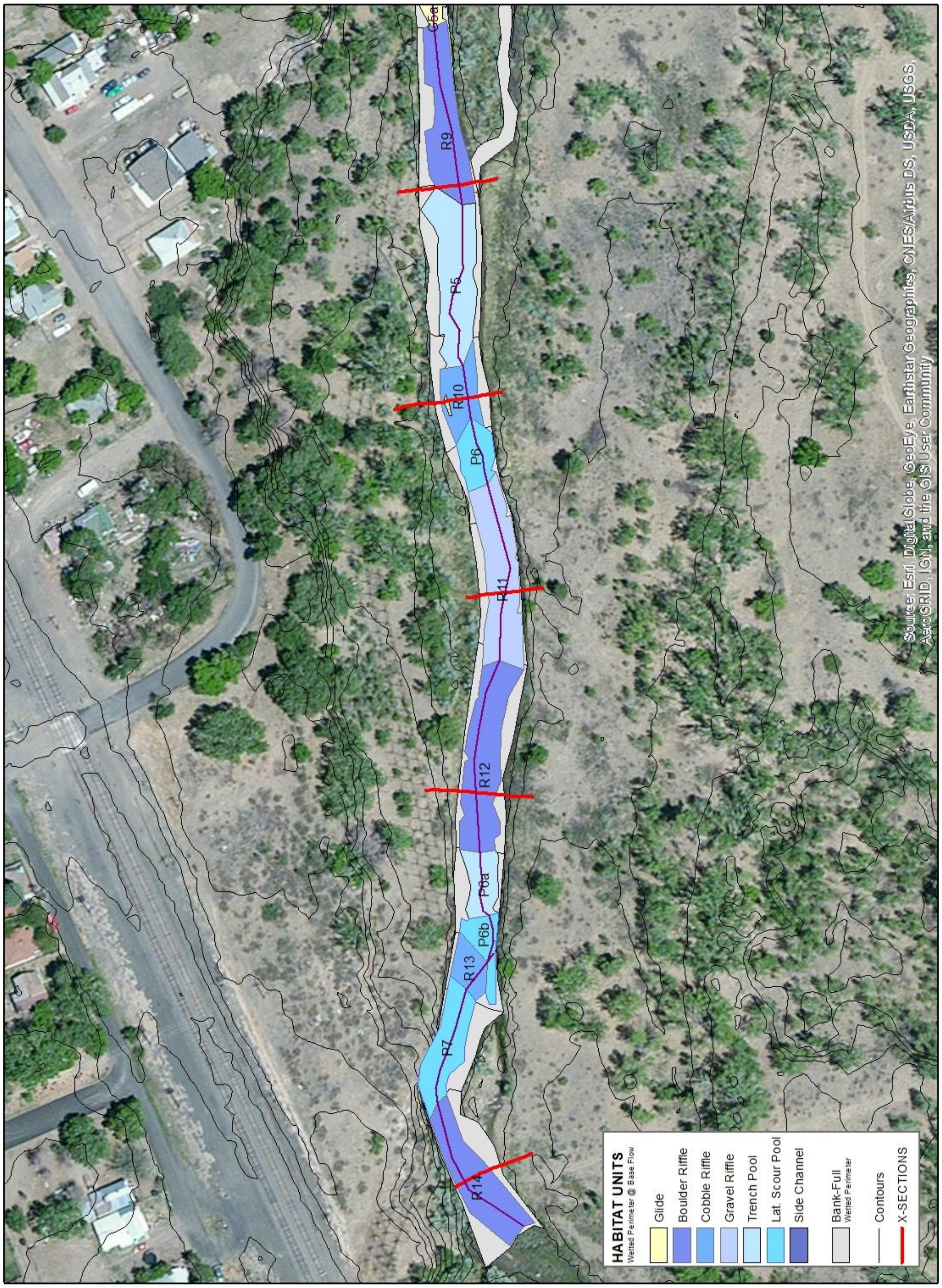
Map 1: Locations of Meso-Habitat Units in the lower half of the Study Reach.



Map 2: Locations of Meso-Habitat Units in the lower middle half of the Study Reach.



Map 3: Locations of Meso-Habitat Units in the upper middle half of the Study Reach.



Map 4: Locations of Meso-Habitat Units in the upper half of the Study Reach.

Table 1. Meso-Habitat Types*

Type #	Meso-Habitat Type	Description
Type 1	Glide	Portions of streams with relatively wide uniform bottoms, low to moderate velocity flows, lack pronounced turbulence, and have substrates usually consisting of either cobble, gravel or sand. Most often found in transition between pool and head of riffle, but are occasionally found in low gradient stream reaches with stable banks and no major flow obstructions. Usually described as stream habitat, with characteristics intermediate between those of pools and riffles
Type 2	Secondary channel pool	Pools found outside of main wetted channel width. During summer, pools may dry up or have little to no flow into them. Usually associated with midchannel bars and may contain deposits of sand and silt. Current velocities are usually very low, compared with the main stream channel velocities. Due to the low velocities, pools may be very important in providing rearing habitat for juvenile and young-of-the-year fish.
Type 3	Backwater pool	Found along channel margins and formed by eddies around obstructions such as boulders, root wads, or woody debris. These pools may be shallow or deep, and are typically dominated by fine-grain substrates. Current velocities are usually low in these pools, and they may be important in providing rearing habitat for juvenile fish.
Type 4	Trench pool	Pools in which the cross-section of the water column is typically U-shaped with bedrock or coarse-grained bottoms flanked by boulder or bedrock walls. Current velocities in trench pools are typically the highest of any pool type and the direction of flow is generally uniform.
Type 5	Plunge pool	Pools created when stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring the downstream substrate, and forming a depression. Water velocities and energy are greatly reduced in these pools. Pools may often be large and deep, and substrate size is highly variable. In disturbed streams, these pools may be significantly impacted due to deposition of sediment and subsequent reduction in depth. In higher gradient headwater tributaries, these habitats are where adult fish are often found, primarily due to reduced velocities, increased depths and availability of cover. They are often the only habitat available in smaller streams for both adult and juvenile fish to overwinter, thus these pools are very important habitats in mountain streams.
Type 6	Lateral scour pool	Occur where stream flow impinges against one streambank or against a partial channel obstruction. The associated scour is generally confined to <60% of the wetted channel width, and obstructions which may be associated with these pools are root wads, woody debris, boulders and bedrock. These pools generally occur in low gradient, meandering streams. Sediment deposition is quite distinct, characterized by bars forming on inside of meander bend. Pools often contain adult fish which utilize overhanging and undercut outer banks of meander for cover and feeding. The macroinvertebrate drift entering these pools from riffles at the point of entrance make these prime habitats for feeding trout.

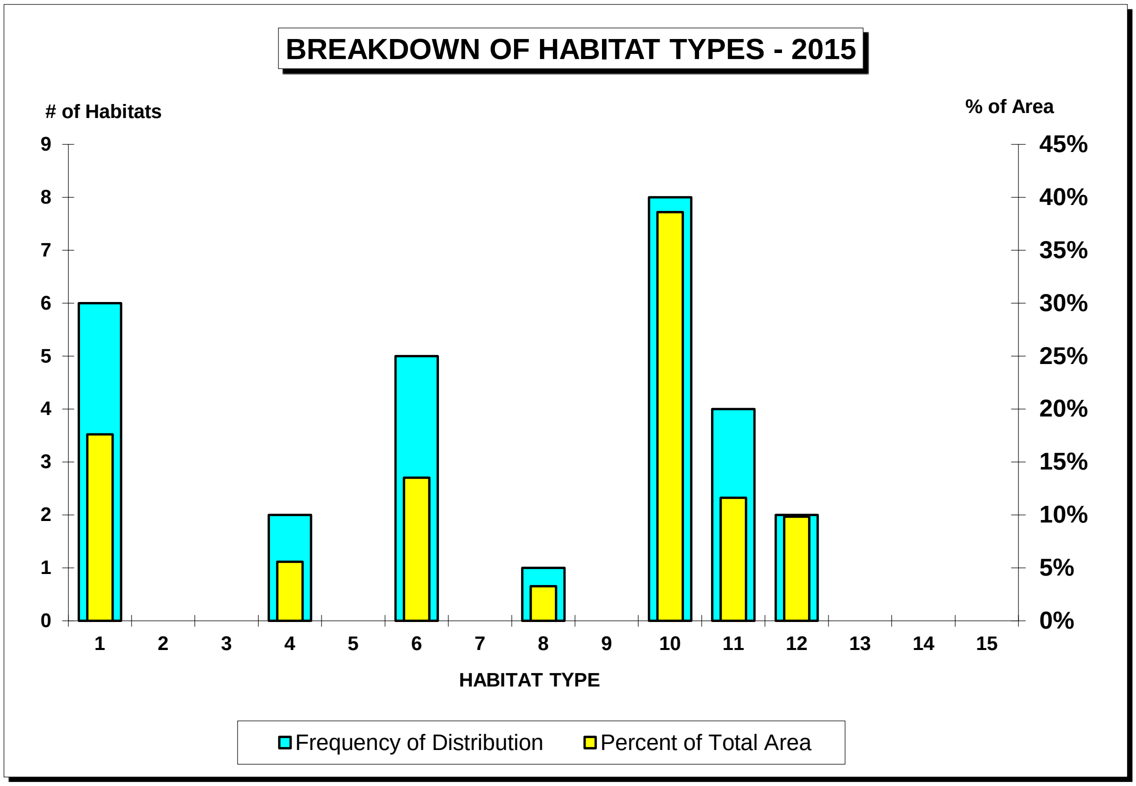
<table>
<tr><td>Type 7</td><td>Dammed pool</td><td>Formed by impoundment of stream flow resulting in complete or nearly complete channel blockage. Dams may be product of debris jams, rock landslides, beaver dams, or man-made structures. The substrates associated with these pools tend toward smaller gravel and sand. Adult and juvenile fish will be found in these pools, which may provide cover, and shelter from excessive velocities. However, these types of pools trap sediment moving down the stream channel, and as a result, dammed pools usually provide adequate cover for only a short period of time, eventually filling and becoming more characteristic of a glide or shallow riffle.</td></tr>
<tr><td>Type 8</td><td>Secondary channel riffle</td><td rowspan="6">Riffles are those areas of the stream in which turbulence in the water column is the major identifying characteristic, as a result of relatively high gradients. These units contain moderately deep to shallow, swift flowing water, and are characterized by boulder or cobble substrates. Riffles are differentiated by being either secondary channels, or by their difference in substrate composition (bedrock, boulder, cobble, gravel, sands and silts). Riffles are very important for macroinvertebrate production, due to the availability of light and oxygen, and the corresponding vegetative growth on the bottom substrate. The quality of riffles, including low sediment deposition and resulting embeddedness can have a direct impact on fish populations. The cleaner and healthier the vegetative growth and benthic macroinvertebrate community, the more food there is for the fish population.</td></tr>
<tr><td>Type 9</td><td>Bedrock riffle</td></tr>
<tr><td>Type 10</td><td>Boulder riffle</td></tr>
<tr><td>Type 11</td><td>Cobble riffle</td></tr>
<tr><td>Type 12</td><td>Gravel riffle</td></tr>
<tr><td>Type 13</td><td>Sand/silt riffle</td></tr>
<tr><td>Type 14</td><td>Rapid riffle</td><td>Riffles associated with high gradients (greater than 4%) with swiftly flowing (greater than 1.5 ft/sec), moderately deep, and highly turbulent waters. These riffles are generally associated with boulder substrates, which protrude through the surface of the water.</td></tr>
<tr><td>Type 15</td><td>Cascade riffle</td><td>Cascades are the steepest riffle habitat unit types, in terms of gradient, in streams. These riffles consist of alternating small waterfalls and shallow pools. Potential habitat for fish in this riffle type is best quantified by calculating the available cover in these small pocket pools, rather than measuring each pocket water as a separate pool. Cascades are characterized by swift current flows and often have exposed rocks and boulders above the water surface, which creates considerable turbulence and surface agitation. The substrate normally found in cascades is bedrock or accumulations of boulders.</td></tr>
</table>

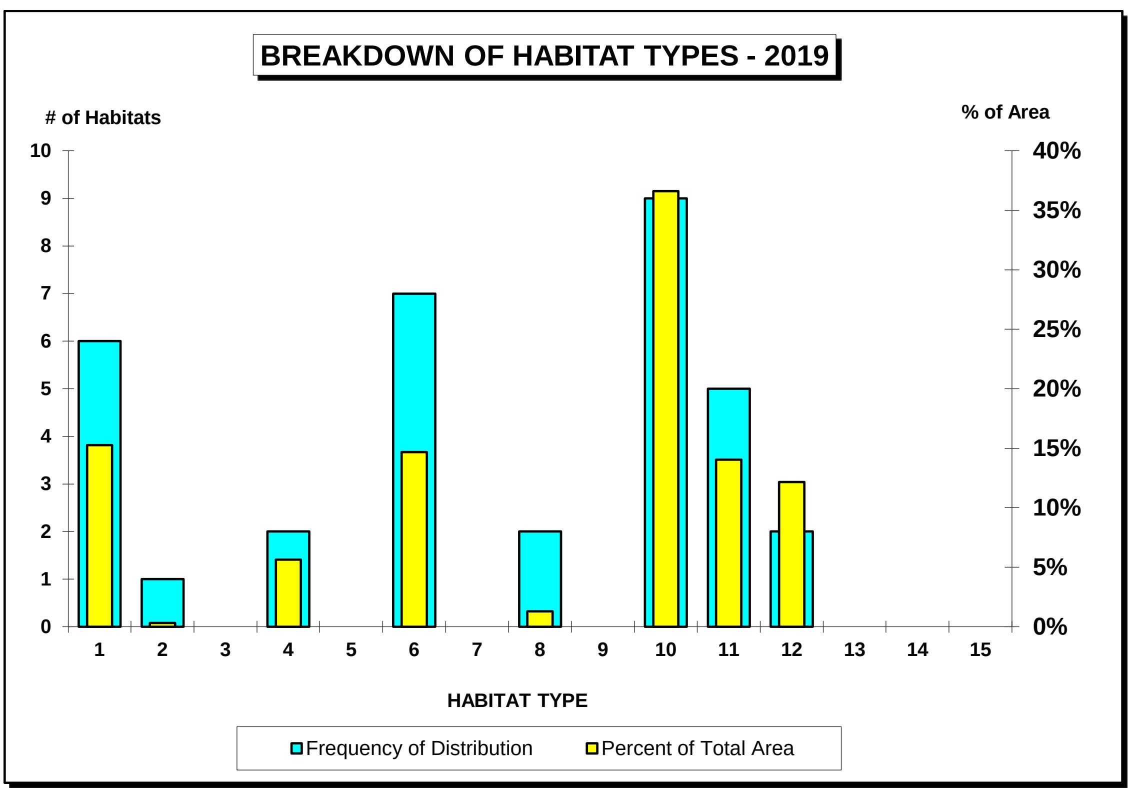
** Source: Winters and Gallagher, 1997*

Riffle habitat was dominated by low gradient boulder riffles (Figure 3). The low gradient boulder riffle form (Type 10) was the most common habitat type in terms of meso-habitat units and of wetted area and accounted for 37% of the total reach. Embedded in-channel boulders are providing velocity shelter and in-channel cover for resident fish in these habitats. Low gradient cobble dominated riffles (Type 11) were the next most common riffle habitat form, accounting for 14% of the wetted area of the reach. These riffles tended to exhibit more laminar flow and less habitat complexity, with little or no velocity shelter or cover. Gravel dominated riffles (Type 12) were also present in the reach, accounting for 12% of the wetted area.

Approximately 1% of the reach consisted of secondary channel riffle habitat (Type 8), and was associated with the large island in the lower half of the reach. Distribution of meso-habitat riffle type was again relatively unchanged from 2015. The only exception was with secondary channel riffle habitat area, which was reduced in 2019 due to the abandonment of a long secondary channel in the upper half of the reach, likely due to deposition of material at the entrance to the channel following the 2017 floods. The average width of all the riffles observed in the reach was 34 feet.

Figure 3. Distribution of Meso-Habitat Types as a percentage of # of habitats and as a percentage of wetted perimeter of Reach 5 on Purgatoire River (see Table 1 above for Habitat Type explanation).





The availability of pool habitat is likely one of the limiting factors to maintaining a robust and sustainable fishery. Pool habitats comprise approximately 30% of the total wetted area. Lateral scour pools (Type 6) are the most abundant, comprising 15% of the total wetted area of the reach (Figure 3). Lateral scour pools are a common feature in C channels, and we would expect this to be the dominant form within the study reach. Trench pools were the next most common pool type, accounting for 6% of the wetted area of the reach, and were mostly associated with constrictions in the channel due to rip-rap or vegetation along the river bank. A single secondary channel pool was observed in the reach, associated with the same island creating the secondary channel riffles described previously. Distribution of meso-habitat pool type was relatively unchanged from 2015. The average wetted width of all pool types found within the reach was 30 feet.

Typical lateral scour pool (Type 6) within the Purgatoire River study reach.

Most of the pools in Reach 5 exhibited only minor in-filling of sediment. The average pool depth in Reach 5 was 1.22 feet. Residual pool depth (RPD) in Reach 5 was found to range from 0 to 2.4 feet, with an average of 1.09 foot throughout the reach. Maximum pool depths ranged from 1.0 to 3.1 feet, with the average maximum depth found to be 2.2 foot. Residual pool depth (RPD) in Reach 5 is fair, but may contribute to over-wintering habitat capacity for salmonids in this segment of Purgatoire River. Average depth, maximum depth, and RPD all increased by 12% -13% between 2015 and 2019, likely a result of significant scouring of the channel bed during the floods of 2017.

Boulder vanes and micro-vortex structures within the Purgatoire River study reach.

Glide habitats were common, comprising nearly 15% of the reach. A few of the glide habitats appeared to be the result of sediment inundating and filling segments of the river. Most of the glide habitats observed are likely formed as a result of armoring of the channel bed and lack of scour. Flows tend to be laminar through this habitat form, resulting in little or no cover and velocity shelter for trout. Glide habitat decreased as a percentage of total wetted perimeter in the reach between 2015 and 2019 by approximately 3%. The average width of glide habitats in Reach 5 was 31.2 feet.

Instream cover more than doubled in terms of useable area in the reach between 2015 and 2019. All forms of cover for adult trout accounted for approximately 5.6% of the wetted area of Reach 5, compared to 2.25% in 2015 (Table 2, Figure 4). In-channel object cover (Cover Type 2) was the most dominant type observed in the reach, being mostly associated with perimeters of the pools in the stream channel, both natural & constructed boulder micro-vortex features, and constructed boulder vanes along the banks of the river. Pool depth cover (Cover Type 5) was the next most dominant form. Pool depth cover greater than 1.5 feet deep is a good indicator of over-wintering capacity of the stream. There was limited combination cover in the reach, and was mostly associated with log bank full bank structures installed along the river banks in 2017. Given the principle objective of the habitat improvements completed in 2017, we are not surprised to see a significant improvement in all cover types within the reach.

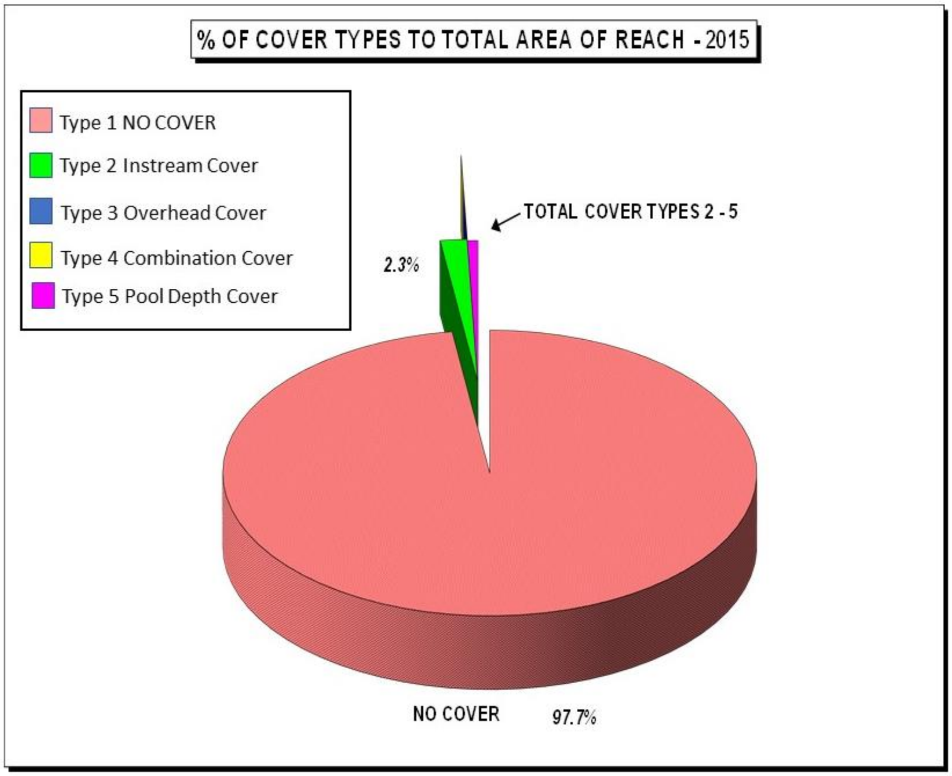
Table 2. Cover Types*

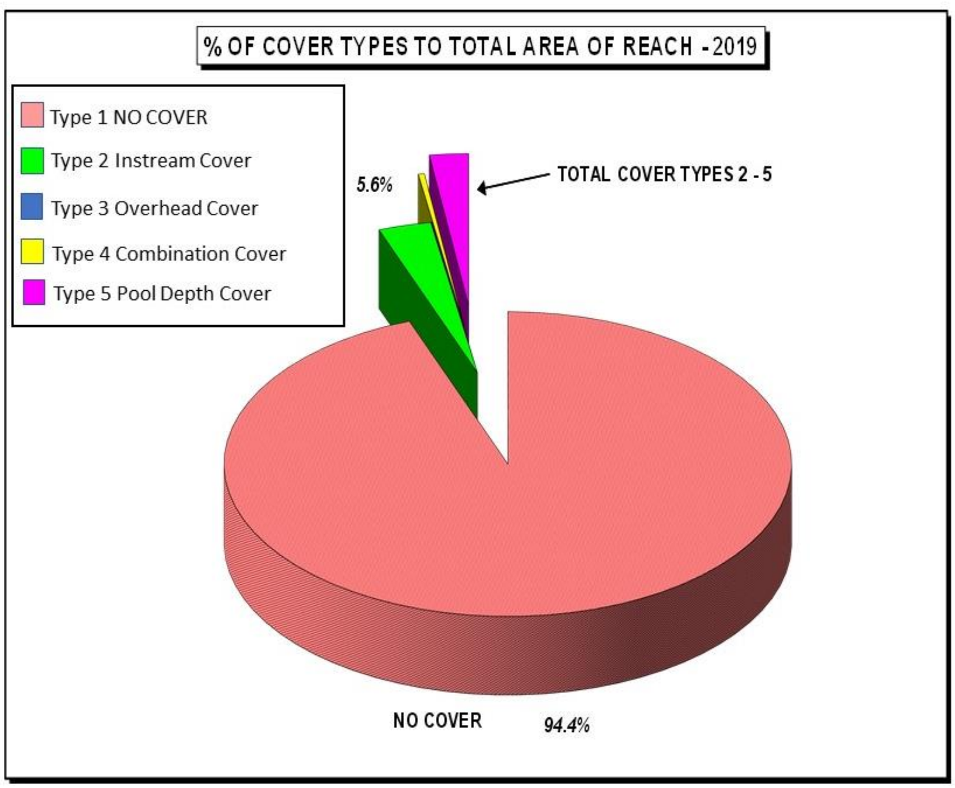
Type #	Cover Type	Description
Cover Type 1	No Cover	Depth < 0.5 feet, velocity ~0.5~/sec in riffle, pools < 1.~ feet deep; offers No Security Cover
Cover Type 2	Instream Cover	Water level 1 foot deep behind objects 1 foot in width, reducing velocities to < 0.5 cfs, large organic debris (LOD) such as tree trunks or root wads, boulders
Cover Type 3	Overhead Cover	Within 2 feet of water surface, vegetation like shrubs above glide or pool, undercut banks, protruding banks providing a minimum of 1 foot of cover, water minimum of 0.5 feet depth, velocity <0.5 cfs; offers No Velocity Shelter
Cover Type 4	Combination Cover	Water > 0.5 feet, passing over fallen trees, debris dams w/branches and/or root masses, overhanging banks with roots, rubble or boulder piles within the stream channel; provides reduced water velocities and overhead cover
Cover Type 5	Pool Depth Cover	Water deep enough to potentially provide cover; plunge pools over debris jam, lateral scour pools in undercut banks, any area of pooling > 1.5 feet deep after codes 2, 3, and 4 above have been measured with the remainder then measured as pool depth cover

** Source: Winters and Gallagher, 1997*

Large wood is lacking in the study reach, with the only pieces observed being associated with bank full bench features. Large wood is an important habitat forming feature in streams like the Purgatoire River, creating additional scour and habitat complexity. The lack of large wood may be a limiting factor for resident trout populations in the reach.

Figure 4. Percent of cover for trout to the total wetted perimeter in Reach 5 on Purgatoire River (see Table 2 above for description of Cover Types).





Stream bank stability was generally good throughout the reach, showing an improvement from 2015 (Figure 5, Table 3). Typically, well vegetated stream banks were found on both sides of the stream, with the exception of a few segments associated with high shear along the outside meander bend of the river. Stream bank stability was primarily influenced by generally robust deep-rooted riparian vegetation in addition to the naturally occurring larger cobbles and boulders embedded within the river banks. Approximately 60% of the bank rock content on either side of the river was comprised of smaller gravels and sand (Figure 6, Table 4). The remainder of the river banks consisted of larger materials ranging from small cobble to large boulders and parent bedrock. River banks comprised of smaller materials are susceptible to erosion due to shear along the bank at high flow. In areas where deep rooted riparian vegetation has been altered or removed, we observed unstable banks that were in varying states of collapse into the river.

Table 3. Bank Stability Types*

Type #	Bank Stability Type	Description
Type 1	Vegetated and stable	> 50% vegetated, bank does not show stress
Type 2	Vegetated and unstable	> 50% vegetated, bank does show stress
Type 3	Unvegetated and stable	< 50% vegetated, bank does not show stress
Type 4	Unvegetated and unstable	< 50% vegetated, bank does show stress

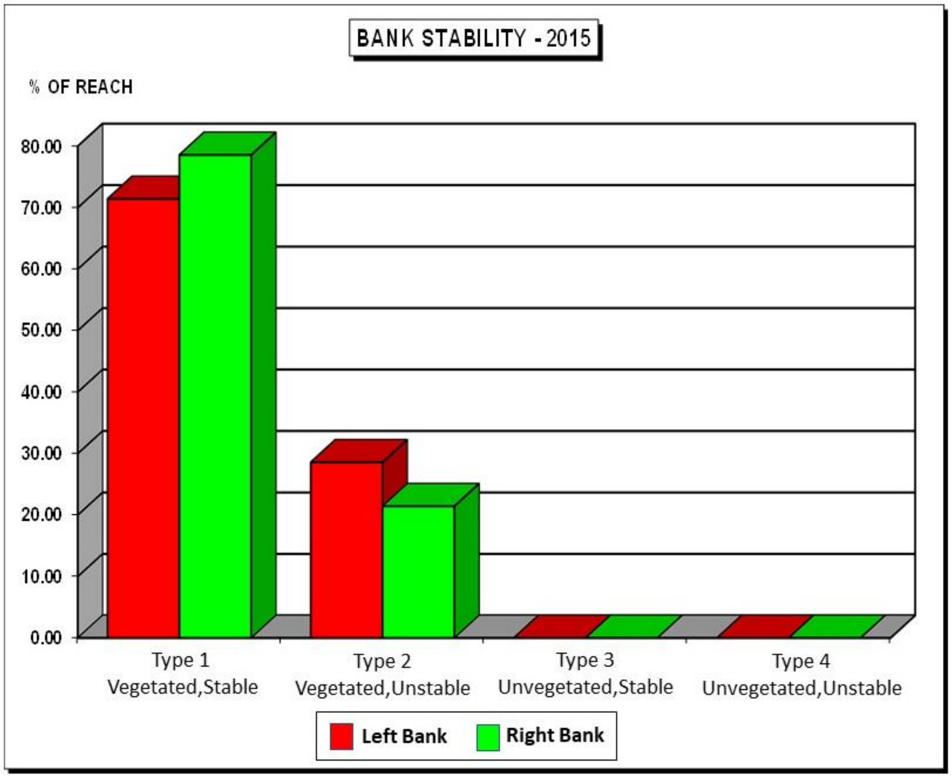
** Source: Winters and Gallagher, 1997*

Table 4. Bank Rock Content Types*

Type #	Size
Type 2	Greater than 65% of large and angular boulders which are 12 inches greater in diameter
Type 3	Average bank rock content between Type 2 and 4
Type 4	Between 40-65% of mostly small boulders to cobbles in the range of 6-12 inches in diameter
Type 5	Average bank rock content between Type 4 and 6
Type 6	Between 20-40% of mostly rocks in the 3-6 inch diameter class
Type 7	Average bank rock content between Type 6 and 8
Type 8	Less than 20% of rock fragments of gravel size, 1/8-3 inches in diameter

** Source: Winters and Gallagher, 1997*

Figure 5. Percentage of stable banks to unstable banks in Reach 5 on Purgatoire River (see Table 3 above for description of Bank Stability Types).



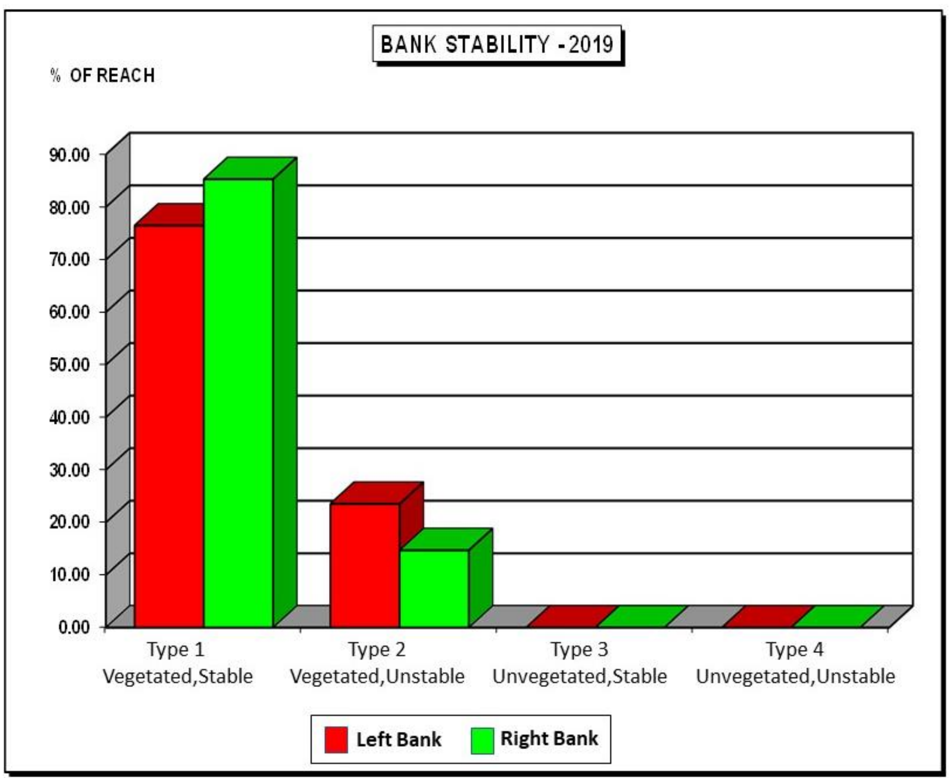
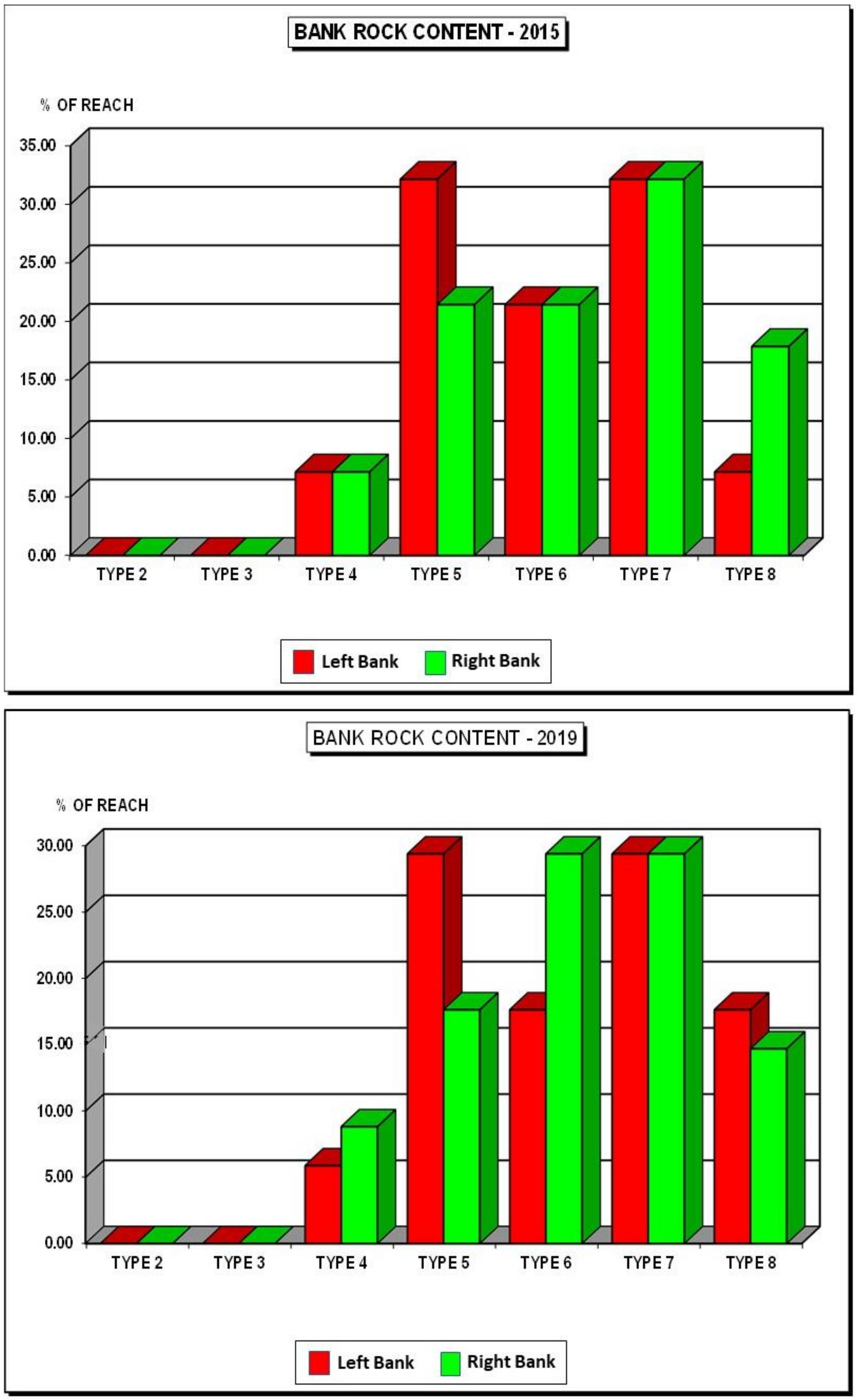


Figure 6. Percentage of bank rock content sizes in Reach 5 on Purgatoire River (see Table 4 above for description of Bank Rock Content Types).



Velocity shelter, cover, and useable habitat has improved in all three river reaches (3-5) after placement of in-channel structures**.** Comparing baseline (2010) to post-construction (2019) photo-points (Appendix 3) along with As-Built photographs (Appendix 4) illustrates improved habitat diversity. Also noteworthy is the apparent improvement in river form and function. The instream and bank stability efforts have encouraged a narrower channel profile to form in an otherwise over-wide and shallow river bed. A deeper, thalweg is forming and the river has become more sinuous within its present active river bed. The rivers ability to transport sediment, neither aggrading nor degrading, has been enhanced with this project. Habitat diversity has improved in all meso-habitats (pool, riffle, and glide) creating the physical habitat necessary to survive and grow trout throughout the year. Also noteworthy, there was no appreciable impact on instream habitat features installed in April 2017 following the high flow event in May 2017. Some bank erosion has occurred, however, and is discussed in later sections.

Habitat improvement goals have been soundly met, but natural reproduction necessary for a self-sustained trout fishery, is absent. Water operation measures to attain this goal are explained in the Winter Flows for Fish Assessment section and further elucidated in the Flows for Fish Recommendations section.

Winter Flows for Fish Assessment

Introduction

This effort focused on determining how to best manage winter flows to create a self-sustained fishery.

In the previously developed report *Assessment of Current River Condition & Fisheries Enhancement Potential*, Fin-Up Habitat Consultants, Inc. indicated that low flow in the winter time is the biggest barrier to maintaining a viable year-round fishery. The final goal of the assessment would be to develop an implementable year-round voluntary flow regime that could enhance trout survival, growth, and reproduction.

Method/Procedure

R2 Cross (Espegren 1996) was used to determine the appropriate minimum instream flow necessary to sustain a trout fishery and "preserve the natural environment to a reasonable degree". R2 Cross is a standard setting technique used to model instream hydraulic parameters across a "critical riffle". A minimum flow is established that is essential to benthic invertebrate production, adult fish passage, spawning and egg incubation, and feeding and cover for fish. Dramatic effects on useable habitat can occur in these sensitive habitats, even with small flow reductions. Maintaining adequate flow in riffle habitats also protects habitat elsewhere in the river (e.g. pools and runs).

Five representative riffle cross-sections were completed throughout the project area (Reaches 1 and 3-6). A cross-section was not completed in Reach 2 due to abundant beaver activity. Three key hydraulic parameters (average depth, percent wetted perimeter, average velocity) were evaluated at each cross-section to compute an appropriate minimum instream flow to protect biological function. The average depth necessary to pass the largest adult trout present is based on $1/100^{th}$ of bank full width (e.g. BFW of 77 feet equates to 0.77 average depth). Wetted perimeter represents the amount of substrate that is covered by water, also based on BFW. A consistent value of 60% (average value) was used across all five cross-sections. An average velocity of 1.0 foot/second was used to protect biological function at all five cross-sections. A winter flow minimum is established when two out of the three habitat criteria are met (Q2) and a summer minimum represents attaining all three criteria (Q3). Mathematical models and equations are used to predict hydraulic parameters. Constant Manning's n, Jarrett Variable Manning's n Correction, and Thorne-Zevenbergen D84 Correction Applied roughness equations were used to determine habitat criteria (Appendix 2). All three equations predicted similar results but Manning's n equation for roughness was chosen because it predicted the most consistent and conservative results.

Results and Discussion

R2 Cross hydraulic output using Mannings n is summarized in Table 5 below.

Table 5. Purgatoire River R2 Cross Output Summary										
				Habitat Criteria (52-77' BFW)						
				0.52-0.77	60	1				
X-Section	Location	BF Width	Analysis Method	Mean Dep Q	% Wet Per Q	Mean Vel Q	Q3 (summer)	Q3 mean	Q2 (winter)	Q2 mean
1-2	Reach 1	52	Mannings n	37.2	3.5	9.8	37.2	43	9.8	9.3
3-1	Reach 3	56	Mannings n	8.8	48.8	1.5	48.8		8.8	
4-3	Reach 4	77	Mannings n	107.5	18.6	7.7	107.5		18.6	
5-5	Reach 5	57	Mannings n	21.8	20.5	18.5	21.8	69.5	20.5	20.6
6-1	Reach 6	67	Mannings n	79.1	22.6	7.8	79.1		22.6	
Note: Reach 1 and 3 cross sections have significant narrow thalwegs (see cross section profiles)										

Cross-sections 4-6 represent a typical "critical riffle" cross-sectional profile (no established thalweg or deeper area), while cross-sections 1 and 3 have an established thalweg (Appendix 2). Discharge values vary accordingly. Mean winter (October 16-March 31) discharge necessary to protect aquatic biota at cross-sections 4-6 is 20.6 cfs while it is 9.3 cfs at cross-sections 1 and 3. Without any change in channel geometry a winter flow of 20.6 cfs, measured at the Trinidad gauge, is necessary to "preserve the natural environment to a reasonable degree" and a summer (April 1-October 15) flow of 69.5 cfs would be needed. Data for cross-sections 1 and 3 suggest a winter flow of 9.3 cfs and a summer flow of 43.0 cfs would be needed to sustain aquatic biota with that cross-sectional profile. Significant and large-scale channel narrowing would be needed throughout the Project Area before a lower flow would be adequate to sustain the fishery. This is **not** recommended and is discussed in detail in the Recommendations sections below.

The amount of water to maintain these winter flow minimums is calculated below. For illustrative purposes, assume no water is being released from Trinidad Reservoir and flow is measured at the Trinidad gauge. Also note that two acre-feet (A-F) of water is needed to maintain a flow of one cfs for 24 hours. The winter (non-irrigation) season runs from October 16 to March 31 (168 days). 168 days X 20.6 cfs/day = 3461 cfs X 2 A-F in one cfs = 6922 total A-F of water needed to maintain this minimum flow through the winter. The volume of water needed to maintain a minimum flow of 9.3 cfs would be less than one-half of the above amount. In reality, the volume of water needed under either scenario would be something between native or base flow and the winter minimum flow value. It is understood that some Municipal/Industrial (M&I) water may be available for instream flow purposes so the minimum winter instream flow target of 20.6 cfs could be achieved. This is the highest priority management action necessary to profoundly improve the fishery, discussed in detail in the Recommendations sections below.

Fishery Biology Assessment

A rivers fish population is a product of its habitat and potential human influence on this habitat; determining species present and their ability to survive, grow, and reproduce. Fishery management attempts to identify and correct the factors that limit, in this case, trout viability in the Purgatoire River within the Project Area. Can management actions be implemented to solve habitat bottlenecks with the goal of creating the best trout fishery possible?

To help answer these questions, fish population surveys were performed by Colorado Parks and Wildlife (CPW), the Purgatoire Watershed Partnership (PWP), and Trout Unlimited (TU) in November 2019. Three stations were surveyed within the Project Area, one in each of Reaches 1, 4, and 6. A single pass, qualitative survey was completed at each site utilizing two backpack mounted electrofishers. The results for the just below I-25 station in Reach 4 are summarized in Table 6 and Figures 7 and 8 below, while results for the other two sites are summarized in Appendix 5.

Table 6. Purgatoire River Fish Population Biometrics, just below I-25, Trinidad, Colorado, November, 2019.

Combined Summaries

Water **31461** **Purgatoire River #1** Date **11/13/2019**

Station **AR2038** **Just Below I-25**

Drainage **Arkansas River** UtmX **543366** UtmY **4113603** Elevation **5994 ft**

Length **410 ft** Width **40.00 ft** Area **0.38 acre**

Surveyors

Tucker, Behounek, Hassler, Policky

Gear **BPEF** Effort Metric **PASS** Protocol **PRESENCE/ABSENCE**

Proportional Stocking Density and Catch/Unit Effort

Species	Total Catch	Min Cut inch	Max Cut inch	Total used	Proportional Stock Density (%)	Percent Stock Size	Percent Quality Size	Percent Preferred Size	Percent Memorable Size	Percent Trophy Size	Max Length inches
CREEK CHUB	34			34							6.77
LONGNOSE DACE	23			23							4.13
BROWN TROUT	3			3	100.00			33.33		66.67	24.02
RAINBOW TROUT	21			21	0.00	100.00					13.62
SMALLMOUTH BASS	1			1	0.00	100.00					7.72
CENTRAL STONEROLLER	25			25							6.18
WHITE SUCKER	70			70	54.55	45.45	31.82	22.73			14.76

Mean, Minimum and Maximum Length and Weight

Species	Total Catch	Min cut inch	Max cut inch	Total Used	Length (inches) Mean	Length (inches) Minimum	Length (inches) Maximum	Weight (lb) Mean	Weight (lb) Minimum	Weight (lb) Maximum
CREEK CHUB	34			34	4.18	0.98	6.77		0.00	0.00
LONGNOSE DACE	23			23	2.31	1.46	4.13		0.00	0.00
BROWN TROUT	3			3	18.23	12.40	24.02	1.53	0.81	2.26
RAINBOW TROUT	21			21	10.99	7.17	13.62	0.52	0.15	1.06
SMALLMOUTH BASS	1			1	7.72	7.72	7.72		0.00	0.00
CENTRAL STONEROLLER	25			25	3.97	2.76	6.18		0.00	0.00
WHITE SUCKER	70			70	5.31	1.89	14.76		0.00	0.00

Relative Abundance and Catch/Unit Effort

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total used	Weight Lbs	Percent Number	Percent Weight	Catch per Unit Effort Number/Effort	Catch per Unit Effort Lbs/Effort
CREEK CHUB	34			34	0.00	19.21	0.00		
LONGNOSE DACE	23			23	0.00	12.99	0.00		
BROWN TROUT	3			3	3.06	1.69	21.91		
RAINBOW TROUT	21			21	10.92	11.86	78.09		
SMALLMOUTH BASS	1			1	0.00	0.56	0.00		
CENTRAL STONEROLLER	25			25	0.00	14.12	0.00		
WHITE SUCKER	70			70	0.00	39.55	0.00		

Abundance and Biomass

Species	Total Catch	Min.Cut inch	Max.Cut inch	Total Used	Population estimate	Biomass Lbs	Percent Number	Percent Weight	Density estimates Lb/Acre	Density estimates Fish/Acre	Density estimates Fish/Mile
CREEK CHUB	34			34		0.00	19.21	0.00	0.00	90.31	437.85
LONGNOSE DACE	23			23		0.00	12.99	0.00	0.00	61.09	296.20
BROWN TROUT	3			3		3.06	1.69	21.91	8.14	7.97	38.63
RAINBOW TROUT	21			21		10.92	11.86	78.09	29.01	55.78	270.44
SMALLMOUTH BASS	1			1		0.00	0.56	0.00	0.00	2.66	12.88
CENTRAL STONEROLLER	25			25		0.00	14.12	0.00	0.00	66.40	321.95
WHITE SUCKER	70			70		0.00	39.55	0.00	0.00	185.93	901.46

Notes: Settings: 140 V 30 Hz, 12%; Effort BPEF 1: 1718 s; Effort BPEF 2: 1591 s; 2 BPEF 6 netters; sunny, slight breeze

A low-density trout population was documented within the Project Area. Rainbow trout were collected at all three sites along with brown trout at the I-25 location. Trout have survived to successive age classes and grown well in this habitat. Brown trout to 24 inches and rainbow trout to 14 inches were collected (Figure 7). They are in excellent condition (Figure 8). Most trout exhibit relative weight values well over 93 with an average relative weight of 102.5 for brown trout. A riverine trout relative weight value of 93 is normal, representing a fish that's weight is typical for its length. Several native, nongame species were also collected, typical of a fishery transitioning to warm water habitat.

Figure 7. Purgatoire River Trout Distribution, just below I-25, Trinidad, Colorado, November, 2019.

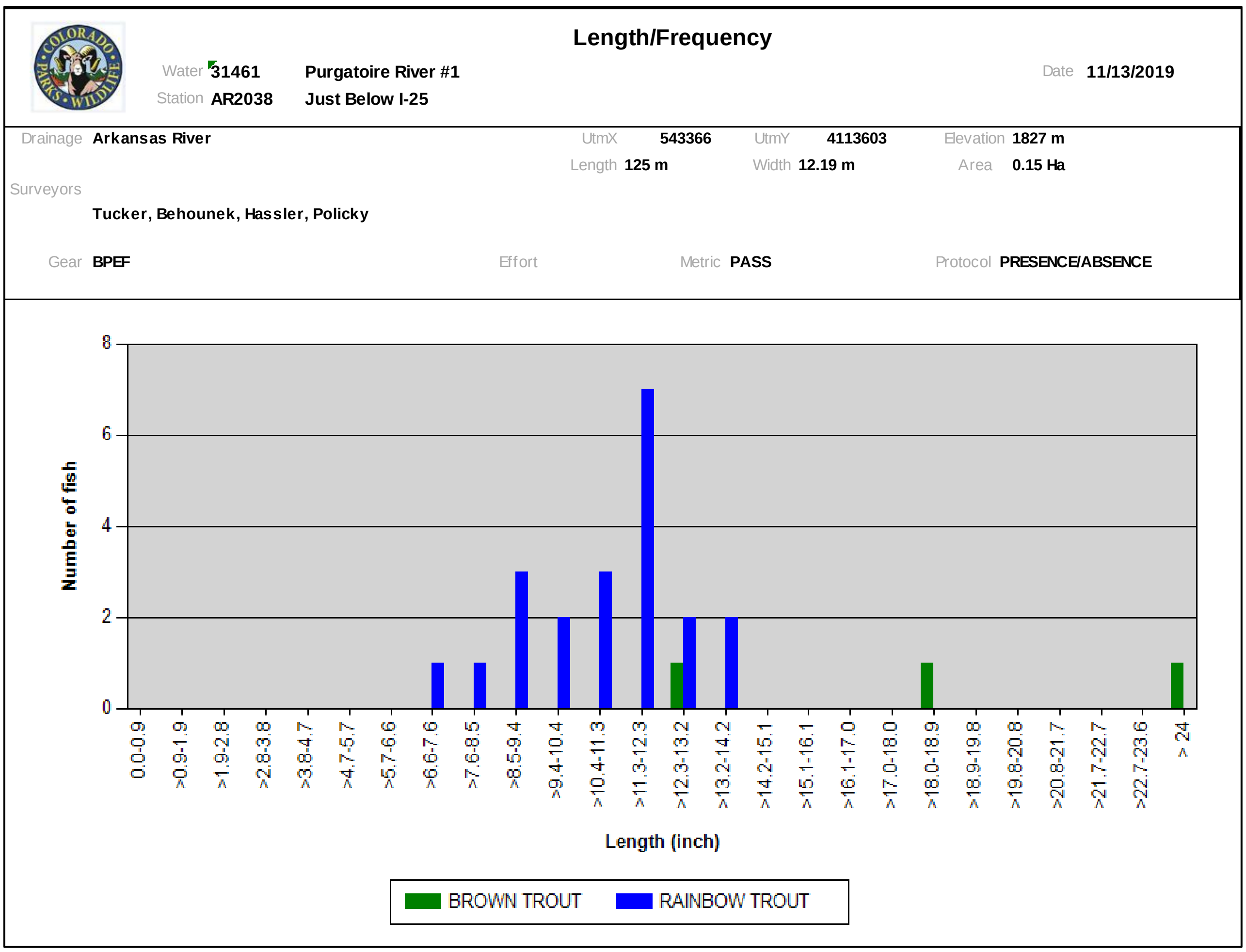
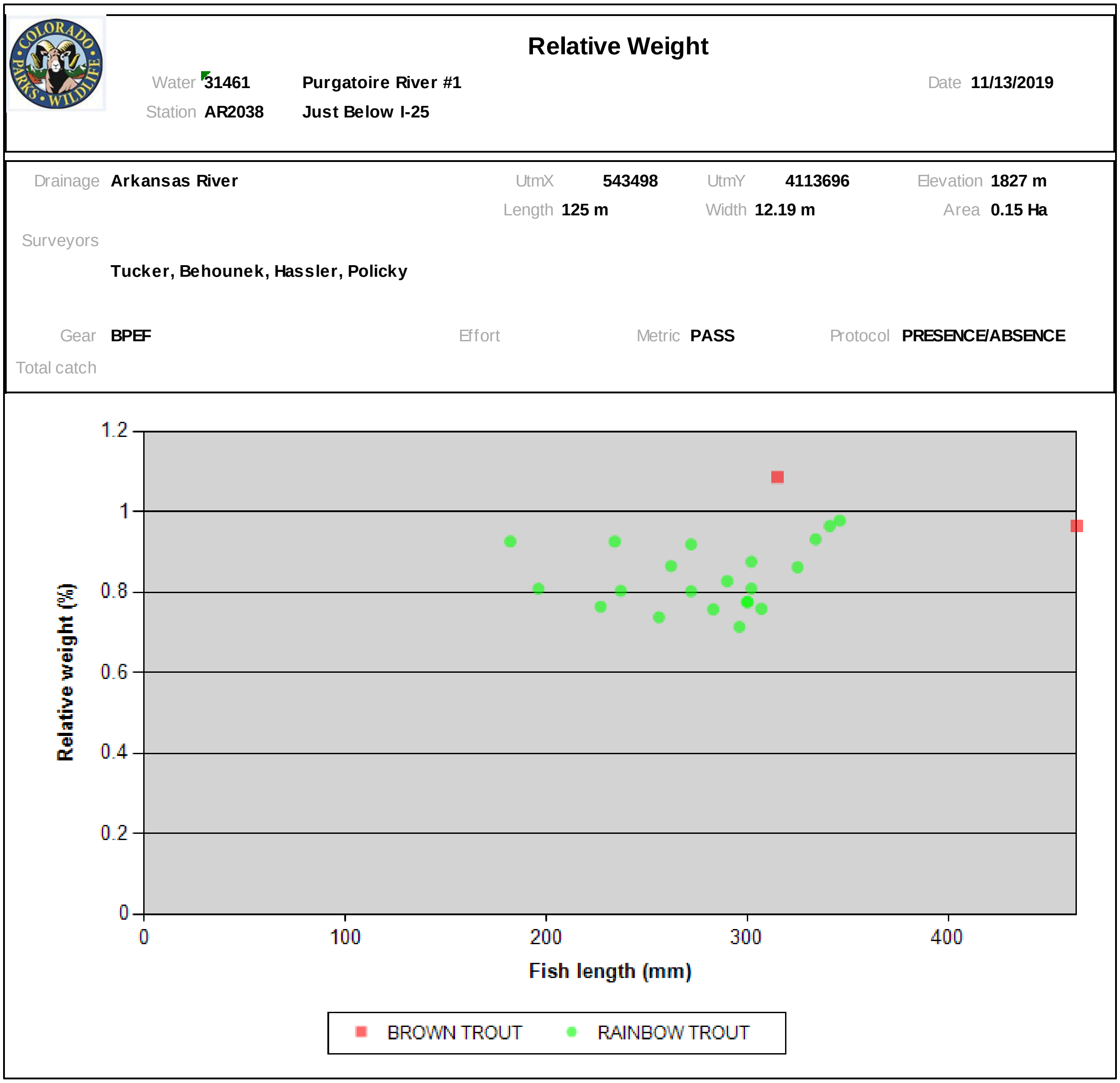


Figure 8. Purgatoire River Trout Relative Weight, just below I-25, Trinidad, Colorado, 2019.



The trout fishery in the Purgatoire River in Trinidad is currently maintained through artificial stocking. Both Colorado Parks and Wildlife (CPW) and Trout Unlimited (TU) have regularly planted numerous trout in the river from near I-25 to SH 160. Their combined efforts are shown in Table 7. Most were 10-14 inch rainbow trout with a stocking of similar sized brown trout in 2015. Some of these fish have survived and recruited to successive age classes (Figure 7). Trout collected just below the railroad bridge crossing in Reach 6 demonstrates their propensity to travel beyond where they were stocked.

Table 7. Trout stocking in the Purgatoire River 2011-2019 (CPW and TU).

Year	Species	Number	Size (inches)
2011	Rainbow Trout	550	10-14
2012	Rainbow Trout	550	10-14
2013	Rainbow Trout	1050	10-14
2014	Rainbow Trout	501	10-14
2015	Rainbow Trout	1098	10-14
2015	Brown Trout	250	10-14
2016	Rainbow Trout	1300	10-14
2017	Rainbow Trout	1300	10-14
2018	Rainbow Trout	1500	10-14
2019	Rainbow Trout	1508	10-14

Velocity shelter, cover, and useable habitat have significantly improved in restored reaches. Trout are surviving to successive age-classes but numbers remain low in spite of liberal stocking and they are not reproducing. Water flow impacts on trout viability and other secondary habitat variables are discussed below.

Flows For Fish Recommendations

Maintaining an appropriate winter minimum flow is necessary to enhance trout survival and growth but is paramount to establishing a self-sustained trout fishery. Trout life history information is important when considering flow management to enhance the fishery. Brown trout, for example, likely spawn in the Project Area from about mid-October through November. Egg incubation follows through March with hatching and fry emergence occurring in April to early May. Rainbow trout likely spawn in February and early March with egg incubation occurring through April followed by hatching and fry emergence in May and June.

Incubating eggs are extremely susceptible to dewatering and desiccation under current winter flow operations. The presence of adult trout, but complete absence of juvenile trout, is premia fascia evidence of poor incubation habitat for both trout species. A minimum winter (October 16-March 31, non-irrigation season) flow of 20.6 cfs is needed to fulfill trout egg incubation requirements. Additionally, an abrupt and dramatic flow increase in April-May renders newly emerged brown and rainbow trout fry vulnerable to "blow out" from elevated flow. Lastly, it is critical to gradually make flow changes throughout the year. An abrupt and large change in flow can be very detrimental to aquatic biota and their habitat. A reasonable ramping policy should be developed that allows water managers to meet downstream obligations while protecting aquatic life and their habitat. To this end, flow changes should not exceed 25% per day. This pertains to any anthropogenic flow change, either up or down, throughout the year.

Administering a winter flow of 20.6 cfs is the preferred action compared to channel modification to validate a lower amount. If water is not available and a lesser delivery is necessary, fish population dynamics, including natural reproduction, should be assessed at this lower flow prior to any habitat modification. If trout density and natural reproduction is inadequate, with a lower than recommended flow, a significant and large-scale habitat effort would be needed to create a low water thalweg within the main channel. This "channel within a channel" would need to be designed to satisfy all trout life history requirements from spawning through adult relative to a target flow, say 9.3 cfs. Appropriate habitat criteria and sediment transport would need to be maintained through this new cross-sectional area.

High and fluctuating summer flows are also of concern. Flows well above baseline occur throughout the irrigation season from May-October, often accompanied by dramatic daily change. Figure 9 includes the high May 2017 flow event caused by releases from Trinidad Reservoir from 5/10-5/15, peaking at 2040 cfs on 5/12-5/14. Very little water entered the Purgatoire River from Raton Creek during this period (DWR flow data). Figure 10 excludes this event to better illustrate typical flow operations during the summer and early fall. Flows of this nature can be extremely impactful to newly emerged fry but also can have profound impact on juvenile to adult trout physiology, life function and behavior. Other aquatic biota (e.g. macroinvertebrates) is similarly impacted along with channel stability (e.g. bank erosion). The entire aquatic ecosystem is vulnerable to such extreme and variable flow events. Attempts should be made to moderate high flow releases during the irrigation season (April 1 to October

15), but most importantly, limiting daily changes to no more than 25%. This flow management policy alone would enable aquatic biota and their habitat to weather these high flow events with far less impact.

Figure 9

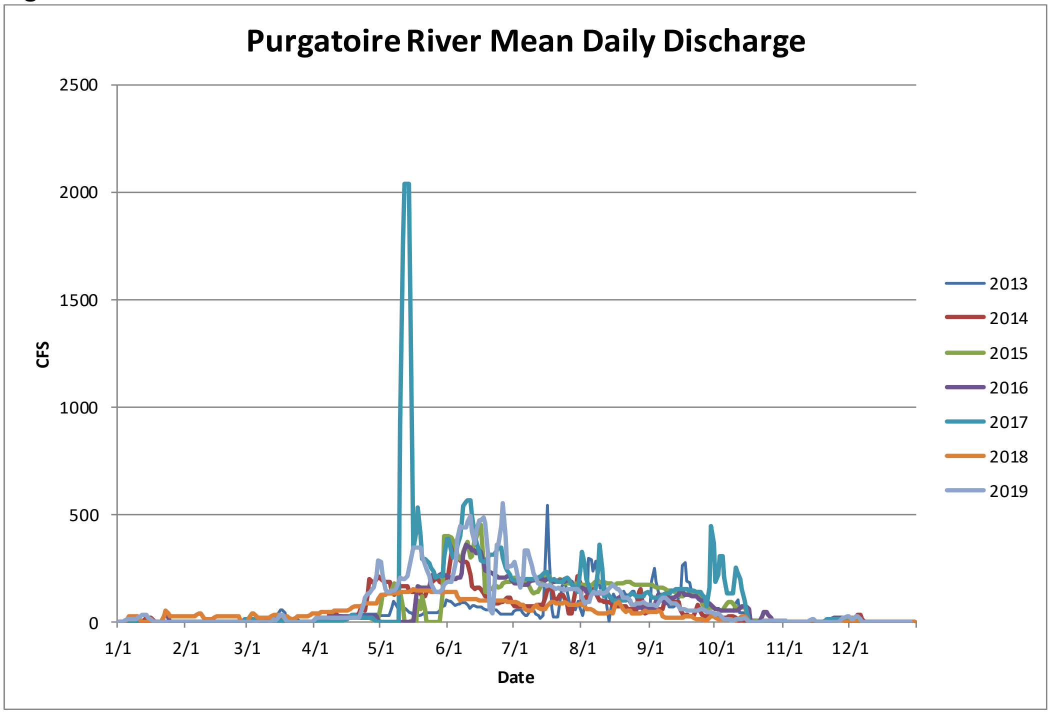
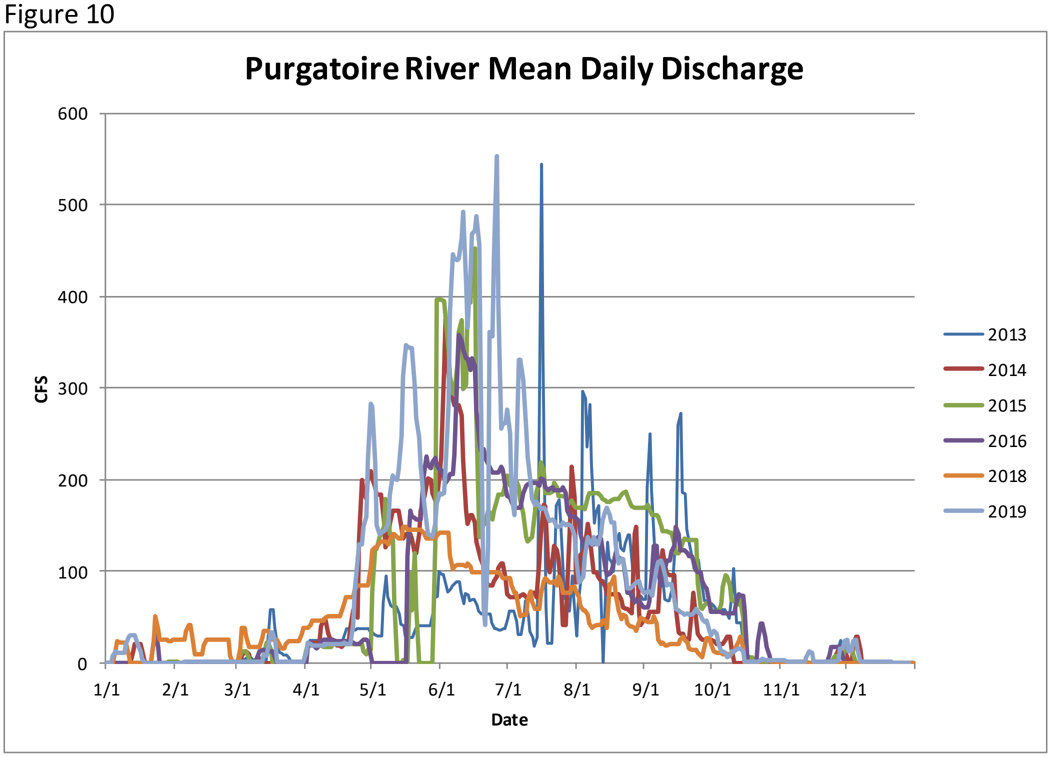


Figure 10



Water Temperature, and Habitat Enhancement Recommendations

The Purgatoire River naturally warms as it progresses to the plains below Trinidad Reservoir. Colder water is released from the bottom of the reservoir but this thermal advantage is largely lost by State Hwy 160 (Figures 11-14), likely the lower extent of viable trout habitat. Trout life function can be impacted as maximum daily water temperature rises above 70°F and their thermal survival maxima is jeopardized as water temperature nears 80°F. This occurred during the summer of 2013, a dry and warm period (Figure 12), but was less dramatic in 2014-2016 and 2019 (Figures 11 and 13). Maximum daily water temperature correlates poorly with flow (R^2 value of -0.27), however R^2 values from 0.76 to 0.84 show a significant positive correlation between air and water temperature (Figure 13). In other words, releasing more water in the summer will not lower stream temperature for any appreciable distance downstream of Trinidad Reservoir but hot summer days will cause stream temperature to rise accordingly. Streams normally cool somewhat during the night, as illustrated by the difference between thermal maxima and minima in Figure 14, affording trout some diurnal relief from warm water. Trout also seek out deeper, colder water when stream temperatures become undesirable. Habitat work to create this summer refugia (also of benefit in the winter) should be considered, recognizing that flow management is of highest priority. It is also paramount to maintain current riparian and floodplain function, enhancing overall river health and cooling through overhead cover and shading. Any actions that degrade this should be avoided and efforts to enhance it (e.g. bank stabilization, invasive species removal, native species planting, jetty jack remediation) should be encouraged.

Figure 11

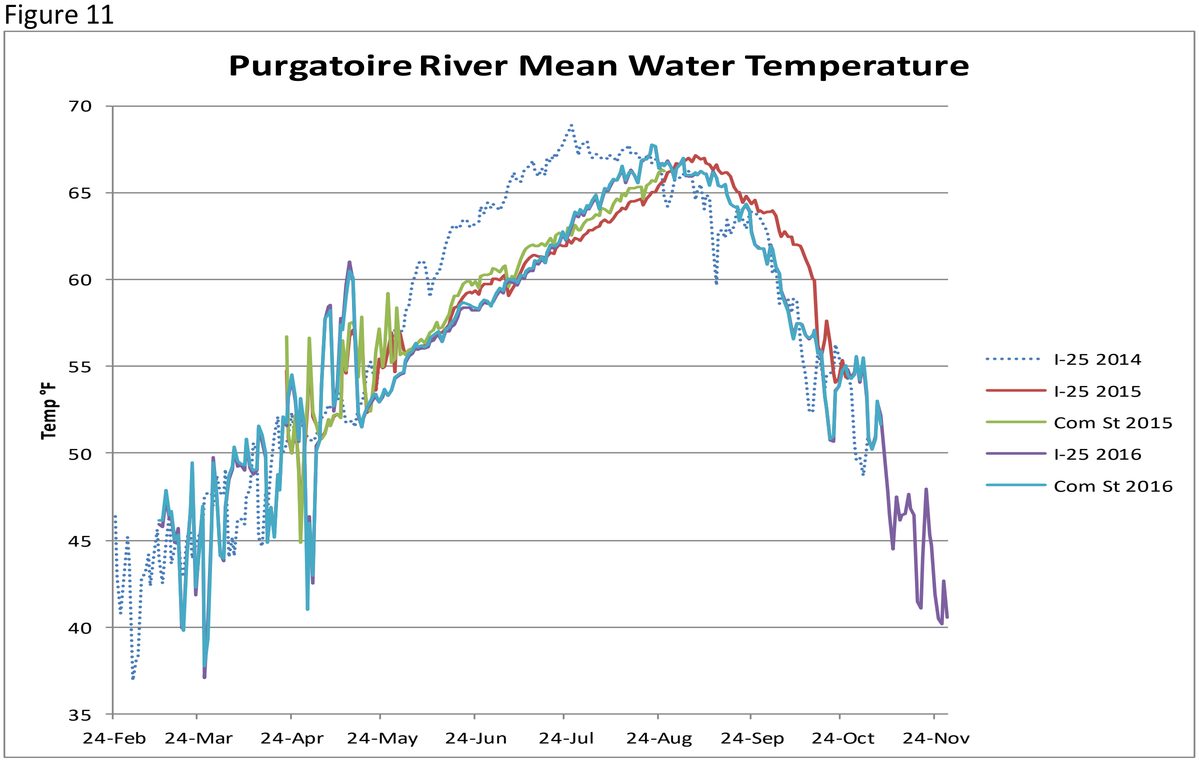


Figure 12

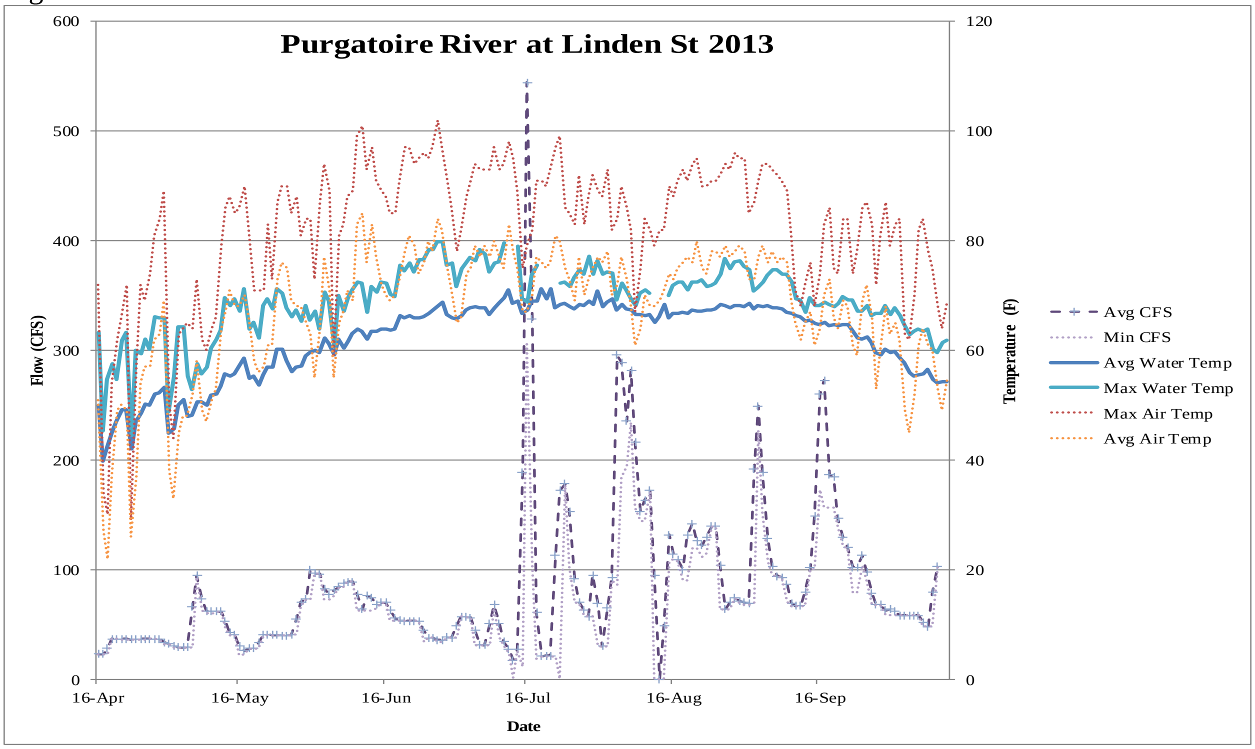


Figure 13

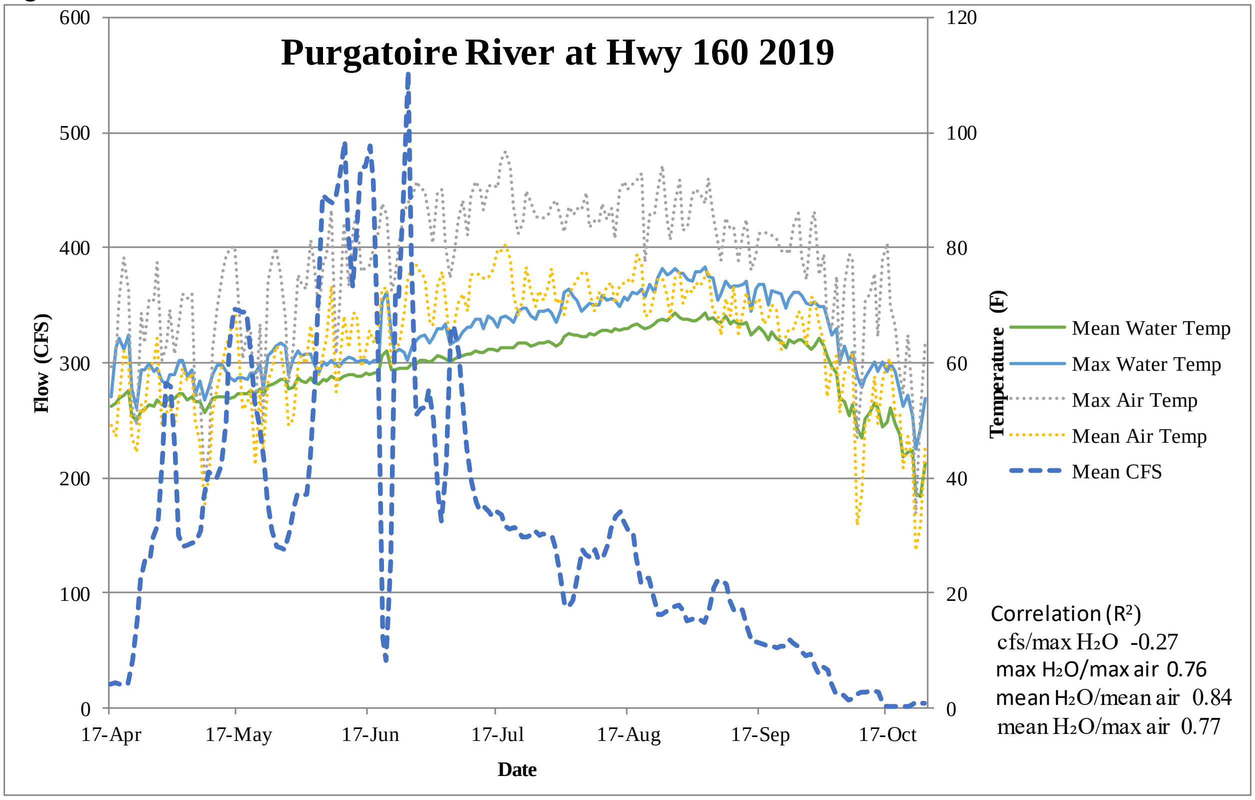
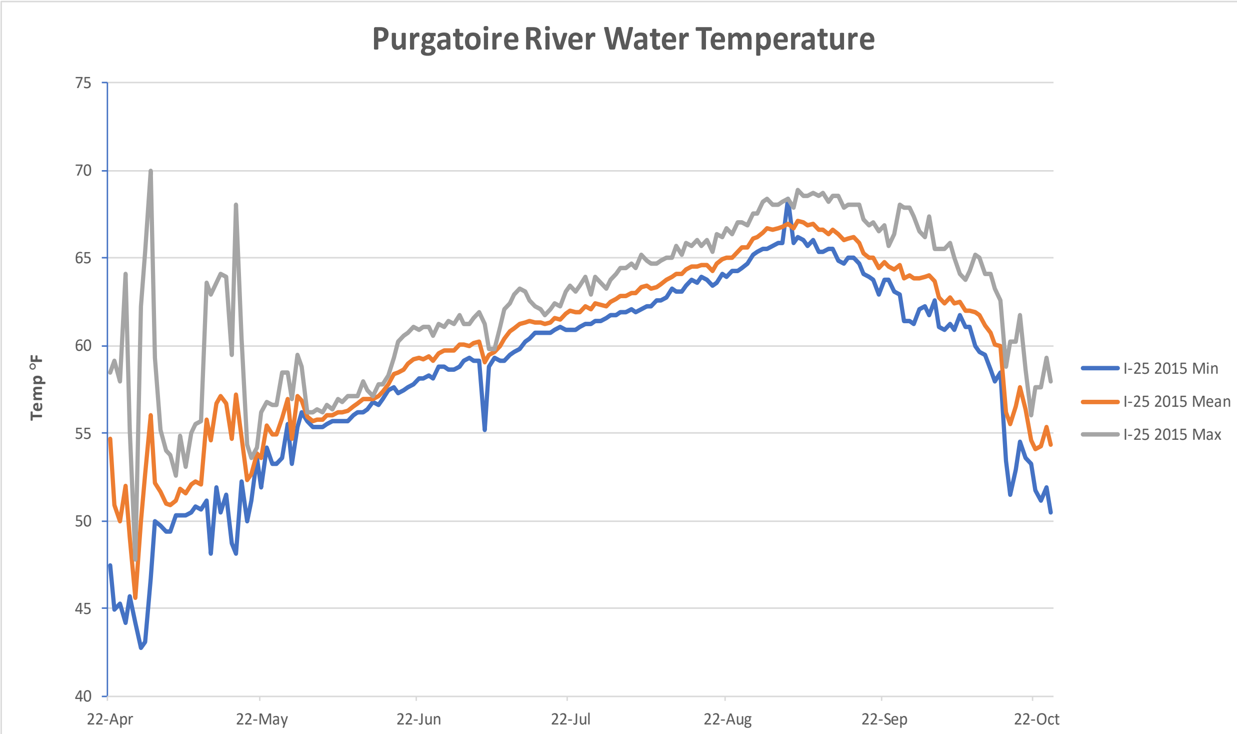


Figure 14


Purgatoire River Water Temperature
75
70
65
60
55
50
45
40
Temp °F
22-Apr
22-May
22-Jun
22-Jul
22-Aug
22-Sep
22-Oct
I-25 2015 Min
I-25 2015 Mean
I-25 2015 Max

Additional Recommendations

Brown trout have the best opportunity of becoming self-sustained in this habitat (warm water tolerant and competitive advantage). Fingerling (four inch) brown trout should be stocked in May at approximately 1000/mile for at least five consecutive years. They should be marked (e.g. adipose fin clipped) to differentiate them from natural reproduction and to monitor recruitment to successive age classes. Approximately 1000 catchable (10 inch plus) rainbow trout should continue to be stocked in May in Project Reaches 3-5 to maintain a public "put and take" and diverse trout fishery.

Biennial fish surveys are recommended to assess trout survival, growth, and reproduction relative to flow management changes and stocking protocol. Conduct fall sampling in late October at the beginning of the winter flow program to monitor over-summer trout survival prior to the winter season. Spring sampling (early May) should occur prior to any stocking but after expected brown trout fry emergence. This protocol will enable evaluation of over-winter trout survival and brown trout reproductive success (egg incubation, hatching and fry emergence). This fish sampling protocol will necessarily be led by CPW.

Additional areas of concern include the following. The Picketwire Ditch diversion dam is a barrier to upstream fish movement, restricting aquatic biological function within the Project Area. It is recommended that this situation be appropriately remedied. The channel is overwide and shallow for considerable distance above the Boulevard addition in Reach 6 (2019 photo-points 71-72 in Appendix 3). This likely contributes significantly to water warming, impacting useable habitat downstream. A habitat project to attain proper channel geometry and enhance and diversify instream habitat is recommended in this section. There is also several badly eroded banks in Reach 6 contributing significant sediment to the system (see 2019 photo-points 75,79 in Appendix 3). These should be remediated through appropriate bank stabilization methods (e.g. wood toe, riparian benches). Other than these issues, habitat in Reach 6 is good. Much of reach 6 is privately controlled but habitat efforts are important and should be pursued in the name of "river health". Better yet, efforts to secure public access should be actively pursued. In Reaches 1 and 2, there is considerable bank erosion (2019 photo-points 5, 6, 10, 11; Appendix 3) and channel thread movement (2019 photo-points 15-17, Appendix 3). Habitat actions to correct these issues should be considered.

Summary of River Habitat Management Recommended Actions

The following habitat management actions are listed in order of priority.

- Maintain a winter (October 16-March 31) flow of 20.6 cfs measured at the Trinidad gauge.
- Establish a year-round ramping rate where daily, anthropogenic flow change does not to exceed 25%. Moderate high flow releases during the irrigation season (April 1 to October 15), when practical.
- Cooperate with private landowners to enhance instream and riparian habitat in Reach 6 and secondarily discuss public access opportunities.
- Address bank erosion and channel movement issues in Reaches 1 and 2 and fish movement barrier at the Picketwire Ditch diversion.
- Institute Project Area river enhancement efforts if fish population objectives are not met by the Winter Flow Program (e.g. "channel within a channel" modifications).
- Maintain and enhance current riparian and floodplain function.

Fish stocking and fish population monitoring, as detailed above, should be concurrent with habitat management actions.

References

Espegren, G.D. 1996. Development of Instream Flow Recommendations in Colorado Using R2Cross. Colorado Water Conservation Board. 34 pp.

Winters, D.S. and J.P.Gallagher. USDA-Forest Service. 1997. Basinwide Stream Habitat Inventory - A Protocol for the Pike and San Isabel National Forests and the Cimarron and Comanche National Grasslands. 41pp.