Stream Habitat Investigations and Assistance

Federal Aid Project F-161-R

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Job Progress Report

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Aquatic Wildlife Research Section

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The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Division of Wildlife policy by the Director or the Wildlife Commission.

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SEGMENT NARRATIVE

State: Colorado

Project Number: F-161

Project Title: Stream Habitat Investigations and Assistance

Period Covered: July 1, 2010 through June 30, 2011

Principal Investigator: Matthew C. Kondratieff

Project Objective: To evaluate fishery response to stream aquatic habitat treatments; to evaluate the barrier potential of instream obstacles; and to provide technical assistance for statewide aquatic habitat improvement projects and fish passage structure and barrier designs.

STUDY PLAN A: DESIGN, CONSTRUCTION AND EVALUATION OF STREAM HABITAT RESTORATION TREATMENTS AND INSTREAM STRUCTURES

Job A.1. Fishery Response to Stream Aquatic Habitat Treatments

Job Objectives

Stream habitat improvements will be evaluated to quantify changes in salmonid biomass (quantity), individual fish size (quality), and fish utilization of habitat treatments in restored versus un-restored river segments. A Before/ After/ Control/ Treatment (BACT) study will be conducted at appropriate site locations. A combination of field and theoretical results from this study will be used to evaluate the fishery response to stream habitat treatments. Research findings will generate information useful for quantifying how much improvement in the fishery can be expected from stream restoration projects. Results from this study will refine stream aquatic habitat restoration techniques that will benefit anglers and improve trout fisheries.

Segment Objectives

1. Develop list of candidate stream segments to conduct pre- and post- stream habitat improvement studies. Select appropriate study site location(s) for evaluation.

ACCOMPLISHMENTS

Table 1 lists selected candidate sites that have been proposed for conducting BACT studies on fish response to selected treatments. Candidate stream locations for conducting detailed studies on the fishery response to stream habitat restoration have the following characteristics: fish populations have stabilized post-whirling disease infection, multiple years (at least 2) of baseline fish data have been collected prior to stream restoration, DOW leases or owns stream public fishing access, proposed restoration sites have been identified, prioritized and funded allowing adequate time to collect good “before” data prior to construction and Colorado Parks and Wildlife (CPW) personnel will be able to work closely with contractors on design and implementation of habitat treatments (design build).

Construction on the Middle Fork of the South Platte River project (Table 1) began prior to collecting “before” fish data for this site. However, a control reach located within 1.0 mile downstream of the project site has been monitored for 19 years and serves as a good spatial control site that is representative of the condition of the Middle Fork project reach prior to implementing habitat enhancement treatments. Pairing the Middle Fork project with the downstream control reach should allow for a direct comparison of fish population statistics.

The Tarryall Project and Phase 1 and 2 of the South Platte River (downstream of Spinney Mountain Reservoir) were both constructed prior to any control reach being established. However, they both include good “before” data for the treatment reach so we included them in Table 1 as locations we plan to continue monitoring over time.

Study sites include a variety of scales including smaller headwater streams with bankfull widths less than 20 feet (i.e. South Fork of South Platte River) to larger rivers with bankfull widths over 100 feet wide (i.e. Rio Grande River).

Table 1. Proposed stream segments to conduct pre- and post- stream habitat improvement studies.

Stream	Construction Years	Project Status	Length (mile)	Primary Treatments	Treatment Reach: No. Years fish data collected "Before" work started / No. Years fish data collected "After" work completed	Control Reach: No. Years fish data collected "Before" work started / No. Years fish data collected "After" work completed	Project Description
Rio Grande River	2006	Completed	4.4	Reduce channel width, excavate pools, enhance trout habitat	8/4	0/3	Wason and La Garita Ranches
Upper Arkansas River	2011-???	Future project	3.0	Reduce channel width, excavate pools, enhance trout habitat	>2/0	>2/0	Upper Arkansas NRD project at Hayden Flats
Middle Fork South Platte River	2007-2010	Completed	2.0	Reduce channel width, excavate pools, enhance trout habitat	0/2	19 /2	Upper Spinney SWA/Lower end of Badger Basin perpetual easement
South Fork of South Platte River	2011-2012	Future project	1.0	Reduce channel width, excavate pools, enhance trout habitat	2/0	2/0	River reach upstream of Badger Basin HQ - Lower end of Badger Basin perpetual easement
South Platte River-Phase 1 & 2	1993 & 1998	Completed	0.6	Reduce channel width, increase adult fish cover (vegetative cover and deep pools), stabilize eroding banks and improve instream habitat complexity.	1/8	No control reach	South Platte River downstream of Spinney Reservoir
South Platte River-Phase 5	2013-2015	Future project	1.0	Reduce channel width, excavate pools, enhance trout habitat	0/0	0/0	Lower Spinney SWA (Dream Stream)
South Platte River	2015-2017	Future project	1.0	Reduce channel width, excavate pools , enhance trout habitat	0/0	0/0	River segment downstream of Park Co. Rd 59
Tarryall Creek	2005	Completed	0.6	Increase trout biomass and number of quality-sized (> 14" TL) trout, stabilize eroding banks, reduce channel width, increase habitat complexity	2/2	No control reach	Tarryall Creek on Tarryall SWA
Hartsel Townsite	2012?	Future project	0.6	Reduce channel width, excavate pools, enhance trout habitat	2/0	2/0	Hartsel Townsite between Highway 24 and Highway 9

2. Research potential theoretical modeling techniques for evaluating stream restoration treatments (PHABSIM, River 2D, MDSWIMS, IBMs) to determine what will function best to model changes in fish population response related to stream habitat manipulations.

ACCOMPLISHMENTS

No progress on this research question was made during this segment period due to higher peak and longer duration stream flows. We will attempt using PHABSIM to model habitat conditions to serve as baseline conditions on a portion of the Upper Arkansas River by segment period ending in 2013.

3. During summer and fall months conduct electrofishing sampling to determine salmonid biomass, densities and individual fish lengths in control and treatment study sites to serve as baseline for later comparison.

ACCOMPLISHMENTS

We collected fish sampling data on selected pre- and post-treatment stream reaches to monitor fish response to aquatic treatments with assistance from area aquatic biologists and research scientists. Fish sampling was conducted at the following three study locations:

Rio Grande River: We collected fish sampling data on treated sections of the Rio Grande River on Wason Ranch (3.8 miles) and untreated portions of the Rio Grande River on La Garita Ranch (2.4 miles) by electrofishing with two rafts equipped with throw electrodes. Data collected included fish population estimate data, fish size by relative abundance data, age and growth (scales), and fish species composition data. Three years of fish data have been collected on the Wason Ranch since Dave Rosgen completed work in 2006.

Data was collected October 11-15, 2010. Data analysis was completed this winter including scale analysis with assistance from Barry Nehring (February 14-17, 2010). A preliminary report was generated this spring for circulation to interested landowners and project managers. We plan to continue monitoring this site for a minimum of three more years prior to concluding the study and publishing results based on previous studies suggesting five to six years required for fisheries to stabilize post-restoration activities. This study has unique value since it is being conducted on a large river system (most published habitat restoration evaluations are conducted on much smaller streams). See Appendix A for a preliminary report of findings from this study.

South Fork of South Platte River: Fish sampling was conducted on two treatment sites and one control site. Three stream electrofishing reaches in South Park (South Fork of South Platte River and South Platte River) were sampled with assistance from Jeff Spohn, Fisheries Biologist, NE Region. Sampling sites are scheduled for future CPW stream restoration work. Data was collected for all three sites (October 7, 2010). We now have two years of pre-restoration, baseline fisheries data for the two proposed restoration sites and the designated control reach (Table 1). Data collected included fish population estimate data, length/frequency data, and fish species composition.

Buckley Ranch: Fish sampling was conducted at two sites on South Platte River as part of a long term effort measuring fish response from the Buckley Ranch habitat improvement project. Fish surveys were conducted on the Buckley Ranch including two sampling stations (treatment and control) on October 6, 2010. Fish sampling had been conducted from 1990 until 2000 as part of a monitoring effort, but none since that time. Data collected included fish population estimate data, fish size by relative abundance data, and fish species composition. As of this fall (2011), we will have 20 years of fish monitoring data collected for both the treatment and control sites including two years of pre-restoration baseline fisheries data. The treated reach has consistently had two-three times higher biomass than the control reach for every year of this monitoring effort post-construction (Table 2, Figure 1).

Badger Basin SWA: Toe-wood sod mat treatment: In addition to sampling the traditional Buckley Ranch sampling sites (see previous paragraph), a new electrofishing site was established to measure fisheries response due to recent habitat improvements within the Badger Basin SWA project (October 8, 2010). In particular the toe-wood sod mat treatment (approximately 200 linear feet of wood-toe treated banks of the 1000 foot electrofishing station) will be evaluated. Fisheries response data collected from this new reach will be compared with data collected from the control and treatment reaches from the Buckley located just 0.15 miles downstream from the Badger Basin project boundary (Table 2, Figure 1).

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Table 2. Buckley Ranch Project brown trout biomass (lbs/acre) (± 95% C.I.) results for control, boulder treatment, wood-toe treatment and reference reaches pre-and post-project.

Year	Biomass (lbs/acre)			
	Boulder treatment	Toe-wood treatment	Control	Reference
1990	29 (±5)	N/A	69 (±4)	N/A
1991	44 (±9)	N/A	37 (±5)	N/A
	STREAM RESTORATION			
1992	40 (±3)	N/A	16 (±2)	N/A
1993	50 (±3)	N/A	11 (±1)	N/A
1994	103 (±39)	N/A	18 (±1)	N/A
1995	33 (±2)	N/A	30 (±5)	N/A
1996	66 (±5)	N/A	52 (±2)	N/A
2000	87 (±3)	N/A	35 (±1)	N/A
2002	N/A	N/A	N/A	130 (±16)
2003	51 (±4)	N/A	27 (±1)	215 (±10)
2004	49 (±3)	N/A	10 (±2)	289 (±3)
2007	N/A	N/A	N/A	484 (±6)
2009	41 (±4)	N/A	13 (±2)	204 (±7)
2010	58 (±7)	83 (±10)	24 (±2)	121 (±3)

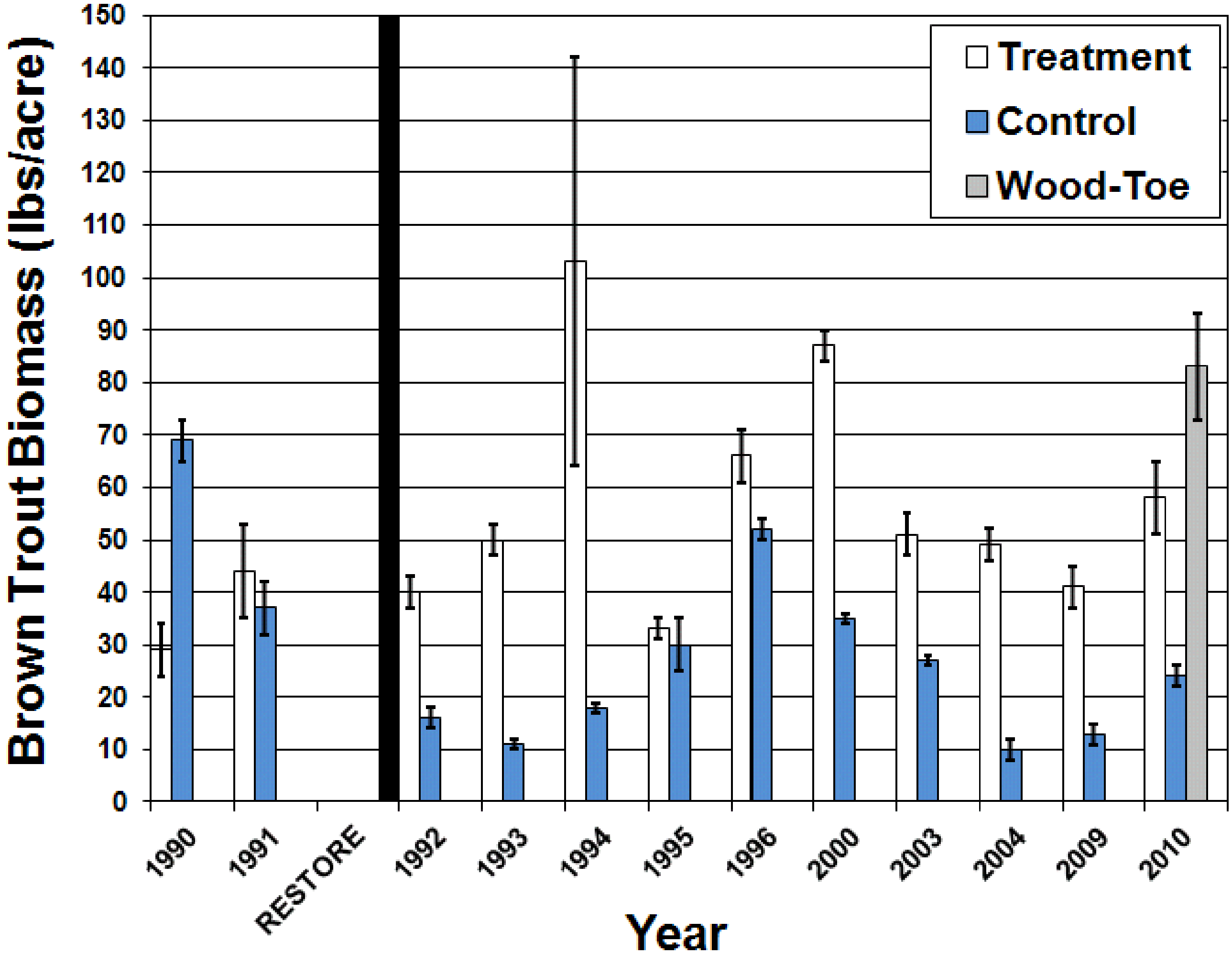

Figure 1. Buckley Ranch Project brown trout biomass (lbs/acre) (± 95% C.I.) results for control, treatment (boulder) and wood-toe treatment reaches pre- (1990-1991) and post- (1992-2010) project.

<u>Middle Fork of South Platte River/ Tomahawk SWA:</u> We collected fish sampling data on Middle Fork of South Platte River. Data had been collected as part of a study completed by George Schisler (2002-2004) but no data had been collected since. Fish biomass and density data collected from this site and one site upstream will serve as a “reference reach” and help us set target levels for expected fisheries response for the Badger Basin SWA habitat restoration project. Detailed habitat surveys from these locations along with fisheries data serve as reference conditions for impaired sites within the South Platte river basin (Table 2).

<u>Upper Arkansas River:</u> No fish sampling work was scheduled for this year. Fish sampling will occur at selected monitoring sites during fall 2011.

4. Conduct physical habitat surveys for use with best theoretical modeling techniques to assist with evaluating fish response to stream habitat manipulations.

ACCOMPLISHMENTS

We completed topographic surveys of pre- and post-treatment stream reaches utilizing assistance from CPW engineering staff and CPW volunteers (Stantec Engineering).

<u>South Fork of South Platte River:</u> Topographic habitat surveys were conducted using survey-grade GPS equipment to serve as baseline data for use in evaluating project goals once two future projects (Hartsel townsite and Upstream Badger Basin Headquarters) are completed (Table 1). Habitat survey data will also serve to assist with project designs for these two future river restoration projects.

The Hartsel townsite project has been delayed until further consultations with CPW aquatic biologist Jeff Spohn. Baseline fisheries data collected in the proposed project area indicated that the fishery is performing better than expected. Consequently, CPW is considering re-directing resources elsewhere to other potential project locations that are a higher priority for restoration.

A partial topographic habitat survey has been completed for the proposed future project location called “Upstream Badger Basin Headquarters” on a 1.0 mile segment South Fork of South Platte River. This habitat survey will be completed during summer 2012 prior to beginning any construction activities associated with the project.

<u>Middle Fork of South Platte River/ Tomahawk SWA:</u> We completed a topographic habitat survey of a 3000 ft reach of the Middle Fork of the South Platte River that serve as reference reach on Tomahawk SWA for use in designing future river restoration projects in South Park, CO. Physical habitat data taken from reference reaches serves as a guide for directing restoration activities on impaired river sites.

<u>South Platte River/Charlie Meyer SWA:</u> We completed a topographic habitat surveys to serve as baseline data for monitoring post-project effectiveness for the final phase of Dream Stream /Charlie Meyer SWA (approximately 1.5 miles) which is located above Elevenmile Reservoir (Table 1). Habitat survey data will also serve to assist with project design for this future river restoration project.

Job A.2. Effectiveness of Stream Aquatic Habitat Treatments Within Functional Categories

Job Objectives

The effectiveness of specific habitat treatments will be evaluated by addressing the following research questions: how do fish utilize the treatment, what is the life expectancy of the treatment, what maintenance is required to keep the treatment functioning properly, what is the initial cost in terms of labor and materials to install the treatment, and how immediate is a given treatment able to provide the desired benefit? A variety of methods will be tested (snorkel survey, underwater videography and photography, PIT tag arrays, electrofishing sampling) to determine how fish utilize specific treatments. Individual treatments and project cross sections will be surveyed, monitored and inspected over time to determine their life expectancies, maintenance costs and how quickly they are able to provide the desired benefits. The material costs and length of time to install particular treatments will be recorded to determine overall costs for installation of particular treatments. Various treatments will be compared within functional groups to assess their relative costs and benefits.

Segment Objectives

1. Fish utilization of various treatment types: During summer and fall months conduct pilot studies using a variety of potential fish monitoring techniques including some or all of the following: PIT tagging, radio telemetry, snorkel surveys and underwater videography and photography for evaluating fish use of specific aquatic habitat treatments.

ACCOMPLISHMENTS

Pilot studies using PIT tagging technology were initiated during a study investigating fish passage through White Water Park (WWP) structures, habitat improvement structures, and natural pools in Lyons on St. Vrain Creek. Assistance was also given to two graduate students using PIT tagging technologies to monitor fish movements within two different streams (South Boulder Creek and the Cache La Poudre River). Pilot studies using PIT tagging technologies with fixed antenna systems were effectively applied in order to monitor fish movements within each of the three study sites. PIT tagging shows promise as a possible technique to evaluate how fish utilize specific habitat treatments in future studies.

No pilot studies with radio telemetry, snorkel surveys, or underwater videography and photography techniques were used during this segment.

2. Treatment longevity: Cross-sections at specific aquatic habitat treatment locations for which we have before, as-built and post-monitoring data will be re-surveyed to monitor treatment longevity and evaluate stability over time.

ACCOMPLISHMENTS

No cross-section monitoring surveys were conducted during this segment on reaches for which we have before, as-built and post-monitoring data.

However, longitudinal surveys and cross-section surveys were conducted on a two-mile restored reach of the Middle Fork of the South Platte River (Badger Basin SWA). We have collected this data for "before" and as-built conditions at this reach (Figures 2-9). We will begin post-monitoring surveys beginning in the next research segment. Data from this project site will continue to be collected and analyzed over the next five years to monitor treatment longevity and evaluate stability over time.

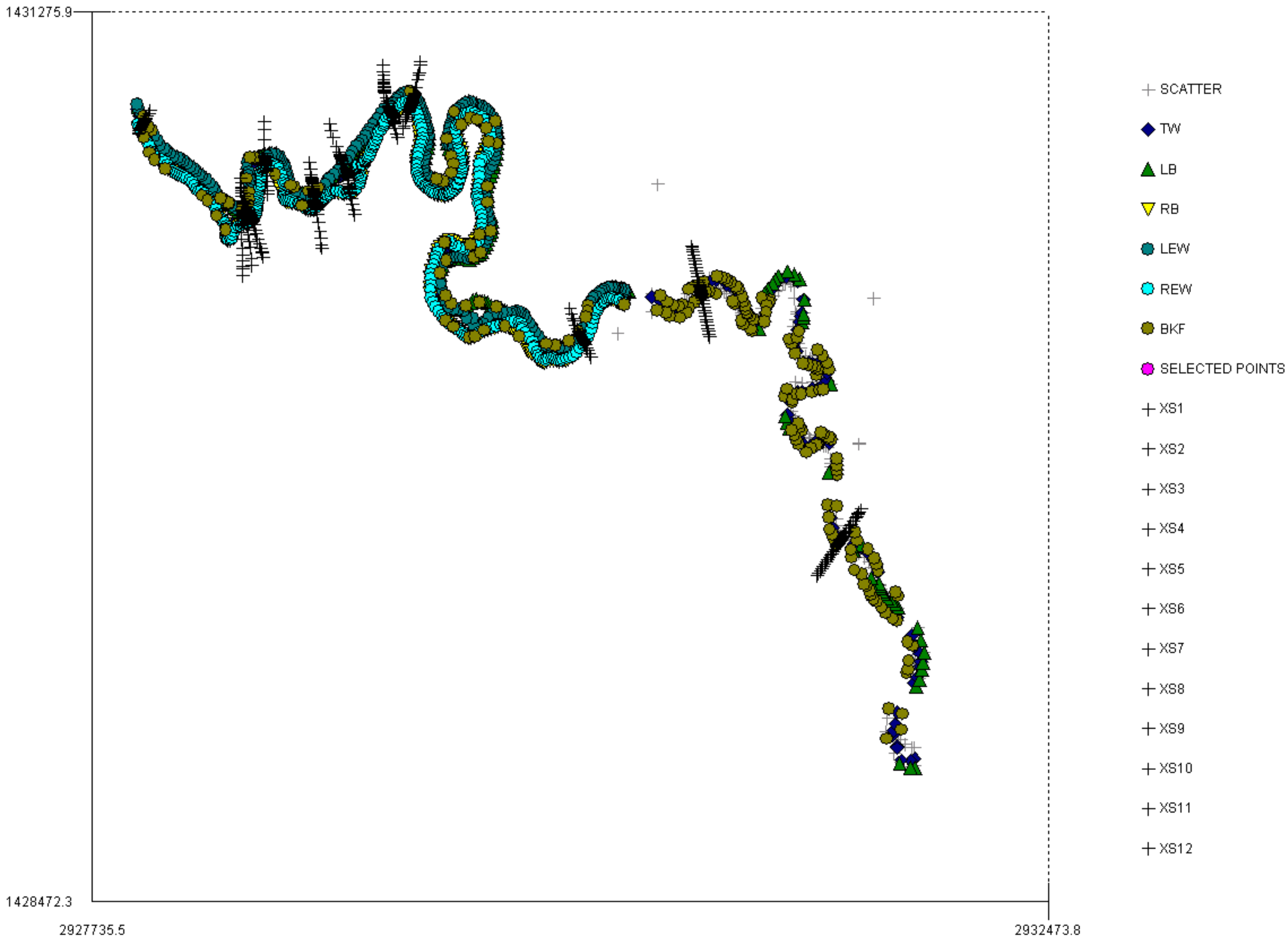

Figure 2. Plan-view of survey points measured on Middle Fork of the South Platte River (Badger Basin SWA) "BEFORE" work was initiated. A total of 3300 topographic survey points were taken including the following features: 12 cross-sections (+), thalweg (TW), left bank (LB), right bank (RB), left-edge water (LEW), right-edge water (REW), and bankfull indicators (BKF).

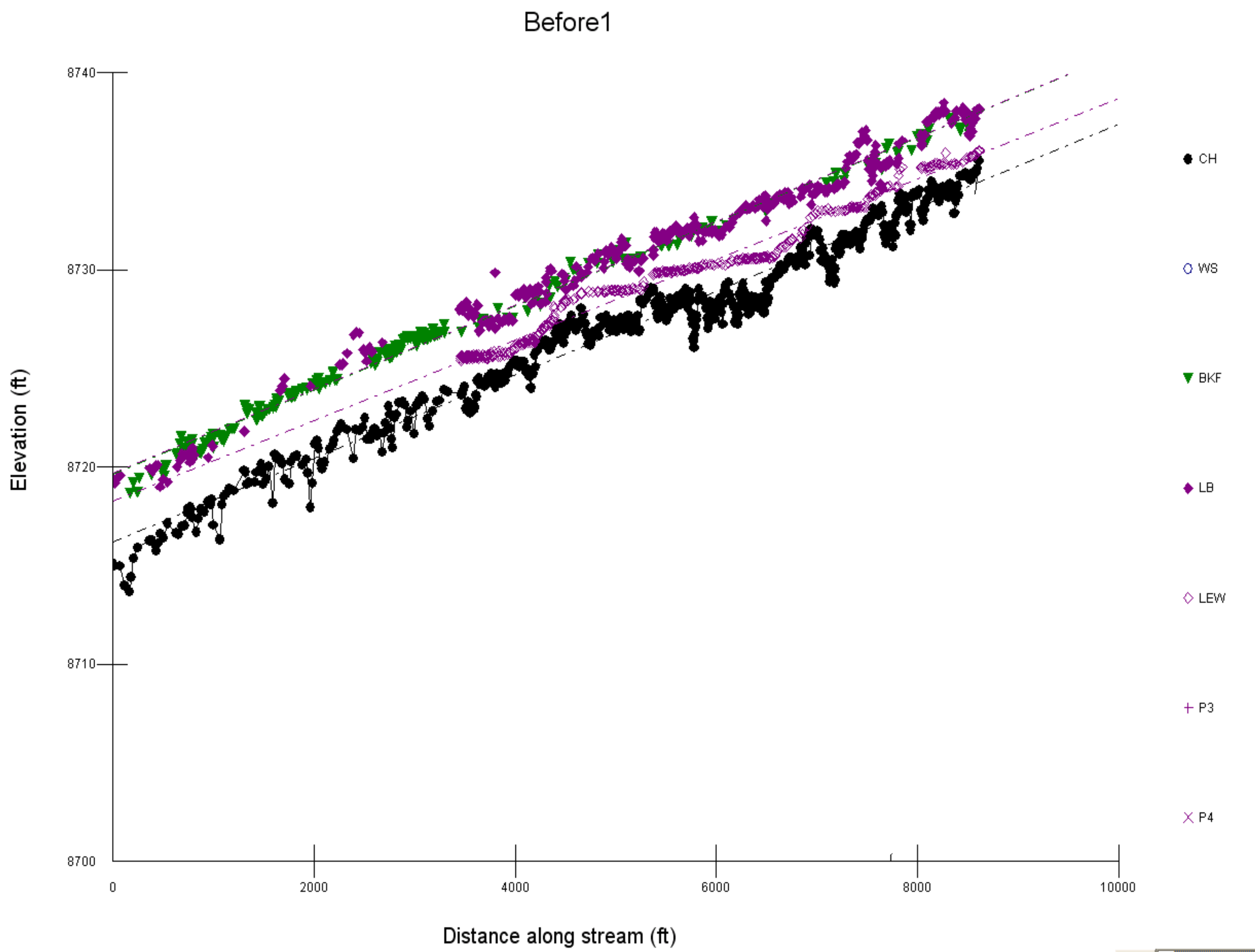

Figure 3. Longitudinal profile of Middle Fork of the South Platte River (Badger Basin SWA) "BEFORE" work was initiated. Longitudinal survey points included the following features: thalweg (CH), bankfull indicators (BKF), left bank (LB) and left edge of water (LEW).

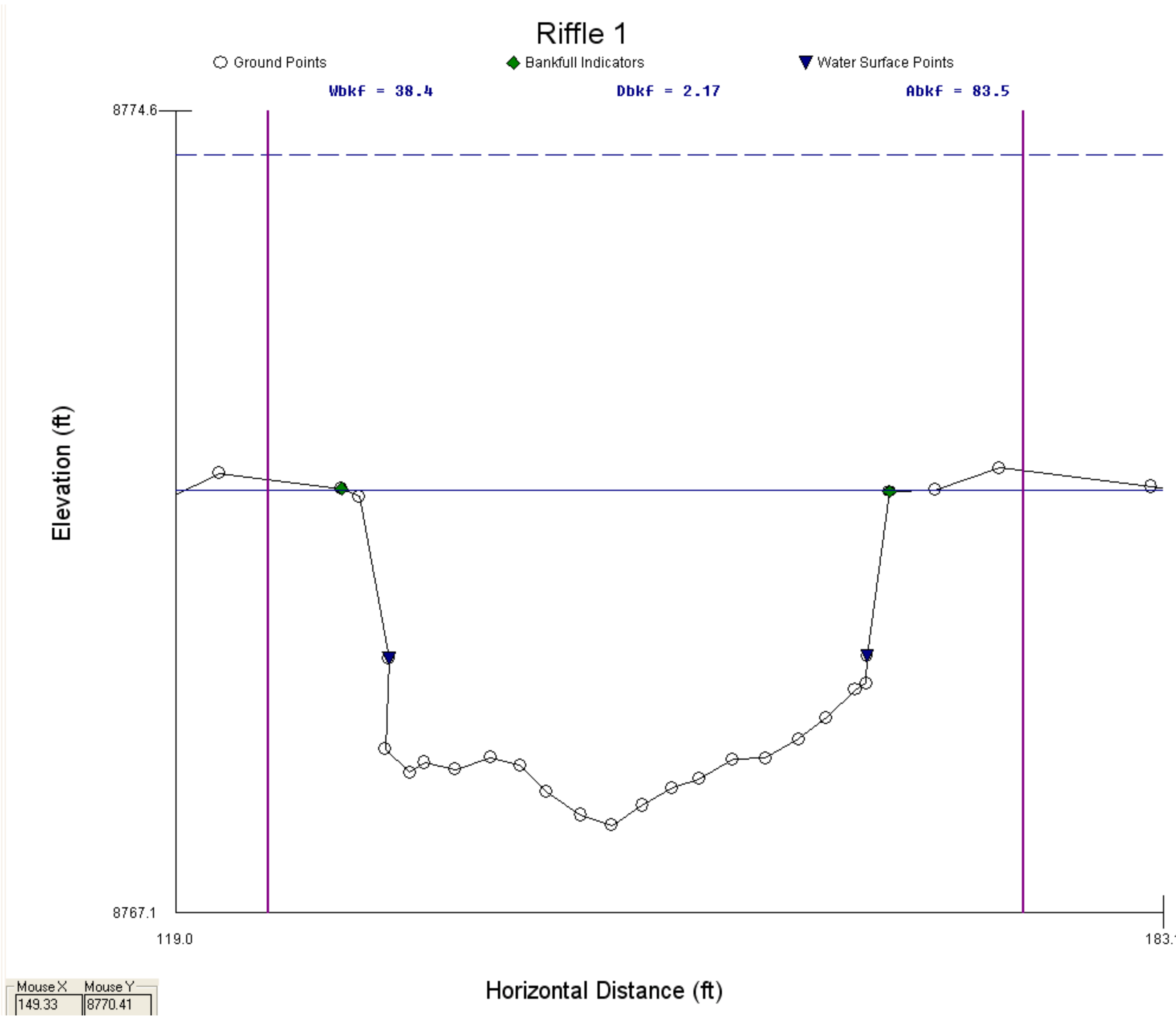

Figure 4. Reference riffle surveyed on Middle Fork of the South Platte River (Badger Basin SWA) "BEFORE" work was initiated.

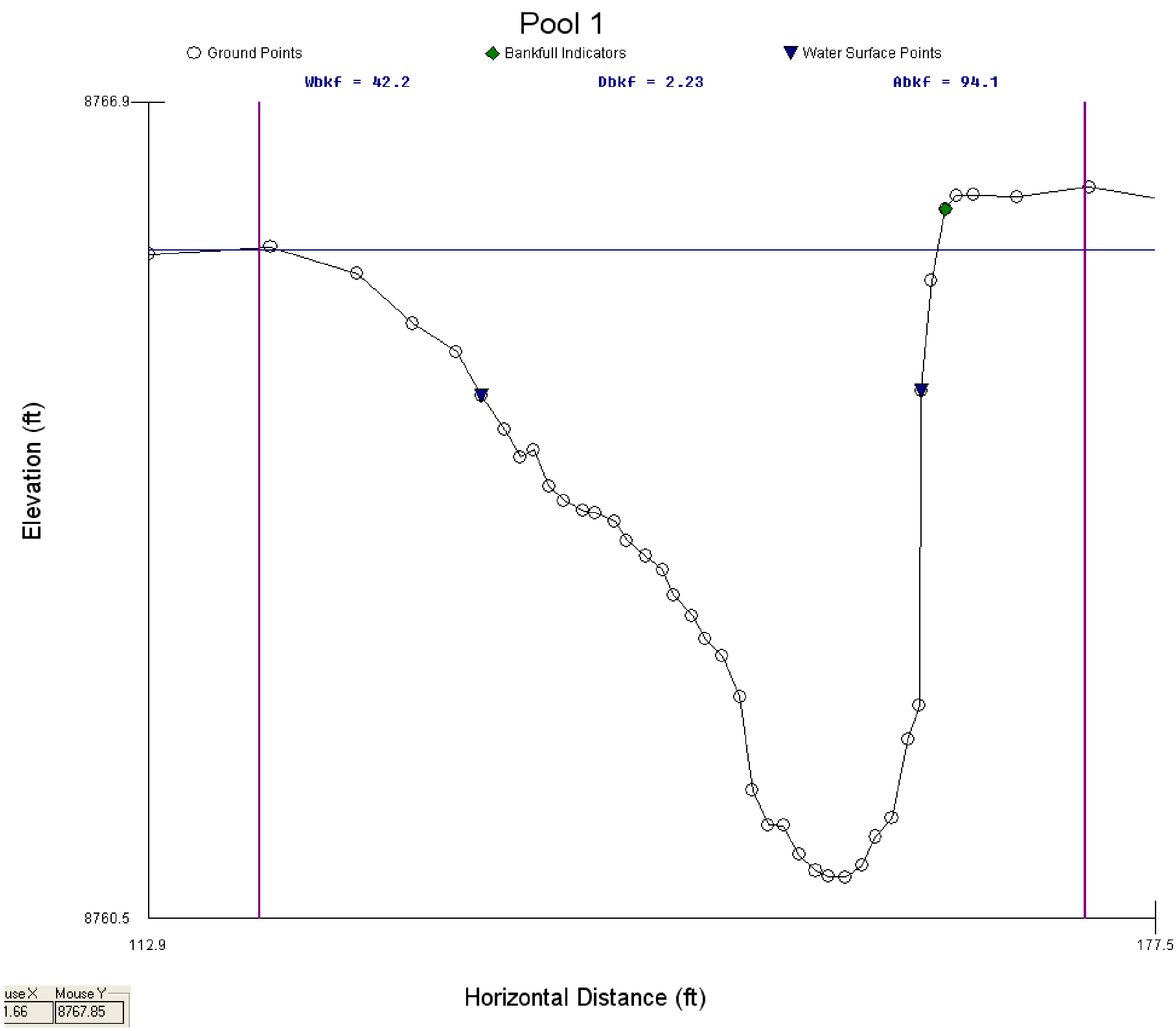

Figure 5. Reference pool surveyed on Middle Fork of the South Platte River (Badger Basin SWA) "BEFORE" work was initiated. This pool was the deepest natural pool in the entire 2.0 mile reach at a maximum depth of just under 5 feet (4.9 feet) measured from bankfull elevation.

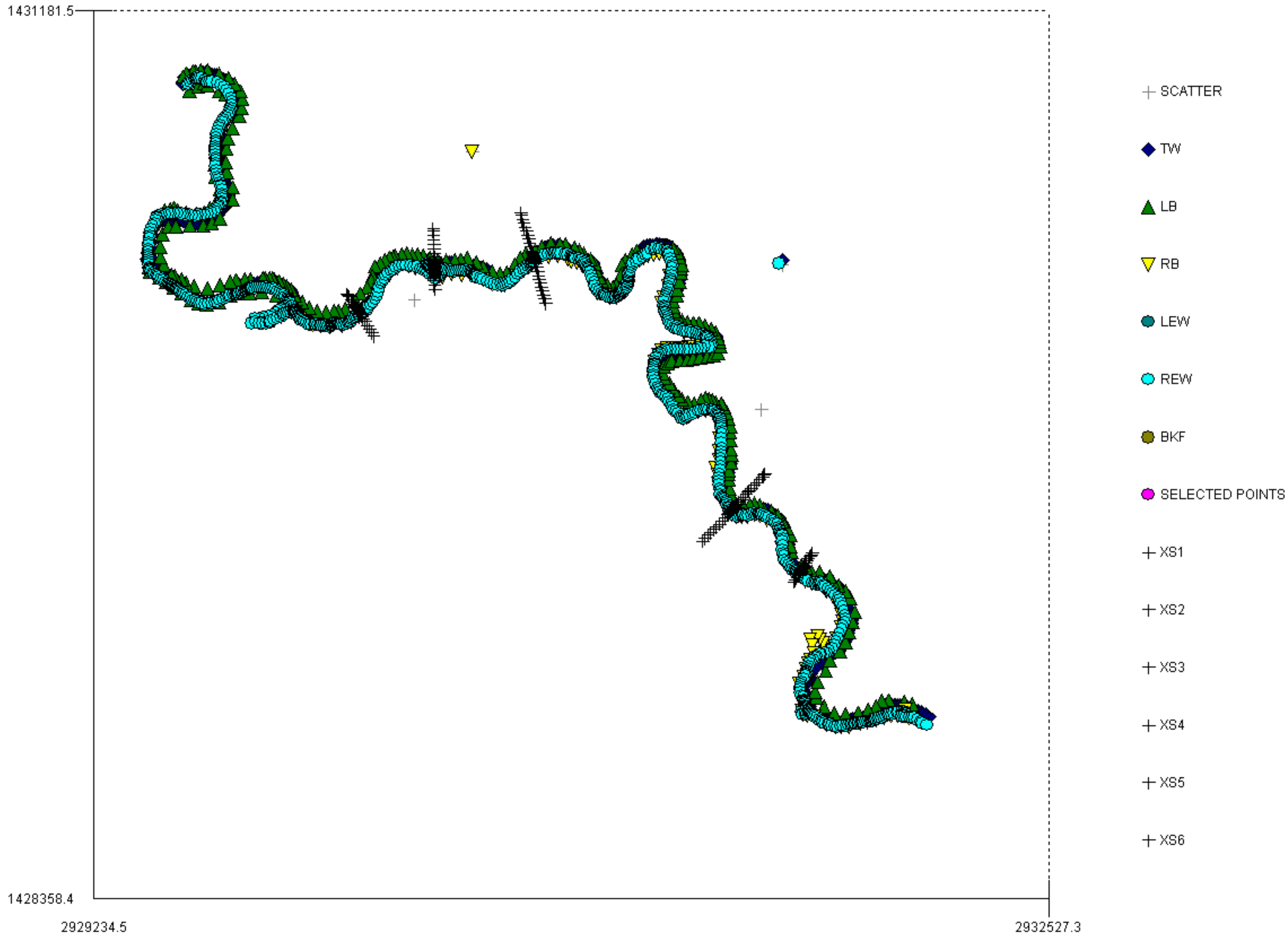

Figure 6. Plan-view of survey points measured on Middle Fork of the South Platte River (Badger Basin SWA) "AFTER" work was completed (as-built). Over 3600 topographic survey points were taken including the following features: 5 cross-sections (+), thalweg (TW), left bank (LB), right bank (RB), left-edge water (LEW), right-edge water (REW), and bankfull indicators (BKF).

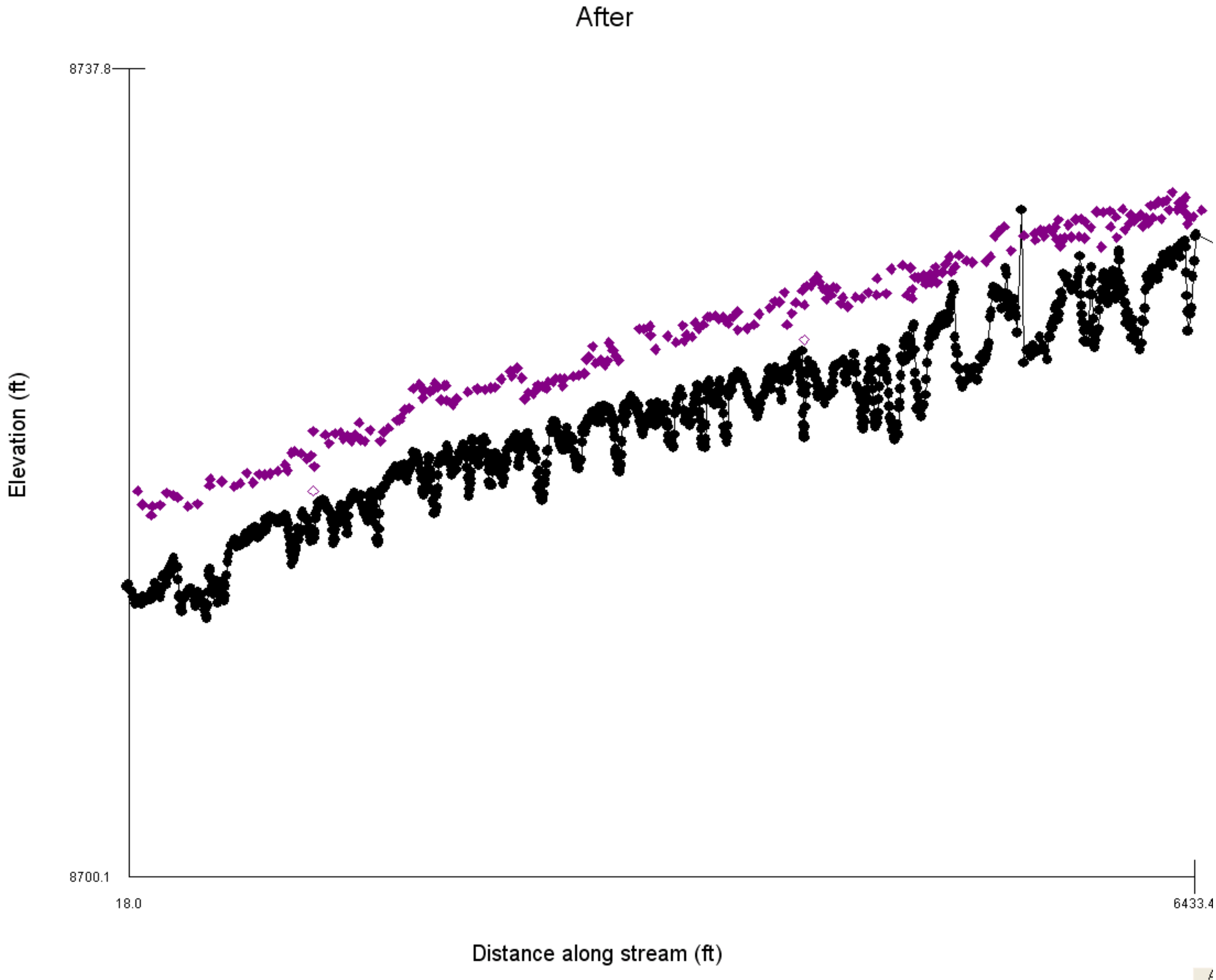

Figure 7. Longitudinal profile of Middle Fork of the South Platte River (Badger Basin SWA) “AFTER” work was initiated. Longitudinal survey points included the following features: thalweg (CH), bankfull indicators (BKF), left bank (LB) and left edge of water (LEW).

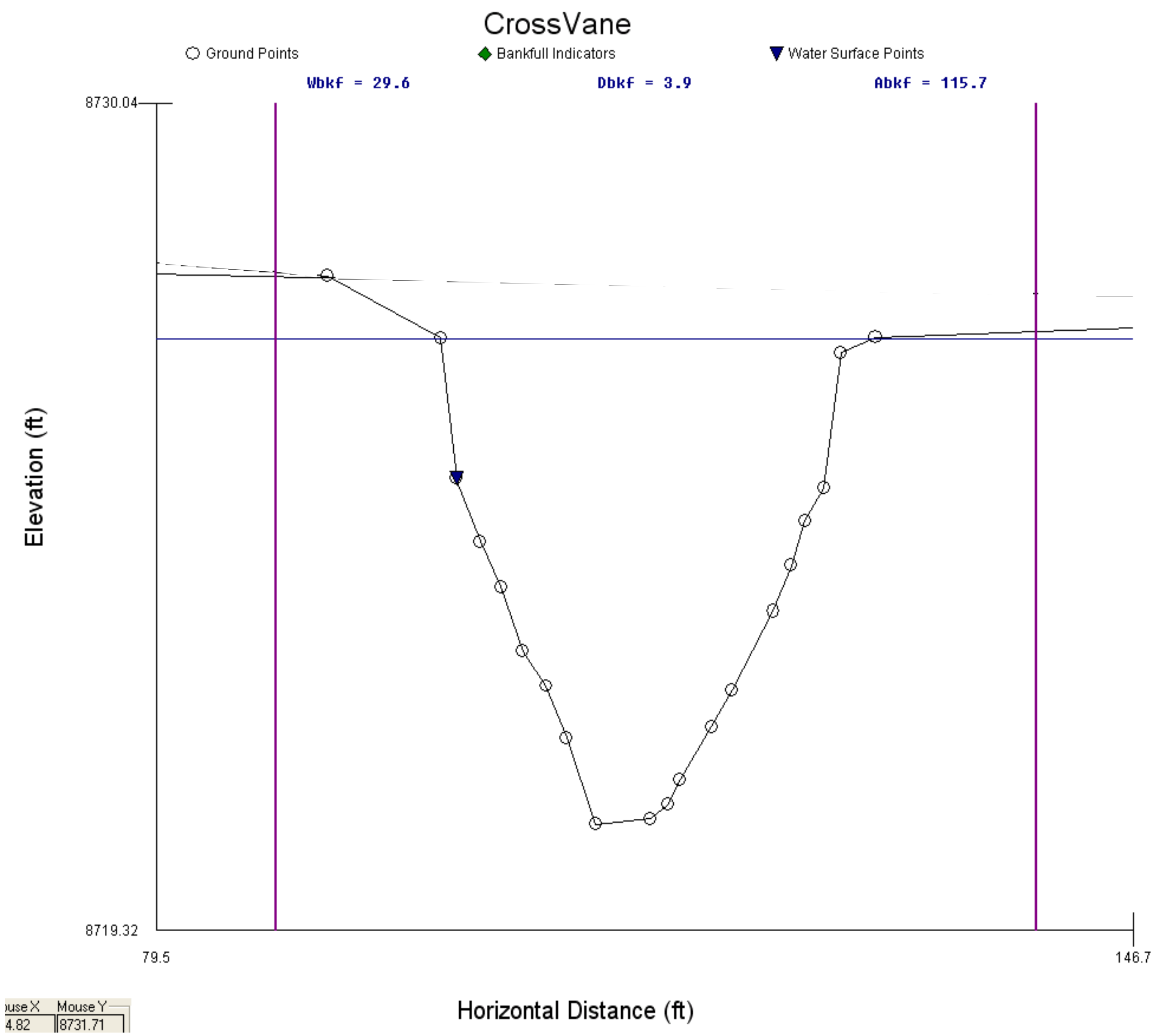

Figure 8. Pool located downstream of cross-vane structure surveyed on Middle Fork of the South Platte River (Badger Basin SWA) "AFTER" work was completed. This new pool was 6.3 feet deep measured from bankfull elevation.

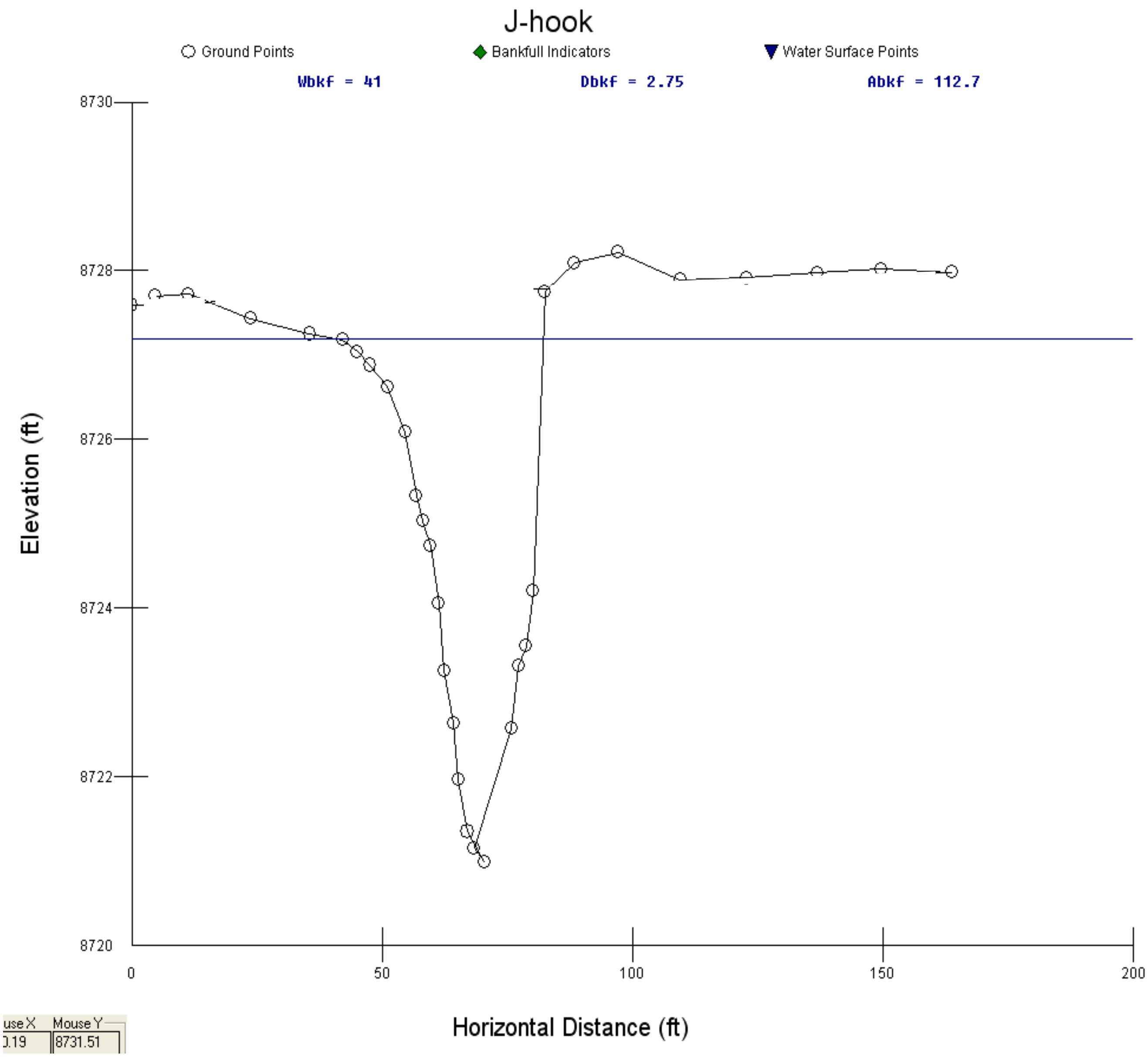

Figure 9. Pool located downstream of J-hook structure surveyed on Middle Fork of the South Platte River (Badger Basin SWA) "AFTER" work was completed. This new pool was over 6.2 feet deep measured from bankfull elevation.

Physical Habitat Assessments

Physical habitat data are being collected to monitor how well various habitat restoration treatments are performing in order to meet specific project goals. The "BEFORE" and "AFTER" survey data collected from the recently completed habitat enhancement projects on the Middle Fork of the South Platte River (Figures 2-9) was used to determine if the specific project goal, "increase over-winter habitat by creating deep pools" was met. Residual pool depths (RPD) were measured using longitudinal profile data collected "BEFORE" and "AFTER" construction (Figure 3 and 7). The habitat enhancement project involved a 2.0 mile reach of the Middle Fork of the South Platte River in South Park. Residual pool depths are defined as the difference between the elevation of the pool tail crest (top of riffle or glide) and the maximum depth of a given pool. This difference would essentially be the maximum pool depth within a given pool if the flow of moving water was shut off completely. The larger the RPD value, the deeper the pool. Table 3 contains RPD values for 20 pool locations before and after habitat enhancements were applied. The number of pools with RPD values greater than 1.5 feet after construction increased from 7 to 11 pools, or almost a 2-fold increase in the number of deep pools over the sampled reach. The number of pools with RPD values greater than 2.0 feet after construction increased from 2 to 8 pools, or a 4-fold increase in the number of very deep pools over the sampled reach. This evidence suggests that the goal of increasing over-winter habitat by creating [more] deep pools was met by conducting this physical habitat assessment. RPDs within the treated reach will continue to be monitored over time to make sure that these depths are maintained (or enhanced) over time.

Table 3. Residual pool depths (ft) for 20 pool locations on the Middle Fork of the South Platte River before and after habitat enhancement treatments were applied.

Pool Number	BEFORE: Residual pool depth (ft)	AFTER: Residual pool depth (ft)
1	1.28	2.51
2	0.60	1.37
3	0.61	1.68
4	1.31	0.54
5	2.15	2.30
6	0.74	1.40
7	1.41	2.19
8	1.85	1.40
9	1.55	1.41
10	2.64	2.51
11	1.45	0.80
12	1.75	2.10
13	1.11	2.75
14	1.20	1.42
15	2.12	2.50
16	1.30	1.40
17	1.20	2.30
18	1.55	1.46
19	0.36	1.60
20	1.39	3.30
Totals	Average RPD = 1.38 Range = 0.36-2.4 No. Pools > 1.5 RPD = 7 No. Pools > 2.0 RPD = 2	Average RPD = 1.85 Range = 0.54-3.3 No. Pools > 1.5 RPD = 11 No. Pools > 2.0 RPD = 8

3. Treatment maintenance and costs: Past project restoration costs will be evaluated with the following criteria: material and labor costs for various habitat treatments, length of time to install specific aquatic habitat treatments, maintenance costs associated with specific treatments and how quickly specific habitat treatments provide their intended function. Various aquatic habitat treatments will be compared within functional groups to assess their relative costs and benefits.

ACCOMPLISHMENTS

Data on past project restoration costs from various CPW stream restoration projects is currently being collected. We will continue to collect and analyze data related to treatment and maintenance over the next five years to try and determine how various habitat treatments compare using a cost/benefit analysis.

Job A.3. Angler Use in Restored Versus Un-restored River Channels

Job Objectives

A creel study will be conducted to determine how angler use has changed in restored compared to un-restored river channels.

Segment Objectives

1. Historic creel data: Aquatic biologists will be consulted to determine what data (if any) exist at proposed river restoration locations to quantify pre-restoration angler use.

ACCOMPLISHMENTS

Aquatic biologists were consulted for any existing creel data that might exist to quantify angler use in proposed river restoration reaches. No existing creel data were identified for use in evaluating changes in angler use from proposed river restoration reaches.

2. Creel studies: If no historic creel data exists, we will conduct a creel survey to quantify angler use specific to the un-restored river channel segment. Once stream restoration is completed, we will continue conducting creel studies to quantify angler use specific to the restored river channel segment for comparison.

ACCOMPLISHMENTS

Since no existing creel data exists for the proposed restoration reaches, creel studies will be conducted in pre- and post- treatment stream reaches during spring/summer 2012 including: the reference reach (Tomahawk SWA), Badger Basin SWA (Middle Fork of South Platte below

Badger Basin Headquarters), Badger Basin SWA (South Fork of South Platte above Badger Basin Headquarters), Buckley Ranch (South Platte River), Dream Stream (phase 1-3 and proposed final segment upstream of Elevenmile Reservoir) and Upper Arkansas River Project area (NRD project). Creel studies were not conducted during this segment (spring 2011) because river conditions were not representative of a typical year due to unusually high run-off conditions that lasted for a longer than normal duration.

Coordination will occur with George Schisler, Greg Policky, and Jeff Spohn to design creel survey tailored to surveying angler use in pre- and post-treatment stream reaches. A pilot study will be conducted with concealed trail camera systems as a possible technique for conducting creel studies in South Park.

Job A.4. Identification, Evaluation and Development of Fish Barriers for Protecting Colorado Fishes

Job Objectives

Develop field and theoretical techniques for evaluating the barrier potential of instream obstacles. This study will involve multiple years of data collection statewide. Specific projects will result from consultations with aquatic biologists requesting assistance with measuring the barrier potential of instream structures. Examples of past studies include evaluation of fish barrier function to protect cutthroat trout populations from whirling disease or non-native salmonids, evaluation of native sucker and sport-fish passage through whitewater kayak structures and evaluation of culvert structures for passage of various Colorado fishes. Data collected from field sites will be useful in developing species-specific fish passage criteria, evaluating existing instream obstacles, refinement of monitoring techniques for fish passage at potential barrier sites and improvement of theoretical techniques for evaluating fish passage (Lauritzen 2002; Kondratieff and Myrick 2006).

Segment Objectives

1. Continue working with aquatic biologists to evaluate the barrier potential of instream obstacles to Colorado fishes. Develop publishable fish passage criteria for correcting potential barriers (i.e. culverts, diversions, whitewater park structures). Conversely, continue evaluations to assist with new barrier designs or modification of existing barriers to protect native Colorado sportfish from downstream threats.

ACCOMPLISHMENTS

Fish passage studies: Evaluating fish passage for two engineered rock ramps

Techniques to modify existing diversion structures that will allow upstream and downstream migration for various trout are being evaluated. This project includes an ongoing PhD study to determine the effectiveness of existing fishways (such as engineered rock ramps) for salmonids to develop new fishway designs, refine techniques to monitor fish movement at potential barriers and evaluate impacts of artificial in-stream structures such as White Water Park structures and water diversion structures on fish movement.

Status - - Physical habitat alterations have been identified as one of the primary causes leading to declines and extinctions of fishes over the past century. Stream habitat alterations that limit sportfish dispersal and connectivity between populations include diversions, structures installed at road-stream crossings, and impoundments.

Field work included reconnaissance of fishway sites on Boulder Creek and South Boulder Creek to determine suitability for deploying antenna arrays to monitor movement of tagged rainbow and brown trout through existing fishways. Suitable sites were identified on South Boulder Creek in Boulder, with cooperation from City of Boulder Open Space. Once field sites were identified, a pilot study was conducted at one of the locations in summer 2009. Movements of PIT tagged fish were monitored using a pair of antennae placed upstream and downstream of a diversion that has been modified to facilitate fish passage. The antenna system was successfully installed, tested and employed in the field and was used to monitor movements of wild salmonid fishes. A total of four additional antenna systems were purchased, installed, and used to collect fish passage data at two additional sites (one control site with no barrier to migration and one additional modified diversion structure). Fish passage studies on salmonid fish species at both modified diversion sites and the control site using PIT tag technology was completed by summer 2011. In addition, detailed hydrologic and hydraulic measurements have been completed at the two field sites that will be used for evaluation and construction of scale models for a hydraulics laboratory study later in FY 11/12 at the CSU Engineering Research Center lab.

During this research segment period, we provided project oversight to PhD candidate, Ashley Ficke on a project evaluating fish passage at two engineered rock ramps on South Boulder Creek, Boulder, CO. We have provided ongoing assistance with equipment purchases and acquiring necessary research supplies as well as ongoing technical and field assistance through the past year.

CPW has provided assistance collecting fish (including brown and rainbow trout) for PIT tag studies from South Boulder Creek and assistance with re-installing PIT tag array systems after exceptionally high spring flows damaged antennae arrays. We have assisted with routine maintenance, installation of solar panels and changing batteries on PIT tag reading systems.

Topographic habitat surveys of three locations within Ashley’s study reach were conducted on South Boulder Creek including McGinn Ditch, South Boulder Canyon Ditch, and a control reach located in between both diversions. This data will be used to design and construct scale models of rock ramp structures to evaluate performance of existing structures.

An additional component of this fish passage study will examine the influence of white water park (WWP) structures on fish habitat (quality of pool habitat formed by WWP structures), stream longitudinal connectivity, fish populations and fish passage. The goal of this research is to determine whether how WWP structures influence fisheries and therefore population stability. If current designs are found to negatively influence fisheries, we hope to modify white water park structure designs to allow upstream and downstream migration for both game and non-game species. A CSU engineering Master's student is currently working with CPW to study the effects of these WWP structures related to the above stated project goals.

Fish passage studies, White Water Parks

CPW has collected habitat survey data for assessing fish passage at and around three White Water Parks in Colorado including Buena Vista, Lyons, and Salida. Detailed habitat surveys have been conducted at white water play park structures located Buena Vista and Lyons. A partial survey has been conducted on two structures in Salida. Velocity profile measurements have been conducted at one structure in Buena Vista, two structures in Lyons, and two structures in Salida. Preliminary evidence collected during habitat surveys suggests that each of the WWPs studied may serve as a potential barrier to trout upstream movement during low flow periods based on velocity measurements taken using a Marsh McBirney flow meter, data from cross sections, data from tracking rainbow and brown trout using PIT tag technology and from tools provided in a fish passage software program called "Fish Xing."

Preliminary fish passage evaluations at an existing White Water Parks in Lyons, Colorado using PIT tagged fish or mark/recapture techniques suggest that fish passage is restricted during low flows from November through April 2010. A pilot study monitoring PIT tagged fish movements will be continued for at least two additional sampling occasions. This fish passage study includes monitoring of individual fish movements through a grouted WWP reach, a non-grouted habitat improvement reach, and an unaltered control reach.

Some of the hypotheses that will be addressed include:

1) Brown trout [YOY-Adult] and rainbow trout [YOY-Adult] movements through WWP structures are restricted during low flows (October through April) and not during high flows (May through September).

2) Large, deep pools created by grouted WWP structures provide poor habitat for trout compared to a) natural pools and b) habitat enhancement structures.

3) Upstream transition probabilities (movement rates) for fish living in WWP pools are lower compared with upstream movement rates of fish living in habitat improvement pools and unaltered natural pools.

4) More rainbow trout stocked in WWP pools will leave compared to rainbow trout stocked in habitat enhancement pools and natural pools during a one year period.

CPW recently coordinated a meeting with Dr. Brian Bledsoe (CSU Engineering Professor) and Dr. Chris Myrick (CSU Department of Fish, Wildlife, and Conservation Biology) on Whitewater Parks and fisheries impacts to determine whether we might be able to conduct research on the topic and coming up with solutions that would enhance fish passage. A CSU engineering student named Brian Fox has recently begun working on this issue.

In addition to this research, we plan to assist biologists with creel studies with the goal of determining how angler use and fishing quality is affected at and around White Water Parks. Kendall Bakich (CPW aquatic biologist) and George Schisler have assisted to design a creel study that serves two purposes: 1) to collect baseline angler use data to monitor how angler use changes before, during and after WWPs are constructed (Roaring Fork River, Basalt) and 2) determine how angler use changes based on proximity to an existing white water park (Colorado River WWP in Glenwood Springs).

STUDY PLAN B: TECHNICAL ASSISTANCE

Job B.1. Stream Restoration Assistance to CPW Personnel and Other State and Federal Agencies.

Job Objectives

To provide expertise, consultation, evaluation and training related to stream habitat restoration project identification, selection, design and permitting to CPW and other state and federal personnel as requested.

Segment Objectives

CPW and other state and federal personnel are frequently in need of technical assistance related to stream habitat restoration projects. As the need arises, technical assistance related to stream habitat restoration project identification, selection, design, evaluation, and permitting for CPW, and other state and federal personnel will be provided. Technical assistance includes review of stream restoration project designs for aquatic biologists and district wildlife managers (DWMs), site visits to proposed stream restoration locations, consultations with various agencies on stream restoration opportunities associated with highway and bridge improvement projects, project management of aquatic habitat treatment construction during highway bridge replacements or Fishing Is Fun (FIF) projects, consultations and technical support related to stream mitigation work for 404 permit violations, technical and physical assistance related to fish barrier design and construction, and teaching at various technical training sessions for CPW and other state and federal personnel.

INTRODUCTION

Job activities included: presentations to CPW (internal) and non-CPW (external) personnel, technical assistance to CPW area biologists and DWMs, technical assistance to non-CPW external government agencies and private consultants, technical assistance related the Upper Arkansas NRD (Natural Resource Damage) project, technical assistance related to design, construction, and monitoring of fish barriers, providing training to CPW personnel and acquiring additional technical expertise and professional job skills.

ACCOMPLISHMENTS

Presentations, CDOW (internal)

Presentations to CPW personnel were delivered with the goal of increasing interactions and communication with Regional CPW staff (i.e. local Area meetings) and providing current research finding to the CPW Aquatic Section (Aquatic Biologists and Senior Aquatic Staff).

Area 13 Regional Meeting, CDOW Service Center, Salida, CO. "Upper Arkansas River Project: Overview of Potential Treatments." May 5, 2010. Updated CPW regional staff on the status of the Upper Arkansas River project and White Water Park conflicts between boaters, anglers and fish populations on the Arkansas River.

Area 1 Regional Meeting, CPW shop located in Fairplay, CO. "Restoring Rivers in South Park, CO." June 8, 2010. Updated Regional staff on the status of current and future river restoration projects on the South Platte River basin.

2011 Annual Aquatic Biologist Meeting (Section Meeting), Cripple Creek, CO. "Latest river restoration techniques (toe-wood sod mat) and ongoing WWP research findings." January 18, 2011.

Presentations, non-CPW (external)

Presentations to non-CPW personnel were delivered with the goal of communicating recent research findings to interested parties and educating students and professionals on river restoration techniques.

2010 Whitewater Courses and Parks National Conference, Salida, CO. "Whitewater Recreation and Fisheries: Seeking Common Ground." May 26, 2010. Attendees included Army Corps representatives, engineers, WWP designers, town managers and other interested stakeholders.

2010 US Army Corps of Engineers Sacramento Division Consistency Meeting, Grand Junction, CO. "Whitewater Recreation and Fisheries: Seeking Common Ground." June 17, 2010.

US Army Corps of Engineers 2010 Colorado Regulatory Coordination Conference Denver, CO: "Whitewater Recreation and Fisheries: Seeking Common Ground." July 21, 2010. Attendees included USACOE staff all CO districts including Albuquerque, Omaha, and Sacramento Districts.

Windy Gap and Moffat Projects Engagement Workshop, Winter Park , CO. "Natural River Function." January 24, 2011. Introduced concept of the four-stage channel to the group as a potential solution to the impacts from water development. Attendees included Director Remington, Wildlife Commissioner Chairman Tim Glenn, members of Senior Aquatic Staff, and various stakeholders (private landowners, Trout Unlimited, BOR, town representatives, private consultants).

Joint American Fisheries Society Colorado/Wyoming Chapter and Colorado Chapter of the Wildlife Society 2011 Annual Meeting, Fort Collins, CO. "Whitewater Recreation and Fisheries: Searching for Common Ground." February 23, 2011.

Introduction to Fisheries Course 2011, Front Range Community College, Fort Collins, CO. "Fisheries Benefits From Applied River Restoration Techniques." March 25, 2011. Instructed 24 students of Jennifer Lee's 2011Fisheries course on river restoration techniques, fisheries response, and fish passage problems associated with white water park structures.

Wildlife Management Short Course 2011, Colorado State University, Fort Collins, CO. "Restoring Colorado Rivers." March 29, 2011. Instructed 45 students of Dr. Decker's 2011 Short Course on river restoration principles and techniques.

Colorado Division of Wildlife/US Fish and Wildlife Coordination Meeting, Western State College, Gunnison, CO. "Whitewater Recreation and Fisheries: Searching for win-wins for boaters and anglers." May 5, 2011.

Technical Assistance, CPW Area Biologists and DWMs

We provided technical assistance to CPW aquatic biologist and DWMs as requested. Technical assistance included work related to evaluating fish passage at White Water Parks, culverts and other potential barriers, reviewing habitat restoration construction plans related to river restoration and trout habitat enhancement, assisting with physical habitat surveys and equipment, reviewing fish barrier construction designs to protect native cutthroat trout populations, assisting Army Corps of Engineers (ACOE) staff and CPW water specialists to develop a new ACOE 404 permit (Regional General Permit 12) specifically for stream habitat improvement projects with fisheries-related goals for Colorado, providing aquatic biologists with cost estimates for specific habitat treatments to enhance sport fish populations in streams and providing technical expertise related to river impacts from large-scale water development projects in Colorado (i.e. Windy Gap and Moffat Firming Project).

Technical Assistance, non-CPW external government agencies and private consultants

We provided technical assistance to non-CPW external government agencies and consultants as requested. Technical assistance was given specifically to the following private consultants: Wildland Hydrology (Dave Rosgen), Stantec Engineering (river restoration team) and Flywater Consultants (Cory Engin and Matt Burton). Technical assistance included conceptual ideas for providing fish passage at diversion structures and White Water Parks, conceptual ideas for trout habitat improvement and ideas for monitoring stream habitat improvement projects. Technical assistance to non-CPW external government agencies included the Army Corps of Engineers (ACOE) and Colorado Department of Transportation (CDOT) specifically related to potential impacts of White Water Parks to fisheries, creation of a new ACOE 404 permit for stream restoration projects related to improving fisheries and the wildlife impacts from rip rap used for bridge under crossings.

Technical Assistance, Upper Arkansas NRD 11-mile project,

We provided technical assistance to various agencies and organizations involved in the Upper Arkansas NRD project as requested. Technical assistance included: participation in Upper Arkansas Project trustees coordination meetings, LCOSI (Lake County Open Space Initiative) meetings, angler round table meetings and I-team meetings, technical and logistical planning with Rod Van Velson (retired CDOW Aquatic Researcher), Tracy Kittell (CDOW design engineer), Greg Policky (CDOW Aquatic Biologist) and Nicole Vieira (CDOW Aquatic Researcher), presentations demonstrating on-site construction examples of new habitat treatment (toe-wood sod mat treatment) and project site tour to interested parties on Badger Basin SWA near Hartsel, Colorado, review of publications, reports, and other relevant literature related to the Upper Arkansas River NRD project and presenting information regarding river restoration plans and research monitoring to interested publics and CPW staff as requested.

Technical Assistance: Design, Construction, and Monitoring of Fish Barriers

1) Assist area aquatic biologists to monitor fish barrier performance at existing sites.

   Cunningham Creek: Met with Kendall Bakich (CDOW Aquatic Biologist, Area 8) to survey existing barrier location on Cunningham Creek to protect native cutthroat trout population upstream. Completed detailed survey of Cunningham Creek in vicinity of existing waterfall obstacle (marked fish have moved upstream of existing constructed "barrier" including 1 brook trout in 2009 and 47 brook trout in 2010). Survey including photo records, site map, longitudinal profile and cross sections. Kendall plans to work with USFS Fisheries Biologist, myself, and CDOW engineers to re-design fish barrier at this site.

2) Assist area aquatic biologists with fish barrier designs as needed

   Park Creek: Met with Kendall Bakich (CDOW Fisheries Biologist, Area 8) to survey potential barrier location on Park Creek to protect native cutthroat trout population.

Completed detailed survey of Park Creek in vicinity of culvert road crossing including photo records, site map, longitudinal profile and riffle cross section. Kendall plans to use this information and work with USFS Fisheries Biologist, myself, and CDOW engineers to design fish barrier at road-and-stream crossing.

East Fork Parachute Creek: Met with Lori Martin (CDOW Aquatic Biologist), Tracy Kittell (CDOW design engineer), Tom Fresques (BLM Fisheries Biologist) to survey East Fork Parachute Creek and look at potential habitat restoration site and proposed fisheries enhancement techniques on upper Trapper Creek and Northwater Creek. Completed detailed habitat survey that was used to put together Request For Proposal (RFP) for East Fork Parachute Creek barrier project that Trout Unlimited used to generate conceptual designs from prospective bidders. June 29-30, 2010. Assisted Lori Martin, Tom Fresques, and Dave Nickum (President, Colorado Chapter Trout Unlimited) with reviewing proposals from bidders and with selecting the best candidates for designing and building the proposed fish barrier. Continuing ongoing involvement includes reviewing project plans during the design phase of this project.

North Elk Creek: Met with Boyd Wright (CDOW Aquatic Biologist, Area 6) to conduct field visit on North Elk Creek to locate the best potential fish barrier locations for protecting upstream native cutthroat trout populations.

3) Provide technical assistance to biologists and Army Corps representatives involved in reviewing existing and proposed White Water Parks

   Two presentations have been given to Army Corps representatives (Grand Junction and Denver) and resulted in ongoing communications with various Corps representatives. Data from ongoing WWP studies and material from PowerPoint presentations on WWPs have been provided to CDOW aquatic biologists engaged in WWP issues including Billy Atkinson, Kendall Bakich, Jim White, Greg Policky, Ben Swigle, Kurt Davies, and Ken Kehmeier. A PowerPoint presentation on WWPs and fisheries was given to Ken Kehmeier for delivery to Director Staff in September, 2010. I have also provided technical assistance to biologists from California, Tennessee, Idaho and Minnesota who are actively engaged in WWP issues and fisheries (this resulted from a presentation I delivered to the Level 4 Rosgen students in Montana, September 2010). Ongoing communications with Jock Conyngham (Research Scientist with Army Corps of Engineers, Missoula, MT) and Bruce Rosenlund (USFWS, Denver, CO) regarding White Water Parks and impacts to fisheries.

Training to CPW personnel

CDOW publication titled “Colorado Rivers” will be updated with new techniques and fish passage and barrier assessment materials. This is a work in progress. Kay Knudsen (CDOW librarian) is assisting to acquire necessary permissions to publish material from copyrighted materials in “Colorado Rivers” handbook so that it can be more widely (electronically) distributed to CDOW and non-CDOW personnel for training and educational purposes.

Continuing Education: Training to gain additional technical expertise and professional job skills.

1) Completed Level 4 Rosgen training course September 20-September 30, 2010.

2) Total Station Survey training from Tracy Kittell, December 2, 2010.

3) GPS survey gear: Became proficient and able to conduct surveys completely independently December 3, 2010.

4) Joint AFS/CCTWS meeting 2011

Worked on initial joint meeting concepts with members of the Wildlife Society (Dan Walsh and Vicky Dreitz, TWS ExComm officers). Served as Arrangements Committee chairperson, Budget Committee Review FY11 chairperson, Fundraising Committee chairperson, and as a moderator for the plenary session (day 2). ExComm meetings (December 7, 2010 and January 11, 2011).

APPENDIX A

Wason and La Garita Ranch Monitoring Study

Project goals and background

In 2006, the Wason Ranch completed a large-scale habitat improvement project on approximately 3.8 miles of the Rio Grande River that flows through their property. The motivation for conducting this project was based on observations of anglers and ranch members that suggested a gradual degradation in the quality and quantity of fish in their privately-owned stretch of the Rio Grande River over time. While anglers caught some quality-sized fish (>14" or longer) in isolated pockets of the river, Wason members believed they were observing a gradual decline in overall fishing quality. They observed that the river had become wider and shallower over time due to stream bank erosion caused primarily by many years of historic cattle grazing, mining activities which caused excessive sediment contributions from upstream tributaries and historic logging/tie-hack drives. The banks had been broken down and stream side vegetation had been virtually eliminated due to cattle grazing. After consultation with a hydrologist specializing in trout stream restoration, members agreed to improve the river by implementing treatments related to the following goals: 1) elimination of bank erosion, 2) restoration of pre-impairment river depths, 3) restoration of the river channel and adjacent banks to pre-cattle grazing conditions and 4) revegetation of the banks. The Wason members believed that implementation of treatments related to meeting the above stated goals would create substantially more fish habitat that would increase total trout density and biomass and support greater abundance of quality-sized trout (14" and longer).

Colorado Parks and Wildlife is conducting an ongoing monitoring study of the fisheries response to fish habitat improvements on the Rio Grande River with cooperation from the Wason Ranch and La Garita Ranch near Creede, CO. The goal of this research effort is to determine how the fish habitat project has influenced the trout population by monitoring changes in biomass (kg/ha), density (fish ≥ 15 cm/ha), and numbers of quality –sized fish (fish ≥ 35 cm/ha). We determined that the Wason Ranch was an ideal location to conduct this study because: 1) we had seven years of fisheries data collected prior to any habitat improvement work (pre-data), 2) the scale of the habitat improvement reach is large (approximately 2 miles of intensively-treated river and 1.8 miles of lightly-treated river), 3) we have un-treated stream reaches up-and downstream of the improved river sections that can serve as spatial controls for the study (La Garita reach downstream is an ideal study control at 2.4 miles long), 4) although the river is publically accessible by raft for fishing (completely catch and release), the stream reaches are located on private stretches of the river which might remove some of the variability in fish estimates due to public fishing pressure from bank anglers, 5) there is evidence that brown trout numbers have stabilized post-whirling disease infection and 6) we have the ability to monitor these river sections over time with the future cooperation of the Wason and La Garita ranches.

We also believe the Wason Ranch and La Garita ranches are good locations for monitoring fish response because of the nature of the three reaches (Upper Wason, Lower Wason, and La Garita). All three reaches experienced the same historic land uses (grazing history and water quality issues from past mining). The Upper reach contains the most instream structures of the three reaches (J-hooks, vanes, cross vanes, off-channel developments) with many large, deep excavated pools for adult fish holding cover (Figure 1). The Lower Wason has fewer instream structures (J-hooks, cross vanes, excavated pools, etc.) than the Upper reach and consequently much fewer deep pools. Aside from containing fewer deep pools, the Lower reach is characterized overall by more randomly distributed boulders, wider channel dimensions and more streamside vegetation than the Upper reach (Figure 2). The La Garita reach has had the least amount of channel alterations/ improvements conducted on it. There are no instream structures in this reach such as J-hooks, cross vanes, W-weirs, or developed off-channel habitats. It has vegetated banks that are in similar condition to the Lower Wason reach, fewer large boulders than the Lower Wason and has more long areas of slow moving deep water (long runs). The channel width of the La Garita is probably closer to the Lower Wason than the Upper reach (Figure 3).

Figure 1. Upper Wason: Representative photo of the Upper Reach of the Wason Ranch. Notice the periodic large boulder-constructed cross-channel structures (cross vanes) used for grade control, creating deep pools, and narrowing the channels.

Figure 2. Lower Wason: Representative photo of the Lower Reach of the Wason Ranch. Notice the abundance of large protruding boulders, long riffles, coarse cobble substrate, lack of deep pools, lack of woody vegetation (alders and willows) and absence of large cross-channel structures.

Figure 3. Control Reach: Representative photo of the La Garita Reach downstream of the Upper and Lower Wason. Notice the over-wide channel with sparse woody vegetation (alders and willows), dominance of long, continuous riffles and run habitat, lack of deep pools and lack of large protruding boulders.

This report is a preliminary analysis of our finding up through our last fish sampling effort in October 2010. We are not making any conclusions yet related to how well the habitat improvements altered adult brown trout biomass (kg/ha for trout 6 inches or longer) or changed the number of adult and quality-sized fish (number of trout 14 inches or larger). Previous monitoring studies of habitat improvement projects suggest that it may require up to 5 years for trout populations to stabilize once construction is completed. This is why we are hoping to continue monitoring for at least an additional 2-4 years if possible. We are going to cover results pertaining primarily to brown trout and not rainbow trout since rainbow trout have been artificially planted in the river over time. As a consequence, rainbow trout population statistics will not serve as a good indicator of habitat improvement.

Results:

2010 sampling: Water flows were low for 2010 (between 300 and 350 cubic feet per second) compared to previous years (greater than 350 cfs). Lower flows concentrated fish and consequently allowed us to increase our capture probabilities for adult fish. We continued using a second electrofishing raft this year doubling our sampling effort and allowing us to cover more of the river than with only one raft. As a result, our estimates have the tightest confidence intervals of any previous fish sampling (see Tables 1-5). The following are the results of this year's (Fall 2010) fish sampling.

Pre-habitat versus post-habitat comparisons: There are many factors that influence brown trout populations and thus trying to determine how the habitat improvements influenced the brown trout fishery is complex. Sampling results display a large variation in population and biomass estimates across years.

One approach is to average the trout fishery statistics (biomass, population size, densities) for all pre- and post- restoration years. Then we can compare these numbers to determine if there are any differences suggesting that a change in trout biomass or density has occurred from pre- and post-restoration conditions (see Table 1).

Using this approach, we can see that the Upper Wason reach appears to have experienced the largest increase in biomass of adult fish (35% increase, pre-compared to post-restoration) relative to the Lower reach (7 % increase, pre- compared to post-restoration). Also, we observe the largest increase in population size of adult brown trout (22% increase, pre-compared to post-restoration) for the Upper reach relative to the Lower reach (4% decline, pre- compared to post-restoration). One promising trend was the increase of quality-sized fish in both the Upper and Lower reaches with the number of quality-sized fish (14 inches and larger) nearly doubling (80% increase pre- compared to post-restoration) in the Upper reach and increasing by 62% (pre-compared to post-restoration) in the Lower reach. The increase in the number of quality-sized fish in the entire reach may be a result of regulation changes as well as from the improvement in habitat quality, especially for the Upper Wason reach.

Population density estimates: The Lower reach and the La Garita reach contained nearly identical densities of adult brown trout (6 inches and longer) with estimates of 284 adult brown trout/ha and 285 adult brown trout/ha respectively (Figure 4). The differences in adult brown trout density estimates between all sites are small (95% CIs overlap for all three sites). Therefore based on this year's sampling, we do not have sufficient evidence to conclude that improved reaches have higher densities of adult fish than un-improved sites. We plan to continue monitoring brown trout densities to determine if this will change over time.

Biomass estimates: Among the three reaches for 2010, the control reach (La Garita reach) had the highest biomass (83.1 kg/ha) for adult brown trout six-inches and longer followed by the Lower Wason (80.6 kg/ha) and the Upper Wason (65.4 kg/ha) respectively (Figure 5). This result is completely the reverse of last year's sampling (2009). However, the magnitude of the differences between reaches is not statistically significant (95% CIs overlap for all three sites). Therefore, we concluded that for this year's sampling, there is not sufficient evidence to conclude that adult brown trout biomass differs among any of the three reaches. Additional years of fish sampling data from the La Garita will be very valuable as a means to compare against the Upper and Lower Wason in determining what influence the habitat improvements have on adult brown trout biomass.

The La Garita reach had the highest densities of quality-sized (14 inches and longer) brown trout. The La Garita reach held 29% (1.3 times) more quality-sized brown trout (> 14 inches) than the Lower Reach and 133% (or 2.3 times) more quality-sized brown trout than the Upper reach. The Lower reach has consistently had more quality-sized fish than the Upper across all years of sampling and again, this year was no exception. This difference has much to do with historic fishing regulations (8 trout/day in the Upper reach versus 2 trout/day, 14" maximum in the Lower reach from 1983-1986). We will need to investigate ways to separate any effects due to fishing regulations from effects due to habitat improvements. Interestingly, we did find evidence that the Upper Wason had statistically significantly FEWER quality-sized brown trout than either the La Garita or Lower reaches (95% CI for Upper Wason did NOT overlap with the other two sites, see Figure 7).

The largest brown trout captured was just under 20 inches long and the largest rainbow trout was approximately 20.5 inches long. The largest brown was captured from the Upper reach and the largest rainbow was captured from the Lower reach.

<u>Comparison across years:</u> We will review fish population statistics for all three reaches (Upper, Lower and La Garita). Population estimates have varied widely across years for all three reaches (Figure 6). Fluctuations in trout population statistics (i.e. population and biomass estimates) are caused by a number of factors including the following:

1) Magnitude and duration of flooding in high versus low snow-pack years.

Magnitude (highest peak flow) and duration (how long high flows persist) of high versus low snow-melt years influence brown trout fry survival. Brown trout year classes are highly correlated with water conditions during hatch-out and fry emergence. When brown trout emerge from the gravel under high run-off years, survival of brown trout fry is low and consequently a smaller number of adult fish (age 4 and older) will result from that year-class, 4 years later. Conversely, under low run-off years, brown trout fry survival is high and usually a higher number of adults will result from that particular year class 4 years later. This is important to understand when looking at the results of our data collection across years (see population estimates in Table 1: 1982-1983 compared with 1984-1986). The early '80s were some of the highest water years on record. Consequently, there are several year classes that were very small relative to age classes hatched in low water years. For instance, 1981 was a low water year with a peak flow of 2260 cfs compared to 1984 which had a peak flow of 4100 cfs (highest recorded mean daily peak flows). Refer to the life tables for the Upper and Lower Wason for examples of this effect (Table 6). The age 1 cohort for brown trout emerging in a low water year (1981) was 71 compared to only 9 in a high water year (1984) for the Lower Wason reach. Similarly, the density of the age 1 cohort for the Upper Wason reach that emerged in 1981 was 63 compared to 18 for 1984. These population effects are carried out over time and may lead to fluctuations in trout densities (number of fish per area) and biomass (weight of fish per area).

2) Electrofishing efficiency in high versus low water conditions.

Under low flow conditions, more fish are captured by electrofishing which increases the capture probability of individual fish leading to more accurate fish population estimates. Conversely, higher flows make fish sampling more difficult since individual fish have lower capture probabilities and thus leads to less accurate fish population estimates.

3) Changes in fishing regulations.

In 1983, regulations for the Lower Wason (flywater) reach changed from a 2 trout/day, 14 inch minimum size limit to 2 trout/day, 14 inch maximum size limit. This change stopped the harvest of 14-inch and longer brown trout and protected larger, quality-sized fish (14 inches and longer) resulting in more large fish, particularly in the Lower Wason. The current regulations in place for anglers fishing on the Wason and La Garita ranch are catch-and-release only for the entire reach. We see that over time, there has been a steady trend of more quality-sized fish in the entire Wason Ranch reach, with the exception of this year (see Figure 7). We believe this trend can be explained by this regulation change in 1983 and the catch-and-release policy currently enforced by both the Wason and La Garita Ranches. Another example of how this change in regulation led to population changes is reflected in the life tables (see Table 6: Lower Wason life tables, 1982-1986 compared with 2008-2009 data). We see in 1982 that there are only 4 age-classes represented in the brown trout population for both upper and lower Wason reaches. In 2008, 2009 and 2010, we see that 6 to 8 age-classes are present. This increase in survival of older age classes is because of the change in regulation that protected these larger-sized fish, allowing brown trout to live longer and potentially grow larger.

4) Channel width computations.

We used a constant channel width value of 100 feet to make comparisons across the three reaches across all years. Channel width is used along with the reach length to determine the area sampled (hectares). Using a 100 foot width across all reaches for the pre-habitat improvement years is probably correct. However, one of the goals of the restoration work was to create a deeper, narrower channel in the Upper Reach in particular. We would like to survey the wetted width at an appropriate flow (Fall flows that are representative of when we usually sample) to determine if there is variation in channel widths between reaches. This is important because biomass and densities are very sensitive to this habitat variable (i.e. we will under-estimate biomass for the Upper Reach if we use a width of 100 feet when we should be using 75 feet instead). This has implications for how much improvement (or not) that we see in the trout fishery post-restoration.

In spite of these various factors that might influence trout population statistics, we were able to make the following observations about brown trout populations across all years of sampling.

The Lower Wason reach consistently has higher adult (six inches and larger) brown trout biomass (kg/ha) than the Upper Wason across all eight years of sampling with the exception of 2008 fish sampling (Figure 5). The Lower Wason has an average of 18.7 kg/ha higher adult brown trout biomass than the Upper Wason Reach. Differences between the Lower and Upper reach ranged from no difference (1983 and 2009) to over 53 kg/ha greater adult brown trout biomass on the Lower Reach than the Upper (1984). We have not collected enough years of fish sampling data from the La Garita reach to make any accurate comparisons. The Lower Wason had higher adult brown trout biomass than the La Garita in 2009, but not in 2010. Also, differences in adult brown trout biomass between the La Garita and Lower Wason were not statistically significant using an alpha of 0.05.

Across all eight years of sampling, the Lower Wason reach has always had a larger population density of quality-sized (14 inches and larger) brown trout than the Upper Wason (Figure 7). The Lower Wason has an average of 20 quality-sized brown trout/ha more than the Upper Wason Reach. Differences between the Lower and Upper reach ranged from 6 quality-sized brown trout/ha in 1985 to over 51 quality-sized brown trout/ha more quality-sized brown trout on the Lower Reach than the Upper (1984). However, it is important to note that these differences in the numbers of quality-size brown trout between the Upper and Lower Wason reaches during the sampling period from 1982 through 1986 was a result of differences in fishing regulations. The Upper section was under an 8-trout/day bag limit with bait angling allowed, compared to a fly-only terminal tackle restriction and a 14-inch maximum size limit in effect on the lower reach from 1983 through 1986. We have not collected enough years of fish sampling data from the La Garita reach to make any accurate comparisons. The Lower Wason had higher quality-sized brown trout densities than the La Garita in 2009, but not in 2010. Also, differences in adult brown trout biomass between the La Garita and Lower Wason were not statistically significant using an alpha of 0.05.

Consequently, the percentage of quality-sized fish out of the total population of adult brown trout has steadily increased from less than 10% of the population consisting of quality-sized-or- larger fish in 1982 for both reaches to approximately 33% quality-sized-or- larger fish for the Lower Wason and 20% quality-sized-or- larger fish for the Upper reach for 2008 and 2009 (see Figure 8).

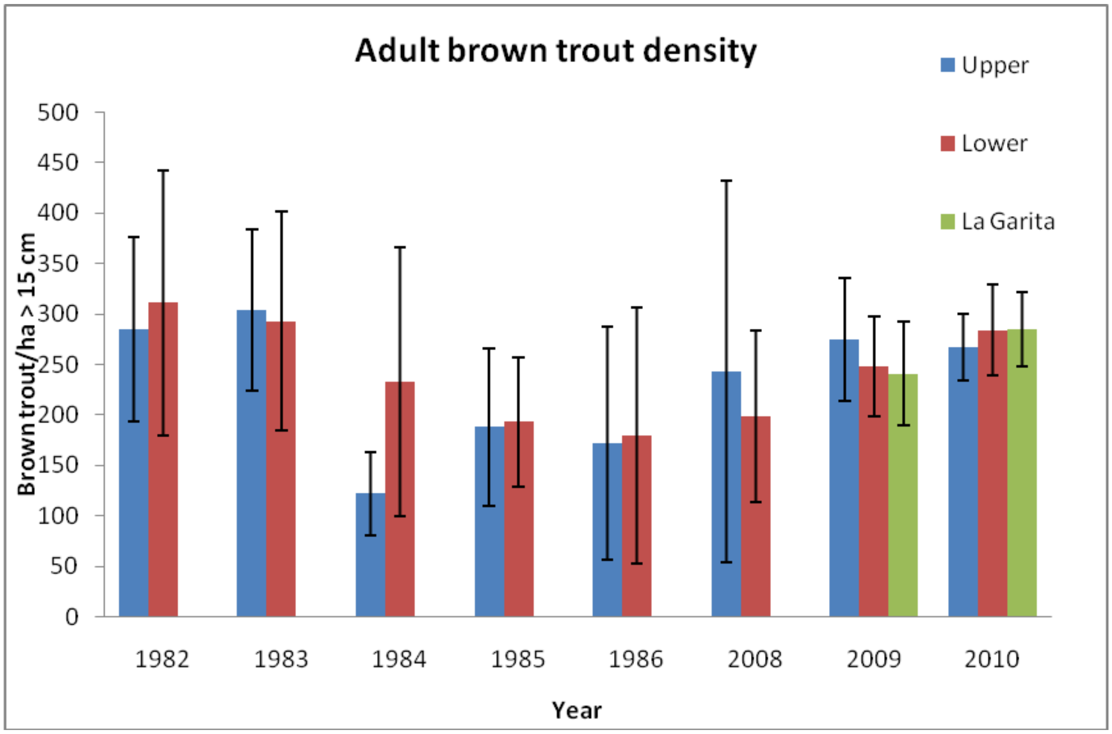

Figure 4. Population density estimates of adult (>15 cm) and longer brown trout in the Upper Wason, Lower Wason and La Garita reaches. Pre-restoration sampling estimates include years: 1982, 1983, 1984, 1985 and 1986. Post-restoration sampling estimates include years: 2008, 2009 and 2010. Black vertical bars represent 95% CI for the estimate.

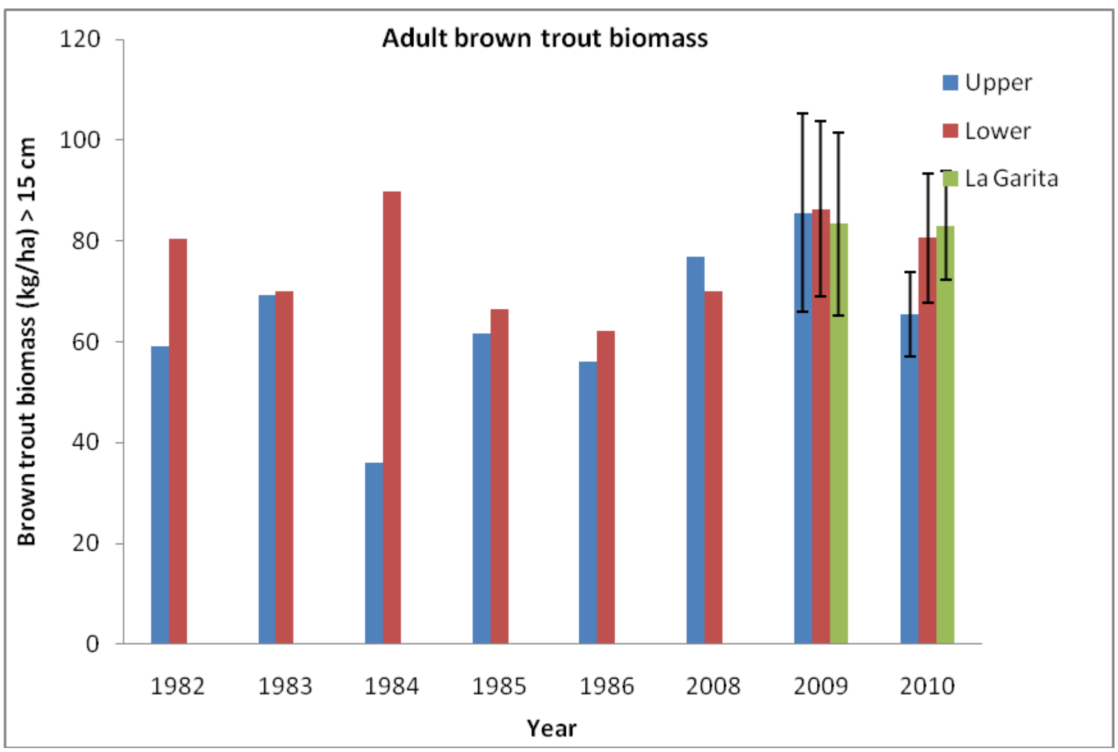

Figure 5. Biomass (kg/ha) of adult (6 inch and longer) brown trout in the Upper Wason, Lower Wason and La Garita reaches. Pre-restoration sampling estimates include years: 1982, 1983, 1984, 1985 and 1986. Post-restoration sampling estimates include years: 2008, 2009 and 2010. Black vertical bars represent 95% CI for the estimate.

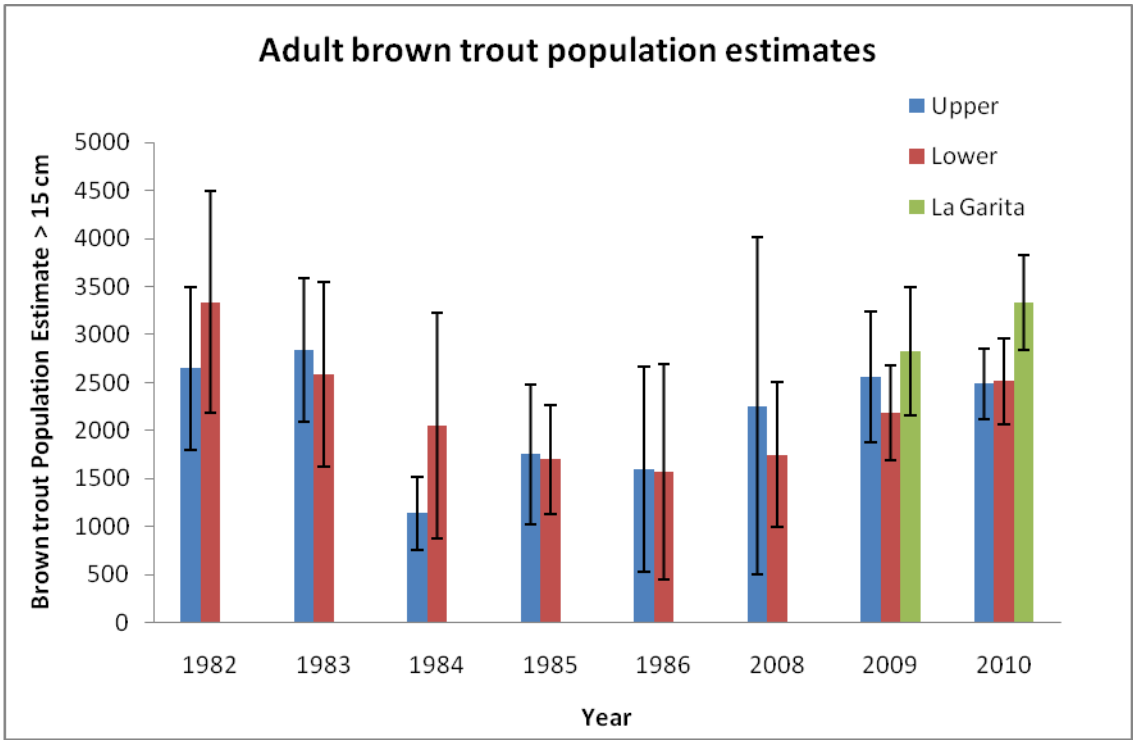

Figure 6. Population estimates of adult (>15 cm) and longer brown trout in the Upper Wason, Lower Wason and La Garita reaches. Pre-restoration sampling estimates include years: 1982, 1983, 1984, 1985 and 1986. Post-restoration sampling estimates include years: 2008, 2009 and 2010. Black vertical bars represent 95% CI for the estimate.

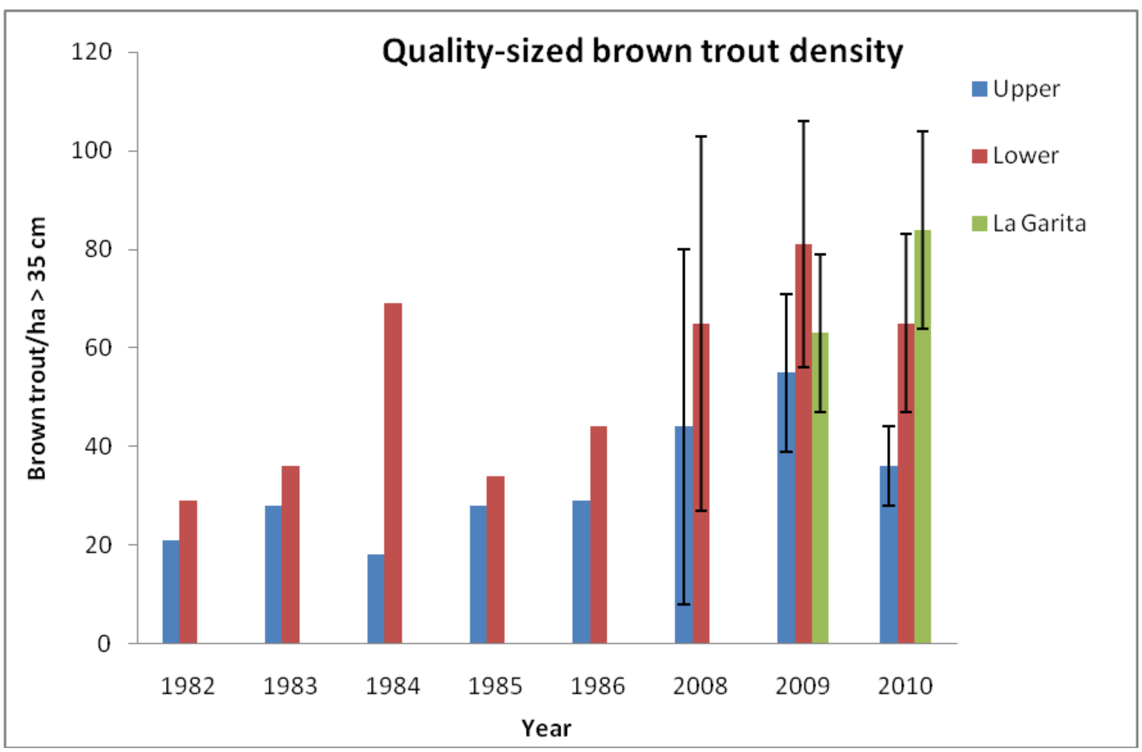

Figure 7. Density (trout/ha) of quality-sized (14 inch and longer) brown trout in the Upper Wason, Lower Wason and La Garita reaches. Black vertical bars represent 95% CI for the estimate.

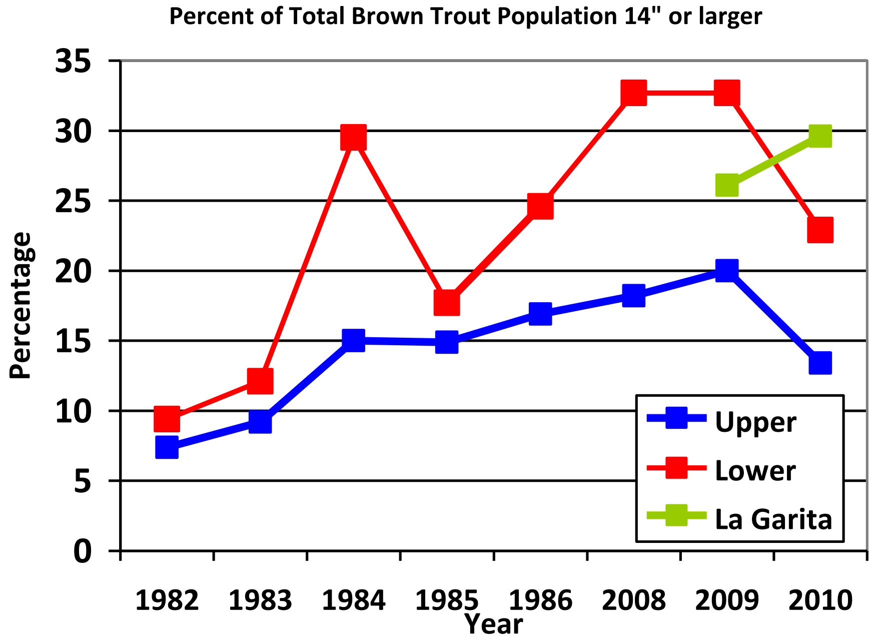

Figure 8. Percent of total trout population consisting of quality-sized (14" or longer) brown trout in Upper and Lower Wason reaches.

Conclusions

Future research directions: In addition to our annual Fall sampling, we are considering adding the following research components to the project to help us refine this study: 1) we would like permission to survey the river channel under a range of conditions that will help us improve our abilities to monitor fish habitat improvements and monitor function of individual channel structures (such as J-hooks and cross vanes), 2) we are interested in conducting a telemetry study of adult brown trout and tracking their movements, particularly during the winter, to determine how where brown trout over-winter. We suspect that the addition of deeply excavated pools especially in the Upper Reach may provide critical habitat for adult fish to over-winter when flows are limiting, temperatures are coldest, and ice reduces connectivity of river micro-habitats (i.e. ability of fish to move longer distances up- or downstream). Lastly, 3) we are interested in monitoring fish movement in and out of off-channel habitats. We are especially interested in tracking fish movements between off-channel ponds on the Lower Wason and the main-stem Rio Grande River.

We have reported preliminary results of fish sampling on the Wason and La Garita ranches. Without further fish sampling and monitoring, we still cannot conclude whether or not habitat improvements influence brown trout populations. Therefore, we hope to continue to work with the Wason and La Garita Ranches in order to continue collecting data on trout fisheries on the Rio Grande River. We thank the Wason and La Garita Ranches for continuing to allow us to conduct this research on their property and their generousity in providing both direct assistance (volunteers, coffee and donuts) and permission to allow us to work in the river. We also thank Barry Nehring for his assistance with coordinating/planning fish sampling efforts and for serving as a reviewer of this report. Our hope is that results from this study will provide guidance on future restoration work and assist ranch managers in understanding what types of habitat improvements are maximizing benefits to the trout fisheries.

Table 1. Summary of brown trout population estimates (N), biomass estimates (Kg/ha) and numbers of "quality" size (n≥35 cm or 14 inches) and density of "quality" size (n≥35 cm/ha) statistics for the Wason Ranch and La Garita reach of the Rio Grande, Fall 1982-1986, 1992, 1999, 2008, 2009 and 2010.

Year	Upper Reach - 3.06 km				Lower Reach – 2.9 km				La Garita Reach – 3.84 km			
	N	**Kg/ha**	**n≥35 cm**	**n≥35 cm/ha**	**N**	**Kg/ha**	**n≥35 cm**	**n≥35 cm/ha**	**N**	**Kg/ha**	**n≥35 cm**	**n≥35 cm/ha**
	Pre-Habitat Improvement Treatment Period											
1982	2,648	59.2	195	21	3,336	80.4	312	29	N/A	N/A	N/A	N/A
1983	2,835	69.3	262	28	2,581	70.1	312	36	N/A	N/A	N/A	N/A
1984	1,136	36.1	170	18	2,055	89.9	607	69	N/A	N/A	N/A	N/A
1985	1,751	61.7	260	28	1,700	66.4	300	34	N/A	N/A	N/A	N/A
1986	1,602	56.0	270	29	1,573	62.1	387	44	N/A	N/A	N/A	N/A
Average	**1,994**	**56.5**	**231**	**24.8**	**2,249**	**73.8**	**384**	**42**	**-**	**-**	**-**	**-**
	Post - Habitat Improvement Treatment Period											
2008	2,256	77.0	410	44	1,749	70.1	572	65	N/A	N/A	N/A	N/A
2009	2,555	85.6	510	55	2,190	86.4	716	81	2,823	83.4	737	63
2010	2,487	65.4	332	36	2,512	80.6	575	65	3,332	83.1	985	84
Average	**2,433**	**76.0**	**417**	**45**	**2,150**	**79.0**	**621**	**70**	**3,078**	**83.3**	**861**	**74**
% Change	**+22.0**	**+34.5**	**+80.5**	**+81.5**	**-4.4**	**+7.1**	**+61.7**	**+66.7**	**-**	**-**	**-**	**-**

Table 2. Trout population statistics for the upper 3.06 km reach of the Rio Grande on the Wason Ranch, Fall 1982-1986, 2008, 2009 and 2010.

Year	N ≥ 15 cm	95% C.I. ≥ 15 cm	Fish/ha ≥ 15 cm	Kg/ha ≥ 15 cm	Fish/ha ≥ 35 cm
Brown Trout					
1982	2,648	±850	285	59.2	21
1983	2,835	±746	304	69.3	28
1984	1,136	±385	122	36.1	18
1985	1,751	±728	188	61.7	28
1986	1,602	±1,069	172	56.0	29
2008	2,256	±1,761	243	77.0	44
2009	2,555	±680	275	85.6	55
2010	**2,487**	**±368**	**267**	**65.4**	**36**
Rainbow Trout					
1982	325	±432	35	5.7	1
1983	247	±134	27	5.6	3
1984	83	±63	9	2.4	2
1985	126	±162	14	3.6	3
1986	94	±52	10	2.4	1
2008**a**	567	±346	61	37.1	51
2009	269	±137	29	17.9	25
2010	**143**	**±78**	**15**	**7.8**	**10**
Total Trout					
1982	3,082	±948	331	64.9	22
1983	3,096	±745	332	74.9	31
1984	1,236	±391	133	38.5	20
1985	1,948	±791	209	65.3	31
1986	1,377	±682	148	58.5	24
2008	2,660	±1,396	286	114.1	102
2009	2,765	±654	297	103.5	80
2010	**2,640**	**±383**	**284**	**73.2**	**46**

a: The Wason Ranch purchased and stocked approximately 600 pounds of rainbow trout in the river in 2005 and 2006, 1,950 pounds in 2007, and 1,000 pounds in 2008. These fish were 16 to 18 inches in length.

Table 3. Trout population statistics for the lower 2.90 km reach of the Rio Grande on the Wason Ranch, Fall 1982-1986, 2008, 2009 and 2010.

Year	N ≥ 15 cm	95% C.I. ≥ 15 cm	Fish/ha ≥ 15 cm	Kg/ha ≥ 15 cm	Fish/ha ≥ 35 cm
Brown Trout					
1982	3,336	±1,157	311	80.4	29
1983	2,581	±964	293	70.1	36
1984	2,055	±1,176	233	89.9	69
1985	1,700	±568	193	66.4	34
1986	1,573	±1,122	179	62.1	44
2008	1,749	±750	198	70.1	65
2009	2,190	±494	248	86.4	81
2010	**2,512**	**±453**	**284**	**80.6**	**65**
Rainbow Trout					
1982	39	±52	4	1.5	0
1983	80	±149	9	1.2	1
1984	171	±103	10	1.9	0
1985	15	±7	2	0.4	1
1986	59	±41	7	2.0	2
2008**a**	92	±59	10	5.8	7
2009	91	±59	10	5.8	7
2010	**87**	**±57**	**10**	**4.8**	**3**
Total Trout					
1982	3,021	±1,245	343	81.9	29
1983	2,745	±1,027	311	71.3	37
1984	1,994	±1,091	227	90.2	69
1985	1,609	±501	183	66.8	35
1986	1,425	±842	162	64.1	41
2008	1,750	±664	198	75.9	67
2009	2,272	±488	257	92.2	88
2010	**2,629**	**±470**	**297**	**85.5**	**69**

a: The Wason Ranch purchased and stocked approximately 600 pounds of rainbow trout in the river in 2005 and 2006, 1,950 pounds in 2007, and 1,000 pounds in 2008. These fish were 16 to 18 inches in length.

Table 4. Trout population statistics for the entire 5.96 km reach of the Rio Grande on the Wason Ranch, Fall 1982-1986, 2008, 2009 and 2010.

Year	N ≥ 15 cm	95% C.I. ≥ 15 cm	Fish/ha ≥ 15 cm	Kg/ha ≥ 15 cm	Fish/ha ≥ 35 cm
Brown Trout - Pre-Habitat Treatment					
1982	5,286	±1,353	292	69.5	24
1983	5,325	±1,148	294	68.3	31
1984	2,776	±821	153	41.0	33
1985	3,419	±892	188	50.2	41
1986	3,597	±1,891	198	52.5	41
1992	3,497	±889	192	64.4	64
1999	5,096	±1,637	280	80.3	82
Brown trout - Post-Habitat Treatment					
2008	3,768	±1,454	207	70.7	62
2009	4,717	±814	259	85.7	69
2010	**4,974**	**±569**	**273**	**72.8**	**49**
Rainbow Trout - Pre-Habitat Treatment					
1982	620	±513	34	3.0	1
1983	336	±187	19	2.8	2
1984	103	±67	6	1.6	1
1985	92	±57	5	1.3	1
1986	159	±81	9	2.3	2
1992	620	±233	34	14.4	19
1999	69	±41	4	1.3	2
Rainbow Trout -Post-Habitat Treatment					
2008**a**	672 **a**	±340	37	22.0	27
2009	367	±151	20	10.8	16
2010	**246**	**±148**	**14**	**6.9**	**6**
Total Trout - Pre-Habitat Treatment					
1982	6,128	±1,517	339	72.5	25
1983	5,656	±1,148	312	71.1	33
1984	2,831	±786	156	42.6	34
1985	3,467	±859	190	51.5	42
1986	2,878	±1,119	158	55.0	32
1992	4,007	±848	220	78.3	84
1999	4,878	±1,456	268	81.6	80
Total Trout - Post-Habitat Treatment					
2008	4,207	±1,297	231	92.7	86
2009	5,022	±801	276	97.8	85
2010	**5,230**	**±588**	**287**	**79.4**	**56**

a: The Wason Ranch purchased and stocked approximately 600 pounds of rainbow trout in the river in 2005 and 2006, 1,950 pounds in 2007, and 1,000 pounds in 2008. These fish were 16 to 18 inches in length.

Table 5. Trout population statistics for the 3.84 km reach of the Rio Grande on the La Garita Ranch, Fall 2009 and 2010.

Year	N ≥ 15 cm	95% C.I. ≥ 15 cm	Fish/ha ≥ 15 cm	Kg/ha ≥ 15 cm	Fish/ha ≥ 35 cm
Brown Trout					
2009	2,823	±669	241	83.4	63
2010	**3,332**	**±492**	**285**	**83.1**	**84**
Rainbow Trout					
2009	67	±52	6	3.2	4
2010	**44**	**±40**	**4**	**1.4**	**1**
Total Trout					
2009	2,916	±680	249	86.7	68
2010	**3,391**	**±500**	**290**	**84.5**	**86**

Table 6. Life Tables-Rio Grande River (brown trout/ha) for Fall 1982-1986, 2008, 2009 and 2010.

Wason Ranch-Upper-standard regulations-8 trout/day 1982-1986

Sample Period		**Year Class**										
Month	**Year**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1975**
August	**1982**					**63**	**99**	**136**	**13**	**0**	**0**	**0**
September	**1983**				**61**	**130**	**63**	**41**	**9**	**0**	**0**	**0**
October	**1984**			**27**	**27**	**30**	**32**	**5**	**1**	**0**	**0**	
October	**1985**		**18**	**94**	**45**	**25**	**5**	**1**	**0**	**0**		
October	**1986**	**29**	**48**	**67**	**11**	**10**	**5**	**0**	**0**			

Age 1

Age 4 fish

Wason Ranch-Upper-catch-and-release only

Sample Period		Year Class									
Month	**Year**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
October	2008			11	28	105	56	20	12	0	0
October	2009		13	64	77	63	51	6	4	1	0
October	2010	49	79	60	47	30	3	3	0		

Age 1 fish Age 4 fish

Wason Ranch-Lower-flywater- 2 trout/day; 14 inch min (1982). 2 trout/day; 14 inch max (1983-1986)

Sample Period		Year Class										
Month	**Year**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1975**
August	1982					71	98	190	19	0	0	0
September	1983				61	123	58	38	13	0	0	0
October	1984			43	30	50	89	14	6	0	0	
October	1985		9	67	96	16	5	1	0	0		
October	1986	33	45	63	13	13	11	0	0			

Age 1 fish Age 4 fish

Wason Ranch-Lower-catch-and-release only

Sample Period		Year Class									
Month	**Year**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
October	2008			14	13	79	48	20	11	0	0
October	2009		7	48	66	62	50	9	6	1	0
October	2010	50	76	55	65	37	5	6	0		

Age 1 fish Age 4 fish

La Garita-catch-and-release only

Sample Period		**Year Class**									
Month	**Year**	**2009**	**2008**	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**
October	**2008**			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
October	**2009**		**10**	**46**	**54**	**67**	**60**	**7**	**2**	**0**	**0**
October	**2010**	**43**	**71**	**61**	**65**	**44**	**4**	**5**	**0**	**0**	

Age 1 fish

Age 4 fish

LIST OF SYMBOLS AND TERMINOLOGY

Adult fish	=	Arbitrary category assigned to a fish that has a total length of 6 inches or longer.
Biomass	=	Mass or weight of fish per area, (for example, kilograms brown trout per hectare).
Cfs	=	Unit volumetric flow rate, which is equivalent to the volume of 1 cubic foot flowing every second.
Cm	=	Symbol of length which is equal to one hundredth of a meter (1 inch = 2.54 cm).
Density	=	Measurement of population per unit area or unit volume (for example, number of brown trout per hectare).
"≥" "≤" ">" or "<"	=	Symbols for "greater than or equal to," "less than or equal to," "greater than" or "less than" respectively.
Ha	=	Hectare (see definition of "hectare").
Hectare	=	A hectare (symbol ha) is a unit of area equal to 10,000 square meters (107,639 sq ft) and is commonly used for measuring surface area.
"	=	Symbol for inches, such as a 14" long fish.
Kg	=	Kilogram which is a unit of mass that weighs 1000 grams or 2.2 pounds (lbs).
Life table	=	Life tables are generated by combining trout population estimates and trout age/growth data (from scales) to show relative abundances of various trout age-classes.
Mile	=	Unit of length that is equivalent to 5,280 feet
N	=	Symbol for population abundance (estimated).
Quality-sized fish	=	Arbitrary category assigned to a fish that has a total length of 14 inches or longer.
Total length	=	Length of a fish measured from a fish's snout to the end of the compressed caudal fin.
95% C.I.	=	A 95% confidence interval for a population parameter (such as population abundance, N) is an indicator of the uncertainty of an estimate. The larger the interval, the less precise or reliable the estimate. If a sampling procedure used to generate a specific estimate (i.e. population abundance, N) was repeated 100 times using the identical protocal, crew, and equipment, on average, 95 times out of 100 the true parameter would fall within the 95% confidence interval generated for the particular estimate. In other words, we are 95% confident that the true population parameter is included with the 95% confidence interval for that estimate.