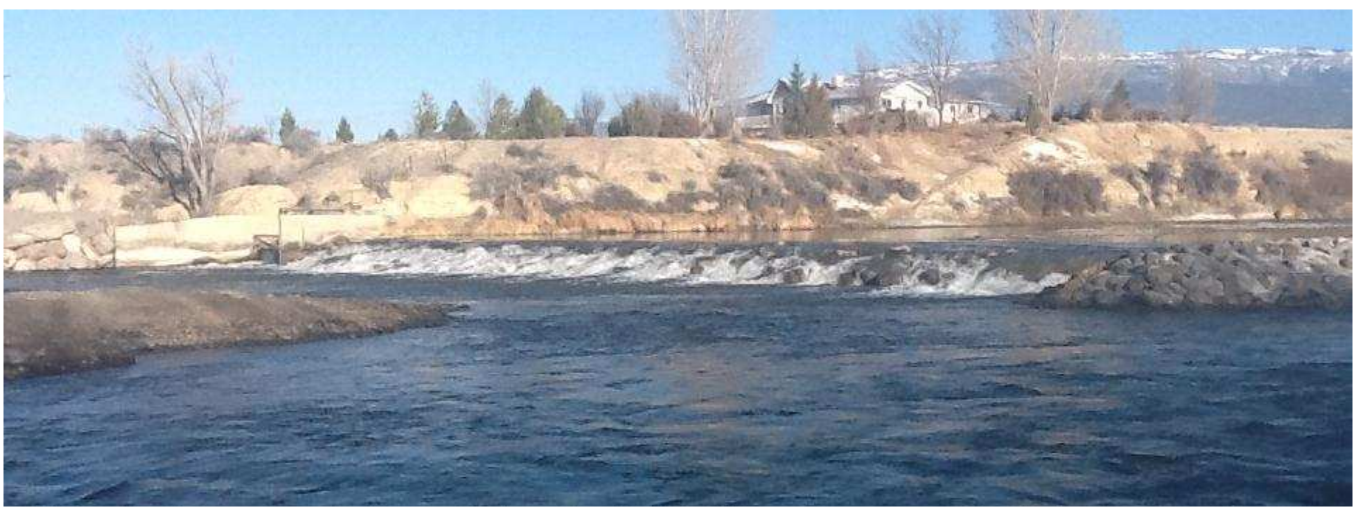
Hartland Diversion Dam
Fish Passage

Final Report



Submitted by:
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Introduction

Hartland Diversion Dam is located on the Gunnison River 3.6 miles upstream of the Uncompahgre River confluence near Delta, Colorado. The 6 foot high structure restricted upstream movement of fish during most flow stages. The Hartland Diversion Dam was construction in 1881 for agricultural irrigation and stock watering purposes. Hartland Irrigation Company diverts 41-43 cfs through their headgate on the north side of the river between March and November. The dam spanned the entire river, approximately 300 feet. The dam was constructed of railroad iron driven vertically into the river and reinforced with steel and rip-rap and was repaired and upgraded in 1942. The Hartland Irrigation Company owns the diversion dam and operates and maintains the headgate and irrigation canal. The structure was unsafe and not passable by river enthusiast. The predominant native fishes include bluehead sucker (Catostomus discobolus), flannelmouth sucker (C. latipinnis) and roundtail chub (Gila robusta). Hartland Diversion Dam and Fish Passage construction began September 1, 2011 and was completed on March 6, 2012. The benefits of providing fish passage at the Hartland Diversion Dam include extending the upstream range and re-establishment of endangered Colorado native fishes and increasing the number of bottomland sites and opportunities for habitat restoration and enhancement to assist the recovery of endangered fish. This would allow fish to utilize habitat to spawn and increase the larvae drifting downstream to utilize additional flooded bottomlands. The passage has allowed for approximately 15 miles of habitat for native and endangered fish. The construction of boat passage along with modifications to the dam to reduce hazard on the north side of the river has allowed for low hazard passage by boating enthusiasts.

Project Construction

Project Statistics:

Location:	Delta, Colorado
County:	Delta
Water Division:	50 cfs
Project Length:	350 feet
Adjacent Property Owners	2
Construction Contractor	Kissner General Contractors, Cedaredge, CO
Began Construction	September 1, 2011
End Construction	March 6, 2012

Project Cost:

Engineering Support	$ 258,837.47
Construction	$1,751,570.00
Rock & Site Preparation	$ 161,620.17
Dam Modification & Site Restoration	$ 50,000.00
Construction Management (Personnel & Travel)	$ 74,872.51
Trout Unlimited – Monitoring & Maintenance for 2012/2013	$ 20,000.00
Painted Sky Overhead	$ 149,269.61
Total	$2,466,170.00

Project Funding Sources:

US Fish and Wildlife Service	$1,394,194
Colorado Water Conservation Board	$ 560,000

Walton Family Foundation	$ 250,000
National Fish & Wildlife Foundation	$ 110,001
Colorado River District	$ 98,875
Gunnison Basin Roundtable	$ 53,100
Total	$2,466,170

Project Design

Background:

McLaughlin Water Engineers (MWE) was retained to complete final design in April of 2010 based on the conceptual design completed by Tetra Tech in December 2009. After the conceptual design was completed, additional design requirements had been added to the project, including 100-year stability, a narrower range of fish passage flows, and limiting the project impact on the existing floodplain. As a result, MWE developed a revised design that reduced the project footprint and costs while meeting the following project objectives:

- Provide fish passage around the diversion dam
- Provide boat passage connecting upstream and downstream river reaches
- Maintain diversion operations including improved stability of the diversion dam structure
- No negative impact to the regulatory floodplain.

Design Criteria:

The following is a summary of the final criteria for design:

- Maintain upstream pool elevation for diversion operations to a low river flow of +/-350cfs
- Structure stability up to the 100-yr flood event
- Low hazard boat passage
- 12” maximum hydraulic drops
- 3:1 or flatter bank slopes
- Fish Passage- Max. Velocity = 4 feet per second (“Fish’s Eye” Location), Depth = 2’ min.
- Fish Passage River Flow Design Range: Low = 750 cfs; High = +/-3000 cfs (Not specifically defined by USFWS)

Hydrology

Seasonal and annual fluctuations in flow on the Gunnison River were important to the design. A detailed hydrology analysis was conducted by Tetra Tech as part of the Conceptual Design Report dated December 2009. The analysis was based on gauge records (Gunnison River at Delta, CO, USGS 09144250) for 1976 to 1999. Of primary interest were typical flows during irrigation season and throughout the year for fish passage and migration and higher flows for structural design. Historic low river flows were also important for design to maintain the upstream pool for diversion. The following is a summary of hydrology results from Tetra Tech’s analysis:

- 90% Exceedence in August = 350 cfs
- Average Lowest Daily Flow (1976-1999) = 650 cfs
- Average Daily Flow August = 1,200 cfs
- Average Daily Flow May = 4,800 cfs
- Peak Flow in May (based on DEIS for Aspinall Unit) = 7,400 cfs (projected)

- 5-yr Return Period = 11,600 cfs
- 100-yr Return Period = 21,200 cfs

Summary of Design Layout & Concept

The design combines a center boat passage and two fish passages along each bank into one hydraulically connected channel. The boat passage is a drop-pool design that utilizes concentrated hydraulic drops between upstream and downstream pools. Fish passages include two "roughened passages", one with Confined Loose Boulder (CLB) and the other with concrete cylinders placed in a chevron pattern both to create different types of fish passage hydraulics. The boat and fish passages are hydraulically connected at the pools, in other words, the water level is equal in the three passages at each pool location. Divider islands adjacent to boat passage drops separates flow until it converges at the pools. A grouted boulder divider wall running parallel and adjacent to the new structure separates flow over the dam and to the boat/fish passages. A counter-weir downstream of the last drop-pool is included to protect the structure from tailwater degradation and help orient flows away from the left bank. Upstream of the chevron fish passage a jetty was designed to reduce local bank erosion, reduce debris and entrance velocities to the chevron fish passage, and direct river users to the center boat passage channel. Figure 1 shows an overall layout of the project.

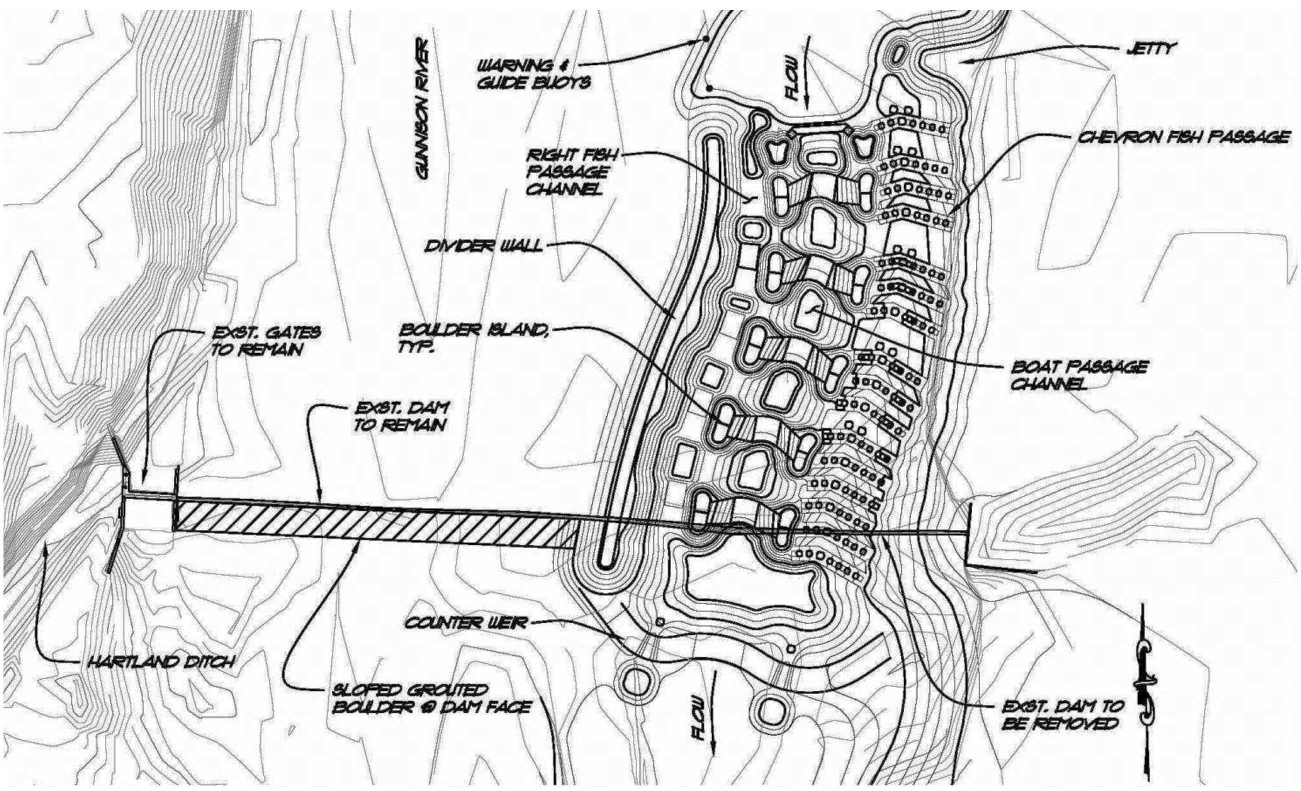


***Figure 1** – Hartland Dam Fish and Boat Passage Final Design Layout*

***Figure 2** – Hartland Dam Fish and Boat Passage*

<u>Fish Passage</u>

Three threatened fish species the Bluehead Sucker, Flannelmouth Sucker, Roundtail Chub were identified as the “target species” for fish passage. However the swimming capabilities and movement preferences of these species are not well known. Therefore the United States Fish and Wildlife Service (USFWS) opted to use fish passage guidelines from the more studied and better understood Razorback Sucker, which is believed to be a weaker swimming fish than most native species including the three identified target species. Fish passage criteria were developed based on research and monitoring of the Razorback Sucker conducted by the United States Bureau of Reclamation and (USBR) and USFWS.

Two fish passage channels were designed for this project to provide flow variation and multiple options for fish movement. A Confined Loose Boulder (CLB) roughened fish passage concept was designed for the “Right Fish Passage” (river right of the boat passage). This concept utilizes large boulders (36”+) placed randomly in the channel to provide highly roughened flow and interstitial spaces between boulders for fish movement. Smaller boulders are used to fill voids at the surface between larger boulders to reduce foot/hand entrapment hazards. Adjacent banks are roughened with large grouted boulders extending into the flow for additional passage. Figure 3 illustrates the Right Fish Passage. The “Chevron Fish Passage” channel utilizes concrete cylinders placed in a controlled chevron pattern to provide fish passage along the river-left bank. The concept creates long narrow eddies behind cylinders that assists fish in orientating upstream and through the structure. Three rows of chevrons at each drop structure create headlosses that maintain the 12-inch water surface elevation difference between pools (hydraulic drop). Chevrons have been designed to distribute the headlosses between each row and to maintain low velocities. The chevron boulder pattern/slots are based upon research performed by B. W. Mefford at the United States Bureau of Reclamation for passing non-salmonid species (Ref: “USBR Experience with Multiple-Slot-Baffled Fishways”, B.W. Mefford, 2009). MWE adapted the USBR design to reduce the hazard to river users and provide “skimming flow” over the concrete cylinders to reduce debris accumulation (See Figure 4).

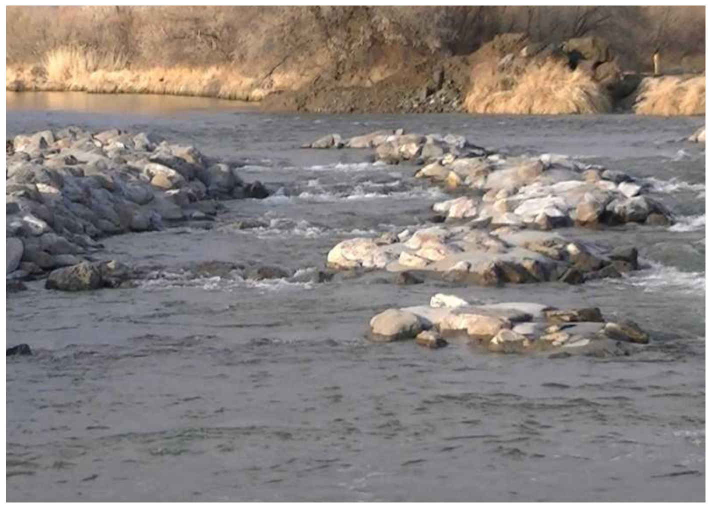


Figure 3 – *Right Fish Passage*

Figure 4 – *Chevron Fish Passage*

The center boat passage channel improves fish passage. Center drop structures are abrupt drops with intermediate pools along the centerline to create resting areas for fish and provide cross passage for fish between channels. Fish moving upstream use the strength of current or "attraction flow" to guide movement. The center channel increases attraction flows to the overall bypass structure.

Hydraulic Modeling

One- and two- dimensional hydraulic models were used for the design of the project. HEC-RAS v4.0 developed by the U.S. Army Corp of Engineers was used for fish/boat passage design, flood conveyance, diversion hydraulics, and ditch capacity analysis. 1D models provide coarse hydraulic results based on average hydraulic properties, such as velocity and depth, at cross section perpendicular to the flow in the river. In order to evaluate more localized hydraulic conditions necessary for fish and boat passage design, a two-dimensional model was developed. 2D models divide a project area into group of small boxes or a “grid” that allows average hydraulic results for the individual boxes within the model. Unlike 1D models, 2D models provide direction of flow. The hydraulic modeling software used for this 2D modeling was **TUFLOW**.

Diversion Hydraulics

A HEC-RAS hydraulic model was developed to determine the required headwater elevation at the dam to maintain the required diversion flow in the Hartland Ditch. The model was developed using on-site survey information and was calibrated using field measurements of the ditch water surface during operation. Orifice and weir calculations were performed for various flow levels and regimes at the existing headgate structure to determine diversion capacity to the ditch. A removable stop log system was designed at the entrance of the center boat passage channel to allow diversion during low river flows (+/-350 CFS).

Flood Conveyance

MWE obtained the Federal Emergency Management Agency (FEMA) hydraulic model results that define the Federal Insurance Rate Map (FIRM) for the Gunnison River. This model is in HEC-2 format, which was converted to HEC-RAS as the ‘Duplicate Effective” model. An “Existing Conditions” model was created using recent site survey information and cross sections from the Duplicate Effective model in areas outside of the survey limits. Lastly, a “Revised Conditions” model was developed based on the fish passage design.

A comparison of the Existing Conditions model and Revised Conditions model results for the final design was performed and indicated that the final design does not negatively impact the floodplain. MWE provided a summary of the analysis to the Delta County Floodplain Administrator for approval prior to construction. MWE performed a similar flood conveyance analysis for the “as-built” project based on a field survey of the constructed structure and submitted to Delta County for final approval. Analysis indicates that the constructed project does not negatively impact flood conveyance. The as-built flood conveyance analysis submitted to Delta County is included in Appendix B.

2D Modeling

Detailed hydraulic analysis and design of the fish and boat passages was performed using a 2D hydraulic model. Two flows were modeled, one at the low fish passage river flow (+/-750 cfs) and another at a higher river flow (+/-3000 cfs) to determine if fish passage and boat passage criteria were satisfied. Hydraulic results for velocity, depth, unit flow, flow direction and water surface elevations (hydraulic grade line) were used to evaluate and design the structure. Multiple design and model iterations were completed to develop the final design of the passages. The following is a summary of the 2D modeling results used for design:

- Flow direction- location of eddies for fish and boat passage, bank conditions, cross flow at pools between channels, entrance/exit conditions
- Distribution of flow between three channels
- Velocity and depth in fish passages
- Super elevation of flow at bends
- Distribution of hydraulic drop (profile) in channels

- Location and form of hydraulic jumps in boat passage

The velocity results from 2D models are "average depth velocities". The average depth velocity in a river, as indicated by its name, is an average of the variable velocities between the river bottom and water surface. It is equivalent to the velocity at 6/10's the total depth.

When fish move upstream they seek the path of least resistant or minimum velocity, therefore fish tend to move along the river bottom and other slow moving areas. The velocity along this path illustrates the concept of "fish's eye" velocity. In other words, the velocity the fish experiences or "sees" during movement with a reach of river. Shear stresses created by the roughness of the river bed result in much slower velocities near the river bottom than at the surface. It is reasonable to define the "fish's eye" velocity as the water velocity at 8/10's the total depth. From empirical data developed by Chow (1959), the velocity at 8/10's depth is approximately 0.75 times the average depth velocity. Additionally, McLaughlin Water Engineers recently completed 3-dimensional hydraulic modeling for another fish passage project using the chevron boulder concept. The results indicate a velocity reduction of approximately 0.6, which closely agrees with the theoretical velocity depth profile presented by Chow. Therefore, an adjustment factor of 0.75 was applied to the average depth velocity results from the two-dimensional modeling to reflect the actual velocity performance of the fish passage structure.

Results of the final design model at both flow conditions indicate that the design meets fish passage depth (2' min.) and velocity (less than 4 feet per second) criteria at the "fish's eye" locality. A sample of the 2D modeling results output is shown in Figure 5.

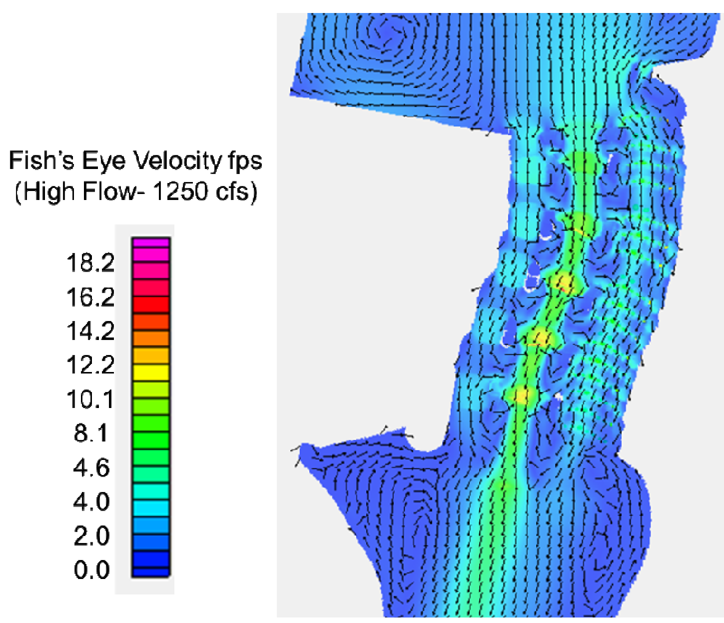


Figure 5 *– 2D Modeling Results Output Example*

<u>Structural Stability</u>

An analysis for stability of the structure up to a 100-year flood event was performed. One- and two-dimensional hydraulic modeling results were used for the analysis. Lane's Weighted Creep Method was used to determine required cut offs to reduce uplift, seepage, and piping under the structure. Boulder sizes were calculated using design criteria for sloped grouted boulder drops as developed by McLaughlin

Water Engineers, 1986 (later incorporated into the “Drainage Criteria Manual”, by Urban Drainage and Flood Control District.) Criteria included tractive force concepts such as shear stress, impact/drag forces, uplift/buoyancy, and bed friction. Scour depths were evaluated at the toe of the counter-weir and jetties using applicable empirical equations presented in “Guidelines for Computing Degradation and Local Scour”, by Pemberton and Lara (Technical Guideline for Bureau of Reclamation, 1982).

A grouted boulder mat of rounded locally available materials was used as the primary armoring type for most of the structure. The mats have various thicknesses and cementations grout is kept as low as structurally prudent. Calculation of riprap size and lack of locally available angular rock (quarry produced) led to this armoring approach. This is reflective of other river projects on the Western Slope. Boulder diameters range from 18” up to 48” - depending on where they are placed in the grouted boulder mat, and their projection above the river bottom.

Figure 6 – *Grouted Boulders*

The design utilizes buried loose riprap on the left bank with buried grouted boulder containment rows placed at approximately 20’ intervals perpendicular to flow. Inclusion of the containment rows allows the use of locally available round stones. Top soil was placed over the riprap and boulder containment rows during construction. The adjacent property owner is planning on planting willows and other vegetation along this bank for further stabilization. Riprap was sized using the Federal Highway Administration and Urban Drainage and Flood Control District design criteria.

Armoring in the chevron fish passage channel consists of loose boulders between concrete walls perpendicular to the channel. The walls provide grade control at each row of chevrons and containment of boulders. Existing river cobble was mixed with locally available round rock to create a well graded subgrade material with a mean diameter of 24-inch. Boulders were placed at the bottom of the channel to provide roughness and resistance to scour. River cobble was used to fill voids between boulders at the surface.

A sloped grouted boulder cutoff was constructed at the upstream edge, downstream edge, and along the divider wall. Shallow (4’ deep) grouted boulder cut offs were installed at the each drop structure. “Selflaunching” riprap was used for toe scour protection along the upstream jetty and downstream of the counter-weir.

Dam Modifications

The remaining section of the existing Hartland Dam, approximately 150’, was modified to improve the structural stability and reduce the hazard to river users. A roughened grouted boulder slope was constructed extending from the face of the existing dam downstream approximately 20’. Painted Sky and Hartland Irrigation Company worked directly with Kissner General Contractors to develop the dam modifications. MWE did not provide the design, engineering or construction observation for the dam modifications.

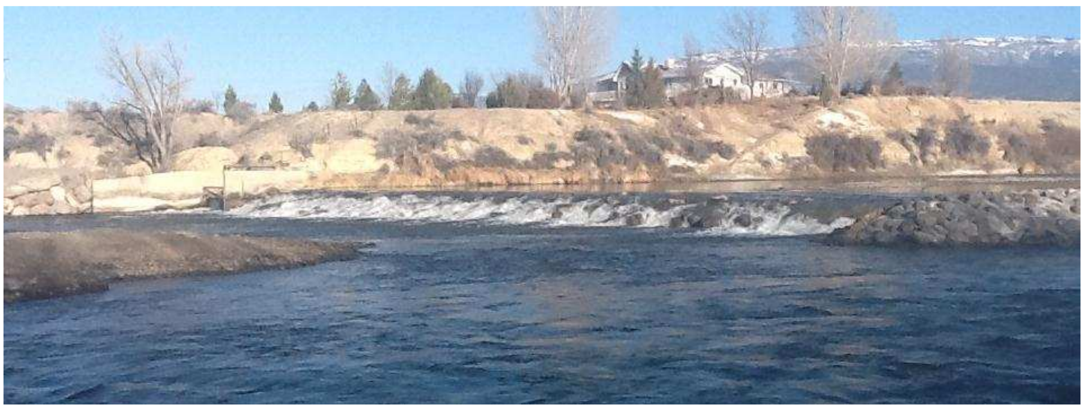


Figure 7 *– Dam Modifications*

Project Monitoring & Tuning

Due to governmental budget cuts, the resource and conservation development program (RC&D) was defunded in March, 2011. This resulted in Painted Sky losing their partnership with Natural Resource Conservation Service that provided office space and a coordinator to assist with the RC&D program. Due to this, Painted Sky has elected to begin dissolving. As part of this decision, Painted Sky along with the Walton Family Foundation transferred the monitoring phase and funds received for that portion of this project to Trout Unlimited. Future monitoring and tuning will be done and reports provided by Cary Denison, Gunnison Basin Project Coordinator.

Several areas within the project reach will need to be monitored and possibly adjusted or “tuned” post construction:

- Bank and channel stability
- Boat passage hydraulics & safety
- Dam modification hydraulics & safety
- Fish passage performance
- Debris in boat & fish passages

Stabilization problems have existed downstream of the existing Hartland Dam on the river left bank owned by the Hutchins for some time. A power pole has been relocated several times due to the erosion of a steep bank approximately 800 feet downstream of the dam. Four (4) boulder structures (jetties) have been constructed along this bank to prevent further erosion.

Modification of the dam for the boat and fish passage structure will affect the flow regime downstream by concentrating more flow along the left side of the river, which could cause de-stabilization of the banks. Prior to construction of the fish and boat passage structure, Painted Sky had been working with the Hutchins and the NRCS to do a comprehensive bank stabilization project for their property utilizing Environmental Quality Incentives Program (EQIP) funds and cost matching. Painted Sky was seeking funds to assist the Hutchins with their portion of the cost matching. The NRCS was planning on evaluating the reach after the dam modifications and boat and fish passages were complete and develop stabilization measure to be implemented. As a result several stabilization measures in the original design including blanketing and revegetation, a boulder jetty downstream of the structure, and removal and replacement of bed material would be evaluated and implemented as part of the NRCS project. For initial bank stabilization at the request of the Hutchins, Painted Sky and Kissner GC installed four boulder jetty structures along the east bank downstream of the dam and upstream of the existing boulder jetties. Stabilization of the channel and banks along and downstream of the new structure is an integral component of the overall project that needs to be pursued and completed based on monitoring of the reach. With the dissolution of Painted Sky this spring, Trout Unlimited will become the lead on monitoring of channel and bank stability and stabilization improvements.

MWE and TU have developed preliminary protocols for monitoring. Periodic site inspection of the structure and project reach will be conducted to monitor and evaluated performance and conditions over a range of river flows. Fish passage monitoring will include measurements of velocity and depth and inspections for debris. Hydraulic conditions are to be observed in the boat passage particularly for conditions that pose safety risks, such as, debris accumulation, “keeper” waves, and flow alignment. Observations of the sloped grouted boulder dam modifications (west side) for similar safety risks will be conducted including inspections for the presence of a reverse roller keeper hydraulic at the toe of the dam. Debris accumulated on the dam or boat and fish passages will be removed immediately due safety concerns and negative performance implications. Cary Denison of TU has conducted two site visits to perform monitoring of the project. Velocity measurements are included in Appendix C.

Hydraulically, this project is complicated. The structure must pass slow swimming fish and boaters, while maintaining the Hartland Irrigation Companies diversion capabilities. Computer modeling was completed as part of the design to reduce the level of uncertainty. A three-dimensional computer or physical modeling effort was initially recommended to further reduce this uncertainty, however funding was not available. As a result, adjustments to in river features or “tuning” will likely be required after construction and initial startup and observation. This will involve the modification of the structure to optimize the performance to meet the project objectives. Tuning modifications will be developed based on evaluations and conclusions from monitoring. Typical tuning of similar structures includes adding or eliminating loose boulders in fish passages, removing chevron faux rocks, and structural modifications to grouted boulders, control crests, and dam modifications.

Cory Williams, Sediment Specialist with US Geological survey has been monitoring the river above and below the project. Channel restoration, rehabilitation, or reconfiguration, to mitigate a variety of riverine problems has become a common practice in the western United States. Reasons cited include restoration to more natural or historical conditions, improved water conveyance in flood-prone areas, mitigation of unstable streambeds and streambanks, increased sediment transport, enhancement of aquatic and riparian habitat, water-quality, and recreation. Numerous private entities and resource-management agencies have attempted to modify stream channels by using designs based on different geomorphic philosophies and classification schemes. However, little work has been done to monitor and assess the channel response to, and the effectiveness of, these modifications over a long period of time. The U.S. Geological Survey (USGS) has established the Reconfigured Channel Monitoring and Assessment Program (RCMAP) to monitor and assess post-restoration geomorphic stability of selected river and stream reaches in western Colorado that have undergone modification. The RCMAP is designed to provide information to resource managers, planners, and designers on the effectiveness and durability of channel modification techniques. Additionally, data collection efforts and analysis can provide information on site-specific effects of flow conditions on channel form and function. This can be used to indicate potential threshold responses of stream reaches to channel form alterations to inform reconfigured channel reach selection processes in the future. Addition of the Hartland Dam reach into the RCMAP monitoring scheme will allow for baseline data acquisition and expansion of RCMAP data sets to include low-dead dam alterations.

Existing geomorphic conditions in the study reach were quantified with a detailed, topographic survey (RTK-GPS) of key hydraulic features. Eight hydrologic cross sections (which included the streambed, banks, and active floodplain), photo-monuments, and 2 pebble counts were used to characterize reach conditions. Additional surveying downstream from the dam at the mid-channel bar and the cut-bank and j-hooks along river left were completed. Water-surface elevation recordings (via pressure transducers and a staff gage) are being recorded for high-flow conditions within the study reach (at 4 location) to obtain the water-surface profile of the reach. These elevations will be correlated with discharge data from a nearby, continuously-recording streamflow gaging station (09144250 Gunnison River at Delta, CO) to estimate long-term hydrologic properties (e.g., flood frequency, flow duration, energy grade line) in the study reach. All survey data were referenced to Online Positioning User Service (OPUS)-corrected RTK-GPS positions, and will be posted to the RCMAP web page at (http://co.water.usgs.gov/projects/CO401/index.html).

Figure 8 *– Monitoring: Velocity Measurements in Chevron Channel*

Future Work

The extent and scope of future work is not clearly defined at this time and will evolve over time based on going monitoring. However, several areas and tasks for future work are anticipated at this time. Bank and channel stabilization improvements adjacent to and downstream of the new structure may be required. The fish and boat passage structure will likely require tuning and some routine maintenance to function properly over the long term. The Gunnison River moves significant amounts of debris and sediment some of which will most likely be deposited in or accumulate on the new structure. Debris and possibly sediment will need to be removed periodically for low hazard boat passage and proper function of the fish passage channels.

Appendix

Appendix A – As Recorded Project Drawings

Appendix B – Copy of Flood Analysis and Letter to Delta County As-built Condition

Appendix C – Initial Monitoring Data

Appendix D - Photos

McLaughlin Water
ENGINEERS, LTD.

May 9, 2012

Delta County Environmental Health Division
c/o Ken Nordstrom, Director
255 W. 6th Street
Delta, CO 81416

RE: Post Construction Floodplain Analysis for Hartland Dam Fish Passage Modification

Mr. Nordstrom:

McLaughlin Water Engineers (MWE) has performed an analysis of the impact of the constructed Hartland Dam Fish Passage project on the existing 100-year floodplain for the Painted Sky Resource Conservation District. A similar analysis for the pre-constructed project was conducted and submitted to the Delta County Environmental Health Division on March 29, 2011 prior to the start of construction. We are submitting this analysis for your records. The analysis approach and results are presented herein.

Background

The project is located on the Gunnison River approximately 2.5 miles northeast of the city of Delta, Colorado (FIRM Map Number 08029C0418D). The existing dam acts as a diversion for an irrigation ditch owned and operated by the Hartland Irrigation Company. This project modified the existing dam to provide fish passage and low hazard boat passage while maintaining its primary function as a diversion. Approximately 150 feet of the existing dam was removed and replaced with a sloped grouted and loose boulder structure. The footprint is approximately 150 feet wide and 300 feet long. During construction the portion of the dam to remain was exposed. It was in poor condition. Painted Sky RC&D, at the request of the Hartland Irrigation Company, completed structural modifications to the approximately 150 feet of dam that was not removed. Structural improvements included adding grouted boulders at the downstream side. As-built survey data for the structural modifications was not provided to MWE. However, a sensitivity analysis was conducted, and is included herein, to evaluate the effect of an increased dam crest elevation on flood conveyance.

Floodplain Analysis

The purpose of this floodplain analysis is to determine the impact of the constructed project on the "true" pre-project 100-year floodplain (Existing Conditions Model). The "true" pre-project floodplain reflects the pre-construction site conditions, not necessarily the floodplain conditions in the FIS hydraulic model or as shown on the FIRM map. This analysis is not intended to be used for a Conditional Letter of Map Revision (CLOMR) or a Letter of Map Revision (LOMR). Results from the Pre-Construction and Post-Construction floodplain analysis are presented.

Floodplain analysis was performed using the hydraulic modeling software HEC-RAS v4.0 developed by the United States Army Corps of Engineers. Cross sections used in the hydraulic models are shown in two exhibits attached. One exhibit is of the overall project reach (#1), including upstream and downstream boundary cross sections. A second exhibit (#2) shows the project reach near the Hartland Dam.

Data from several surveys were used in the floodplain analysis. In October 1999, the United States Bureau of Reclamation (BOR) performed a survey of approximately 3 miles of the Gunnison River in the project reach including the Hartland Dam. A detailed topographic survey of the immediate project area was performed by MWE in April 2010. A third survey was performed by a local Land Surveyor, Kenny Schaaf, in June 2010 to verify the dam crest and project vertical datum from known area benchmarks.

MWE obtained the Federal Emergency Management Agency (FEMA) hydraulic model that defines the Federal Insurance Rate Map (FIRM) for the Gunnison River. This FIS model is in HEC-2 format, which was converted to HEC-RAS as the 'Duplicate Effective" model. FEMA requires that the FIS and Duplicate Effective model results be within 0.5 feet or further calibration is needed. Water surface elevations for the 100-year floodplain in the Duplicate Effective model meet the FEMA criteria. The Duplicate Effective and FIS models were converted from the National Geodetic Vertical Datum of 1929 (NGVD 29) to North American Vertical Datum of 1988 (NAVD 88) to reflect the current project survey datum.

An "Existing Conditions" model was created using the site survey information and cross sections from the Duplicate Effective model in areas outside of the current project survey limits. New cross sections were added to the model at several locations in the project reach to accurately model the current site conditions. Results from the Existing Conditions model were compared to results from the Duplicate Effective model to identify differences. Model results were further compared at the Duplicate Effective model cross sections used in the Existing Conditions model to verify that the 100-year floodplain water surface elevation matched at these upstream and downstream boundary locations. This confirmed that the FIS model outside the project reach is unaffected by the new modeling. A summary of these comparisons are shown in Table 1. The Existing Conditions model provides a baseline hydraulic condition to determine the impact of the improvements on the 100-year floodplain.

Table 1 *– Comparison of 100-year Floodplain Elevation Results for Duplicate Effective and Existing Conditions Models*

Duplicate Effective Model		**Existing Conditions Model**			
Station	100-Yr W.S. El.	Station	100-Yr W.S. El.	100-Yr W.S. El. Diff.	Notes
515927 (51)	4973.51	52	4973.52	0.01	100yr W.S. El. Matches at U/S Boundary
505765 (50)	4969.56	51	4969.60	0.04	
495825 (49)	4967.51	50	4966.96	-0.55	
485489 (48)	4966.67	49	4965.04	-1.63	
475350 (47)	4963.91	48	4963.14	-0.77	W.S. El. Lower due to XS 48 being cut full floodplain width (+/- 2x as wide as cross section 475350 in the dup eff model
465213 (46)	4960.12	47	4961.36	1.24	W.S. El. Rise from dam crest survey actual crest +1.2' above Dup Eff Model El.
-	-	46	4961.16	-	XS 46 Added to Exst. Cond. Model
		45.9	4960.92	-	XS 45.9 Added to Exst. Cond. Model
455171 (45)	4956.77	45	4958.04	1.27	XS 455171 = +/-XS 45
445165 (44)	4954.44	44	4957.97	-	XS 44 Added at different location in Exst. Cond. Model
445163 (44.5)	4955.04	-	-	-	No Exst. Cond. Model XS at location of XS 445163 (44.5)
435074 (43)	4953.83	43	4954.10	0.27	
424989 (42)	4953.04	42	4953.04	0	100yr W.S. El. Matches at D/S Boundary
414757 (41)	4950.11	41	4950.11	0	
404580 (40)	4946.54	40	4946.54	0	

Review of model data indicates that the Hartland Dam crest elevation is approximately 1.2 feet lower in the FIS model than was surveyed. A project survey by Schaaf, mentioned previously, confirmed the Hartland Dam crest elevation and that the project topographic surveys are on the NAVD 88 datum. The Existing Conditions model uses the surveyed dam crest elevation.

A "Pre-Construction Proposed Conditions" model was developed for the fish passage that reflected the designed improvements prior to construction. This analysis and results were first submitted for approval by the Delta County Environmental Health Division on March 29, 2011 and are presented unchanged herein. Comparison of the Existing Conditions and Pre-Construction Proposed Conditions model results, shown in Table 2, indicates that the proposed final design <u>did not</u> negatively impact the "true" existing floodplain.

Table 2 *– Comparison of 100-Year Floodplain Elevation Results for Existing Conditions and Pre-Construction Proposed Conditions Models*

Existing Conditions Model		Pre-Construction Revised Conditions Model		
XS	100-Yr W.S. El.	XS	100-Yr W.S. El.	100-Yr W.S. El. Diff.
52	4973.52	52	4973.52	0
51	4969.60	51	4969.60	0
50	4966.96	50	4966.96	0
49	4965.04	49	4965.01	-0.03
48	4963.14	48	4962.99	-0.15
47	4961.36	47	4960.95	-0.41
46	4961.16	46	4960.30	-0.86
45.9	4960.92	45.9	4959.76	-1.16
-	-	45.8	4959.58	-
45	4958.04	45.6	4956.90	-1.14
44	4957.97	44	4957.88	-0.09
43	4954.10	43	4954.10	0
42	4953.04	42	4953.04	0
41	4950.11	41	4950.11	0
40	4946.54	40	4946.54	0

A "Post-Construction Conditions" model was created from an as-built survey performed by Ken Schaff in January and February of 2012 of the constructed fish and boat passage structure. The Post-Construction Conditions model was based on the Pre-Construction Proposed Conditions model. However, several modifications were made in the final analysis. Cross section geometries were updated with as-built survey data to reflect the constructed condition. The constructed jetty on river left upstream of the structure was added to Cross Section 45.9. At Cross Section 45.8, the effective discharge length along the divider wall crest was reduced by two thirds to account for inefficient discharge due to parallel orientation to the primary river flow. The location of Cross Section 45.6 was relocated along the toe of the dam and crest of the downstream-most drop (Drop #5) in the fish and boat passage structure.

As previously mentioned, the remaining 150 feet (approx.) of the dam outside the fish and boat passage structure footprint was structurally modified by the Hartland Irrigation Company and Painted Sky due to its poor condition. Grouted boulders were installed on the downstream face of the dam. As-built survey data for the work completed was not provided to MWE. A sensitivity analysis was therefore performed to determine the effect on the flood water surface elevations by an increased dam crest elevation. The existing (pre-construction) crest elevation was increased up to 12-inches in the Post-Construction Conditions model. Water surface elevations results were compared to the Existing Conditions model to determine impacts to the 100-year floodplain. Results, shown in Table 3, indicate that the post-constructed project with the existing (pre-constructed) dam crest elevation increased 12-inches does not negatively impact the "true" existing floodplain.

Table 3 *– Comparison of 100-Year Floodplain Elevation Results for Existing Conditions and Post-Construction Conditions Models (w/ Dam Crest Increased 12")*

Existing Conditions Model		**Post-Construction Conditions Model w/ Dam Crest Increased 12"**		
XS	100-Yr W.S. El.	XS	100-Yr W.S. El.	100-Yr W.S. El. Diff.
52	4973.52	52	4973.52	0
51	4969.60	51	4969.60	0
50	4966.96	50	4966.96	0
49	4965.04	49	4965.02	-0.02
48	4963.14	48	4963.05	-0.09
47	4961.36	47	4961.12	-0.24
46	4961.16	46	4960.54	-0.62
45.9	4960.92	45.9	4959.80	-1.12
-	-	45.8	4958.31	-
45	4958.04	45.6	4957.72	-0.32
44	4957.97	44	4957.85	-0.12
43	4954.10	43	4954.10	0
42	4953.04	42	4953.05	0.01
41	4950.11	41	4950.11	0
40	4946.54	40	4946.54	0

Conclusion

Table 1 indicates that there are differences between the results of the Duplicate Effective and Existing Conditions models. There are several factors that cause these discrepancies. Most significantly, the actual Hartland Dam crest elevation is approximately 1.2 feet higher than modeled in the Duplicate Effective and FIS models. Upstream of the dam, cross section 47 in the Duplicate Effective model did not extend across the full floodplain this resulted in an increased floodplain elevation in the Existing Conditions model. Downstream of the dam, the channel invert elevations in the FIS model are 2-5 feet lower than the surveyed pre-project condition. This resulted in a higher floodplain elevation in the Existing Conditions model at XS 45. A "Corrected Effective" model that would resolve these errors was not created because, as stated previously, the objective of this analysis was to determine the impact of the project on the "true" existing 100-year floodplain as calculated using the Existing Conditions model. The analysis is not intended for a CLOMR or LOMR. A profile exhibit is attached (#3) that shows the minimum channel elevations and 100-year water surface elevations for the Duplicate Effective, Existing Conditions, and Post-Construction Conditions Models (w/ the dam crest increased 12").

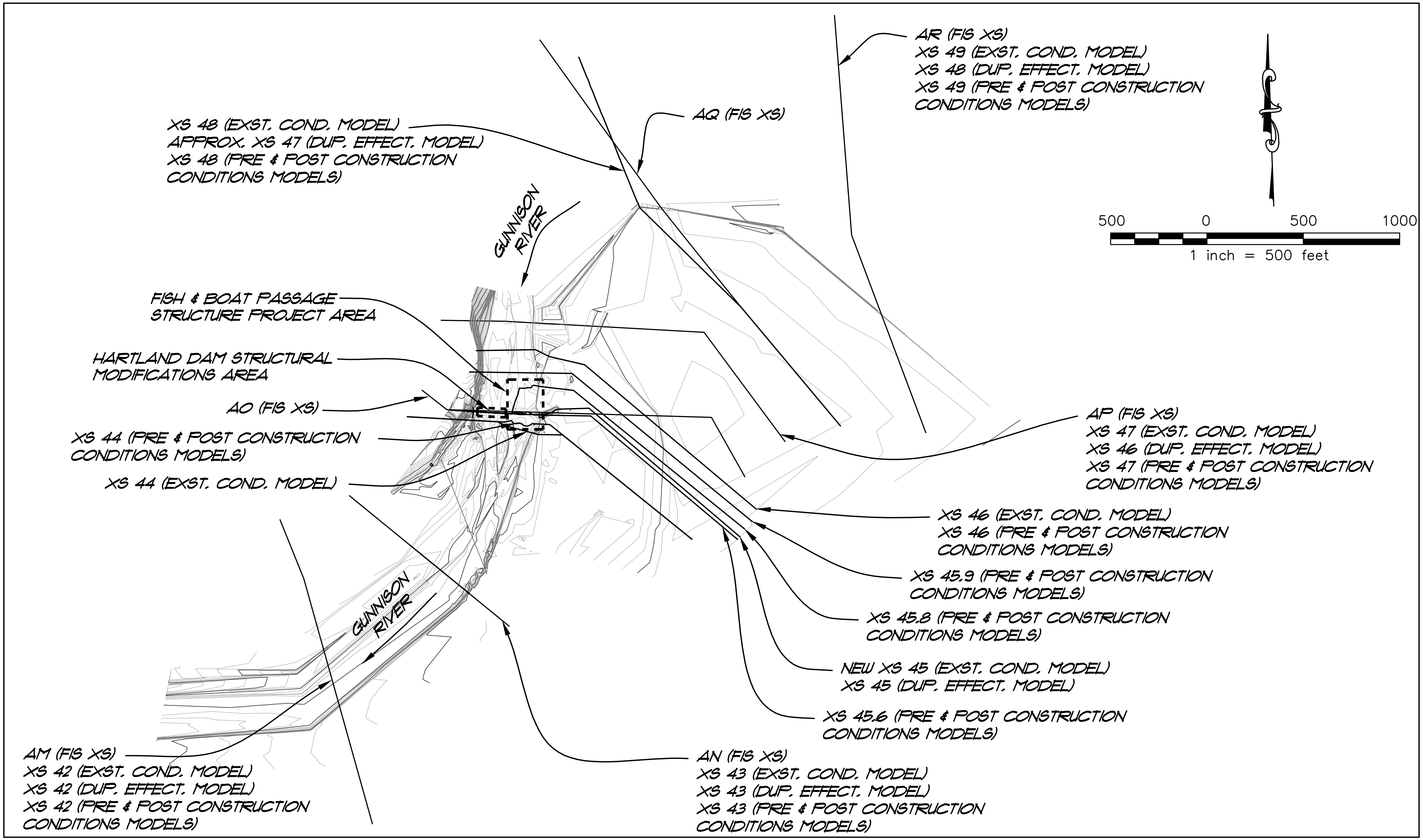
The analysis indicates that the constructed project did not impact the "true" existing 100-year floodplain. In fact, results show the floodplain is actually lowered due to the constructed improvements (see Table 3 and Exhibit #3 attached). A water surface increase of 0.01' at XS 42 appears to be the result of model rounding as this cross section is the same in both the Existing Conditions and Post-Construction Conditions models and is therefore ignored. Placement of the new fish and boat passage structure upstream of the existing dam crest increases discharge capacity, which lowers the floodplain elevation. Discharge capacity is also increased due to a longer effective dam crest length and steeper channel slope.

If you have any questions or need additional information please don't hesitate to call at 303-964-3333.

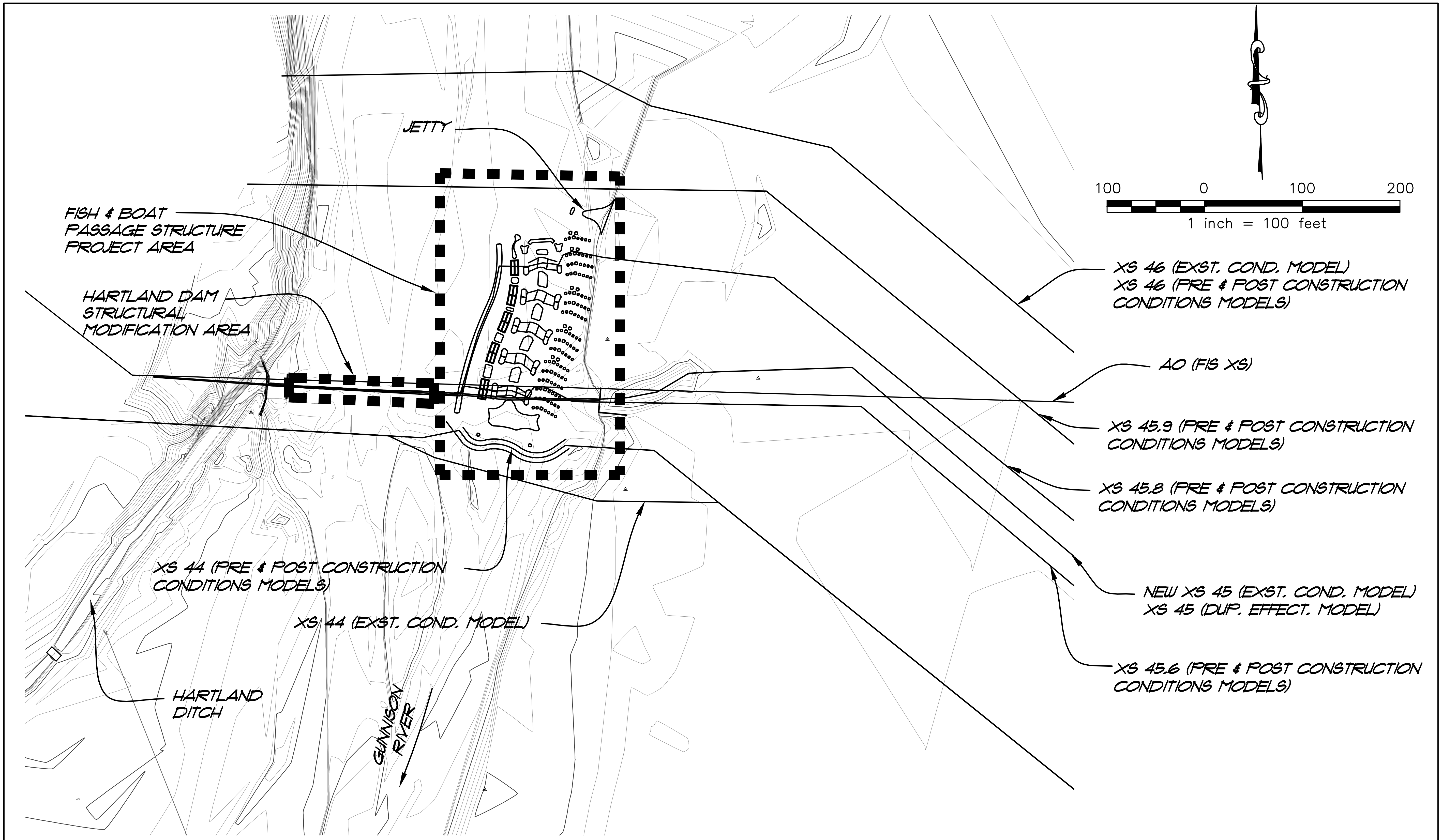
Very truly yours,
McLaughlin Water Engineers, Ltd.

Benjamin A. Nielsen, P.E., L.E.E.D. A.P.
Project Engineer

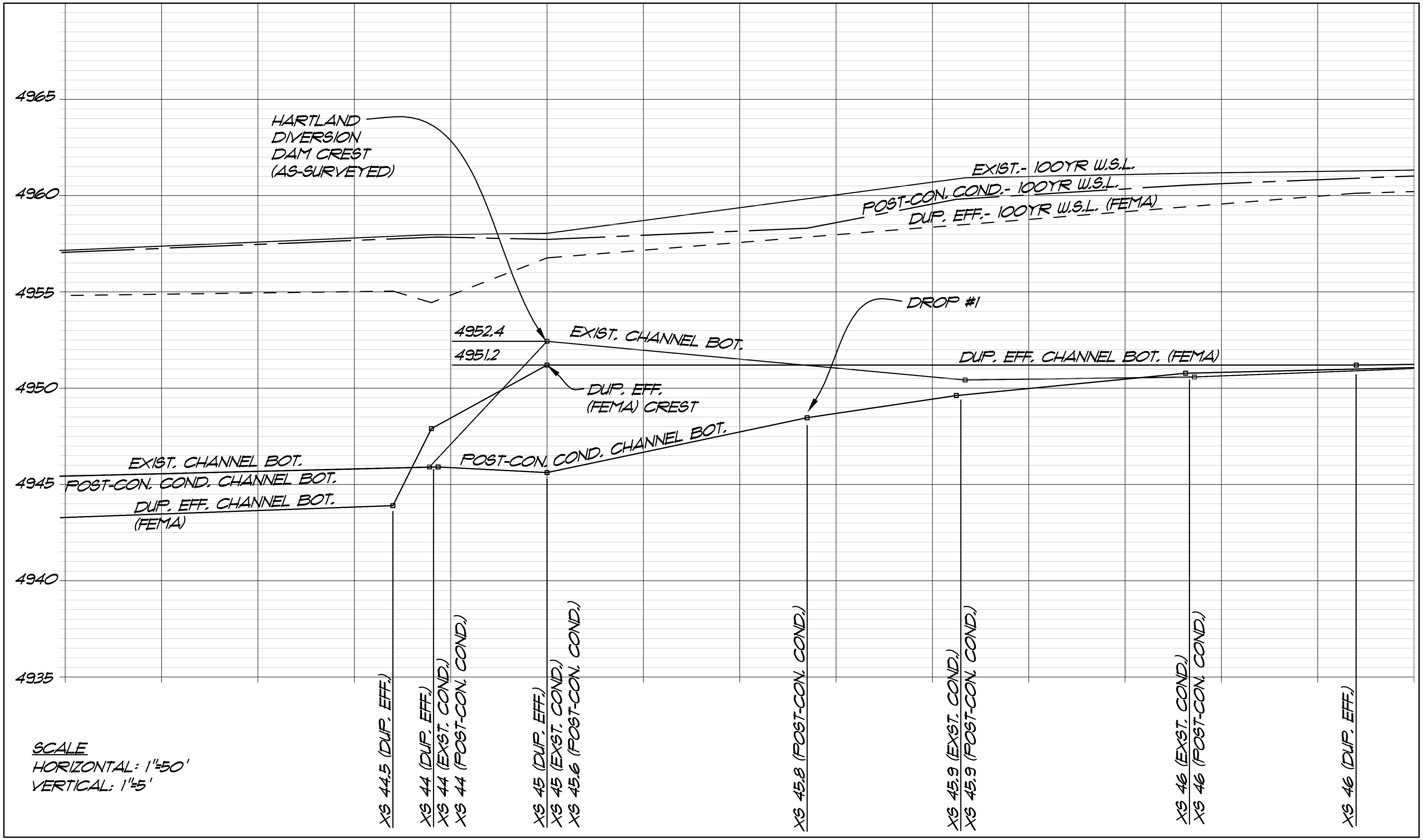
Attachments: -Hartland Dam Fish Passage Overall Floodplain Exhibit (#1)
-Hartland Dam Fish Passage Project Area Floodplain Exhibit (#2)
-Hartland Dam Fish Passage 100-Year Floodplain Profiles (#3)



GUNNISON RIVER DELTA, CO	HARTLAND DAM FISH PASSAGE OVERALL FLOODPLAIN EXHIBIT	McLaughlin Water Engineers, Ltd. 2420 Alcott Street Denver, Colorado 80211 T 303.964.3333 F 303.964.3355	1



GUNNISON RIVER DELTA, CO	HARTLAND DAM FISH PASSAGE PROJECT AREA FLOODPLAIN EXHIBIT	McLaughlin Water Engineers, Ltd. 2420 Alcott Street Denver, Colorado 80211 T 303.964.3333 F 303.964.3355	2



GUNNISON RIVER
DELTA, CO

HARTLAND DAM FISH PASSAGE
100-YEAR FLOODPLAIN PROFILE

McLaughlin Water Engineers, Ltd.
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Denver, Colorado 80211
T 303.964.3333
F 303.964.3355

Number	Revision Description	By	Date

TROUT UNLIMITED
DELTA, COLORADO

HARTLAND DIVERSION DAM
FISH PASSAGE

MONITORING
KEY MAP

McLaughlin Water Engineers, Ltd.
2420 Alcott Street
Denver, Colorado 80211

DESIGN: BAN
DETAIL: BAN
CHECK: –
DATE: APRIL 2012

PROJECT NUMBER
10-06-01

Drawing Number:
1

Hartland Diversion Dam Fish Passage
Post Construction Monitoring - Velocity Field Measurements
Measurements By: Cary Denison (TU) & Ben Nielsen (MWE)
Equipment: Double A Meter
Date: March 16, 2012
River Flow (cfs): 1,100

Measurement Location*	Total Water Depth (ft)	Depth of Velocity Measurement From Bottom (ft)	Velocity (fps)	Notes
4D-4	2.4	0.6	5.0	Chevron overtopped
4D-3	2.2	0.2	3.2	Water just to top of chevron cylinder
		0.6	3.7	
		1.1	3.7	
		1.8	4.1	
Pool btw 3D-3 & 3C-3	Not measured	1.0	1.7	Pool measurement
2D-2	1.5	0.6	4.3	Measurement taken just downstream of slot (wall)
2D-3	2.2	0.7	3.3	
2D-4	2.4	0.6	4.2	Chevron overtopped

* All measurements taken in the Chevron Fish Passage

Hartland Diversion Dam Fish Passage
Post Construction Monitoring - Velocity Field Measurements
Measurements By: Cary Denison (TU)
Equipment: Double A meter
Date: 5/15/12
River Flow (cfs) Gunnison at Delta Gauge: 834

Spin test before: Yes /ok 1:35
Spin test after: yes ok 1:16

Measurement Location*	Total Water Depth (ft)	Depth of Velocity Measurement From Bottom (ft)	Velocity (fps)	Notes/Conditiions
1A-4	2.7	0.7	2.8	in slot between rocks, very uniform
1A-4	2.7	1.5	2.0	same as above slower velocity
1A-3	2.1	0.7	2.0	very uniform
1C-4	2.6	0.8	3.2	uniform but question velocity
5C-3	2.0	0.7	2.8	uniform but question velocity

* All measurements taken in the Chevron Fish Passage

Appendix D – Photos

Arial photos are property of Kissner General Contractors, Inc. and were used with their permission. Any reproduction of arial photos must be approved by Kissner General Contractors, Inc.

Arial View prior to construction

Construction progress October 13, 2011

Construction progress November 22, 2011

Arial View November 22, 2011

Fish ladder December, 2012

Grouting structures in boat passage.

Standing on river bank looking across project

Breaking lower coffer dam – standing on island to left of boat passage.

Dam modifications to remaining existing dam

Dam modifications completed.

More photos to follow via compact disk.