Letter of Map Revision (LOMR)

Clark Fork River and Blackfoot River

Near Milltown, Montana

Prepared For:

Montana DOJ Natural Resource Damage Program
PO Box 201425
1301 E Lockey
Helena, MT 59620-1425

Montana Department of Justice Natural Resource Damage Program

United States Environmental Protection Agency
US Federal Building 10 West 15th Street
Suite 3200
Helena, MT 59626

Prepared By:

River Design Group, Inc.
5098 Highway 93 South
Whitefish, Montana 59937

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EXECUTIVE SUMMARY

Milltown Dam was built between 1905 and 1907 at the confluence of the Clark Fork River and Blackfoot River, eight miles east of Missoula, Montana. During the Clark Fork River flood of record in 1908, the reservoir filled with approximately 6.6 million cubic yards of sediment including tailings from mining operations 150 miles upstream near Butte, Montana. In the 1980s, contaminated reservoir sediments were linked to elevated levels of arsenic in drinking water wells in nearby communities. As part of a settlement agreement between the State of Montana, the United States, Atlantic Richfield Company, North Western Corporation and the Confederated Salish Kootenai Tribes, 2.2 million cubic yards of contaminated sediments were removed from Milltown Reservoir and Milltown Dam was removed, setting the stage for restoration of the Clark Fork River upstream of the dam. As part of this effort, Bonner Dam on the Blackfoot River was removed in 2007 and the Stimson Lumber Mill cooling pond was removed in 2010.

Removal of Milltown Dam in 2008 restored fish passage and free flowing river conditions on the Clark Fork River and Blackfoot River for the first time in over 100 years. Integrated planning efforts for restoration of the post-dam Clark Fork River floodplain began in 2000, and implementation of the restoration plan was completed between 2009 and 2012. The restoration plan addressed three miles of the Clark Fork River and over 250 acres of floodplain above the former dam location. No active restoration work was completed on the Blackfoot River.

The methods proposed for use in this study were scoped out during a meeting in Missoula, Montana on May 15, 2012 and conference call with FEMA representatives on June 15, 2012. The procedures agreed upon are documented in a memorandum included in this document as Appendix A.

The Environmental Protection Agency (EPA) and the Montana Department of Justice Natural Resource Damage Program (NRDP) funded River Design Group Inc. to complete a Letter of Map Revision (LOMR) for post-project conditions. This report, accompanying appendices, and digital files comprise the analysis performed for the LOMR and describe water surface elevation changes attributable to the project. Removal of the Milltown and Bonner Dams and Stimson Cooling Pond has a net outcome of lowering the base flood elevation at the location of the former structures and most areas upstream. A Post-project model summarizes the cumulative impacts to the base flood elevation and provides the basis for the LOMR.

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1 INTRODUCTION

1.1 Project Scope

The United States Environmental Protection Agency (EPA) and the State of Montana Department of Justice Natural Resource Damage Program (NRDP) funded River Design Group Inc. (RDG) to complete a Letter of Map Revision (LOMR) for conditions following removal of Milltown Dam, Bonner Dam, and the Stimson cooling pond and restoration of the Clark Fork River. This report, accompanying appendices, and digital files, comprise the analysis performed for the LOMR and describe water surface elevation (WSEL) changes attributable to the project. A Post-project model summarizes the cumulative impacts to the base flood elevation and provides the basis for the LOMR. A watershed and project vicinity map is provided in Figure 1-1. The locations of the dams are provided in Figure 1-2, the pre-project conditions map. The post-project conditions are shown in Figure 1-3.

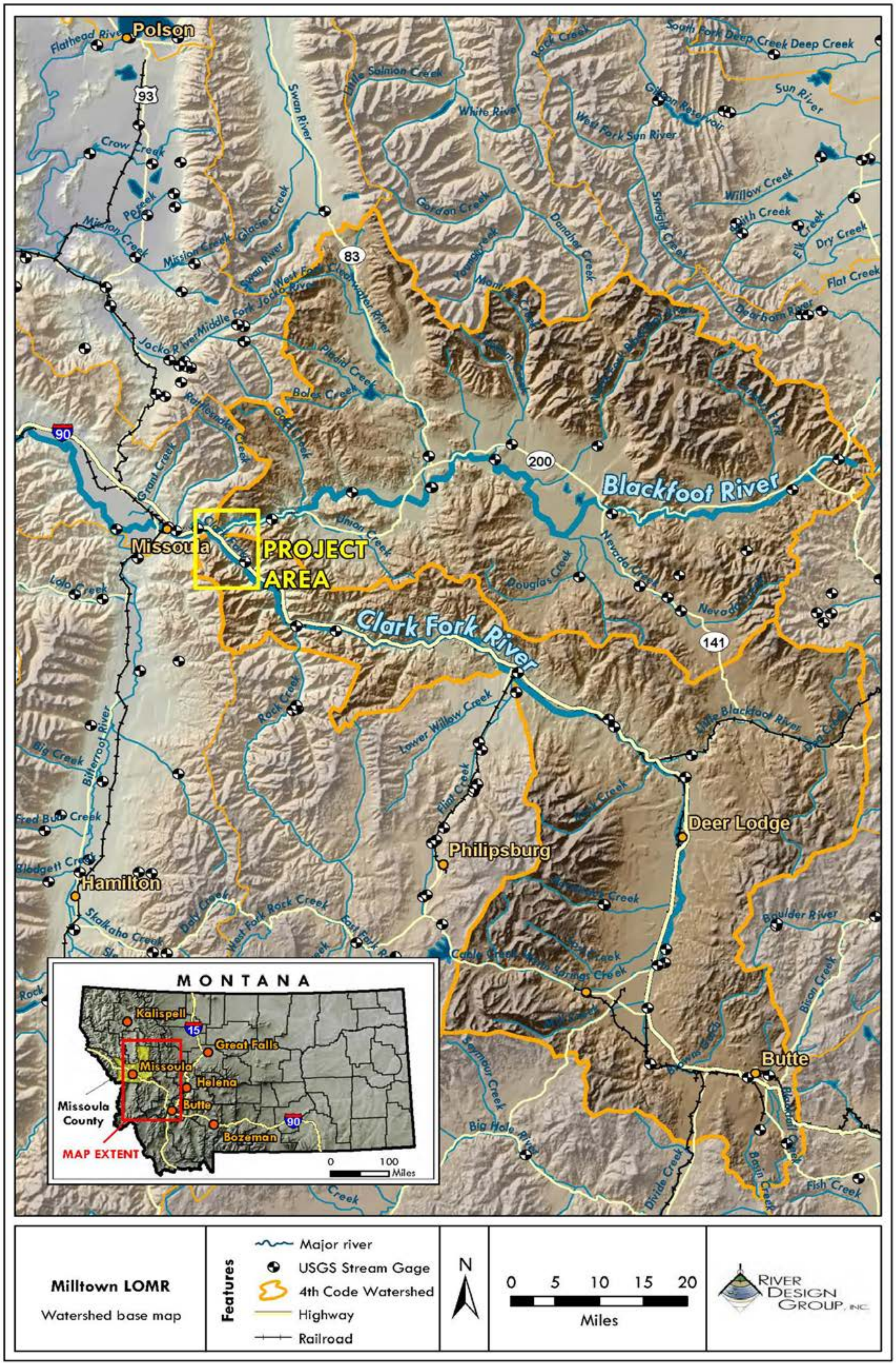
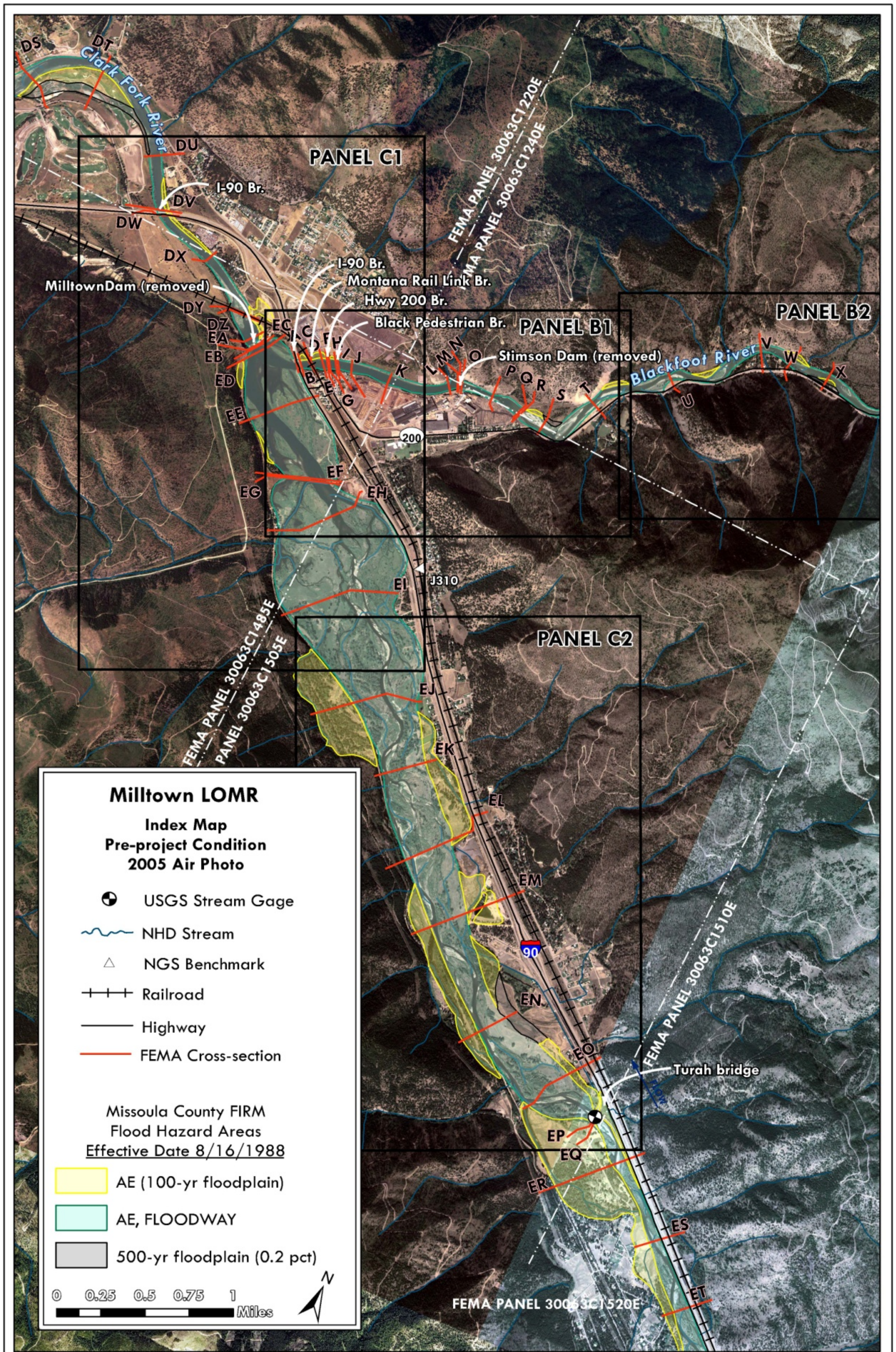


Figure 1-1. Project vicinity map showing CFR and BFR watersheds.



05/2012, River Design Group, Inc. Data: Missoula County GIS; NHD; MT NRIS; 2011 NAIP Imagery.

Figure 1-2. Pre-project conditions map with effective flood hazard data.

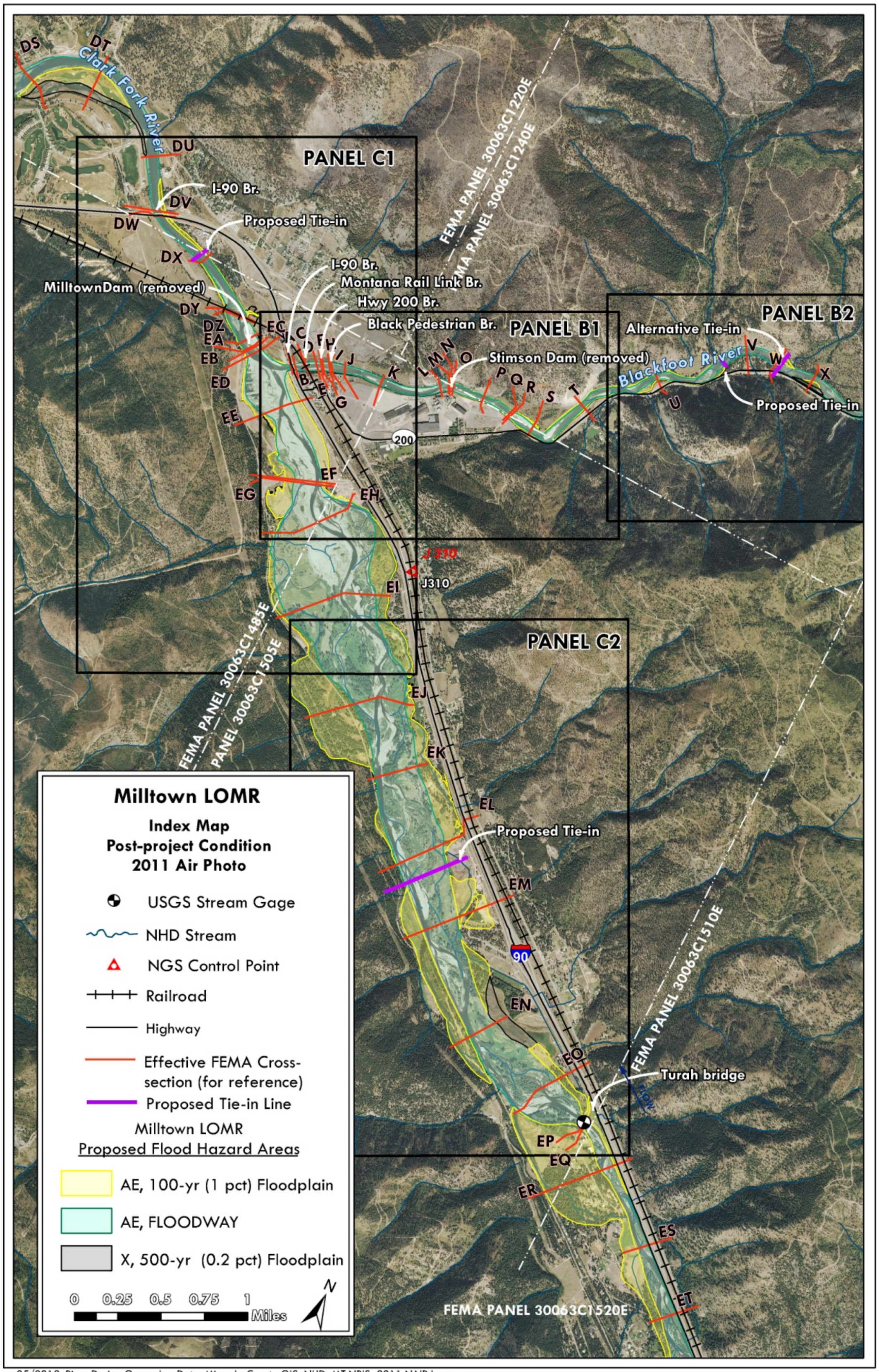


Figure 1-3. Post-project conditions map with revised flood hazard data.

2 PROJECT DESCRIPTION

Milltown Dam was built between 1905 and 1907 at the confluence of the Clark Fork River (CFR) and Blackfoot River (BFR), eight miles east of Missoula, Montana. During the CFR flood of record in June 1908, the reservoir filled with approximately 2.3 million cubic yards of sediment including tailings from mining operations 150 miles upstream near Butte, Montana. In the 1980s, contaminated reservoir sediments were linked to elevated levels of arsenic in drinking water wells in nearby communities. As part of a settlement agreement between the State of Montana, the United States, Atlantic Richfield Company, North Western Corporation and the Confederated Salish Kootenai Tribes, 2.2 million cubic yards of contaminated sediments were removed from Milltown Reservoir and Milltown Dam was removed, setting the stage for restoration of the Clark Fork River upstream of the dam.

Removal of Milltown Dam in 2008 restored fish passage and free flowing river conditions on the CFR and BFR for the first time in over 100 years. Integrated planning efforts for restoration of the post-dam CFR floodplain began in 2000, and implementation of the restoration plan was completed between 2009 and 2012. The restoration plan addressed three miles of the CFR and over 250 acres of floodplain above the former dam location. Photographs of pre and post project conditions are shown in Figure 2-1.

Figure 2-1. On left, confluence of Clark Fork River and Blackfoot River at Milltown Dam. On right, confluence after dam removal and restoration.

Bonner Dam was built between 1884 and 1886 to catch logs floated down the Blackfoot River (TwoRiversHistory.net 2013). A network of wooden cribs filled with rock extended into the channel to catch the logs. The cribs were eventually covered with an earthen berm that walled off a portion of the river creating a pond. The pond became the repository for storm water and wastewater from the Stimson Lumber Mill's boilers which was allowed to cool there before being returned to the river. Petroleum hydrocarbons and polychlorinated biphenyl (PCB) contamination was discovered in the ponds (Montana DEQ 2008).

In 2005, Bonner Dam was removed with the exception of the structural base consisting of wood and rock. Pursuant to concerns regarding stability of the Stimson Lumber Mill's cooling pond and the berm separating the pond from the river, an evaluation of the structural stability of the berm was completed (Montana DNRC 2006). The berm, pond and contaminated materials were removed in 2010 and 2011 and the riverbank was then re-sloped and re-vegetated as can be seen in Figure 2-2 (Montana DEQ 2011). In 2013, the remaining portions of Bonner Dam's timber crib sill were excavated and removed, along with logs that posed a navigational hazard to users of the Blackfoot River (Figure 2-3).

Figure 2-2. On left, Blackfoot River, Bonner Dam and the Stimson cooling pond (Photo courtesy of USACE). On right, Blackfoot River after dam and cooling pond removal (Photo courtesy of Judy and Gary Matson).

Figure 2-3. On left, Blackfoot River, remaining portions of Bonner Dam following removal in 2005. On right, Blackfoot River after remaining portions of dam removed.

This LOMR was developed in accordance with Missoula County floodplain management requirements, Federal Emergency Management Agency (FEMA) Guidelines and Specifications for Flood Hazard Mapping Partners (FEMA 2003), and standard hydraulic engineering principles utilized for floodplain modeling.

The effective FEMA Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRM) for Missoula County are dated August 16, 1988. Between 2008 and 2010, a comprehensive effort was initiated to modernize the FEMA flood maps for Missoula County. The effective paper maps were digitized and a limited number of changes were made to the maps as described in a summary of changes document included in Appendix A of this report (Missoula County 2010). Neither the Milltown and Bonner dam removals nor the floodplain restoration were incorporated into the preliminary Digital Flood Insurance Rate Maps (DFIRM) for Missoula County.

FEMA issued the most recent Revised Preliminary DFIRM for Missoula County on December 20, 2010. Although they have not been finalized for use by FEMA, Missoula County is using the preliminary DFIRMs as best available information for planning, subdivision and permitting purposes (Missoula County 2010). The Board of County Commissioners has formally adopted the DFIRMs as flood information (Resolution 2009-047). Since the updated FIS and DFIRM are only mapping improvements, the effective FIS and 1979 HEC-2 files from the original floodplain model were utilized as existing conditions flood data as described in this report.

3 METHODOLOGY

FEMA maintains and updates the FIS and associated FIRMs for communities, such as Missoula County (FEMA Community No. 300049), that participate in FEMA's National Flood Insurance Program (NFIP). The maps depict land which has been determined to be subject to a 1% or greater chance of flooding in any given year. A flood event with a 1% chance of occurrence in a given year is called a 1%-annual-chance flood, also commonly referred to as a 100-year flood. The FIRM is used to determine flood insurance rates and to help the community with floodplain management.

FEMA has developed a set of procedures to ensure that NFIP maps are revised as appropriate to reflect current conditions. These procedures are described in detail in FEMA form MT-2 (Appendix B), which is the application to FEMA for revisions to effective FIRMs. These forms provide FEMA with assurance that all pertinent data relating to the revision are included in the submittal. Per the MT-2 form, the LOMR submittal should include the following:

1. Completed application forms.
2. Narrative on project and submittal.
3. Hydrologic Computations (if applicable) along with digital files of computer models used.
4. Hydraulic Computations (if applicable) along with digital files of computer models used.
5. Certified topographic map with floodplain and floodway delineations.
6. Annotated FIRM to reflect changes due to project
7. Items required to satisfy any FEMA NFIP regulatory requirements.
8. Review fee payment if applicable.
9. Digital data

The procedures require that two separate analyses be performed to substantiate the impact to the water surface: 1) a step-backwater analysis and 2) a floodway conveyance analysis. In general, the step- backwater analysis involves developing a hydraulic model to reflect the post-project conditions. The post-project and existing conditions models are then compared in order to quantify any changes in the 1%-annual-chance base flood elevation resulting from the proposed project. The floodway conveyance analysis requires demonstrating the change in floodway limits using the cross- sections and 100-year encroached hydraulic data in the post-project model.

The methods proposed for use in this study were scoped out during a meeting in Missoula, Montana on May 15, 2012 and conference call with FEMA representatives on June 15, 2012. A procedures memorandum describing proposed methods for use in this study was provided to all attendees for comment on May 28, 2013. The procedures memorandum contains meeting minutes from the 2012 meetings and is included in this document as Appendix A. Clarifications regarding local floodplain regulations received from Missoula County were incorporated into the appropriate sections of this document. The methods proposed in the procedures memorandum were followed in this study with the exception of item 3 on page 4. Item 3 indicates that two separate hydraulic models would be developed. In the course of the modeling it was determined that a single multi-reach model with a junction would best reflect actual hydraulic conditions at the confluence of the CFR and BFR.

The overall approach to modeling the CFR and BFR was to develop a model that accurately reflects the post-project as-built conditions using conservative assumptions where appropriate. All assumptions made in developing the hydraulic model are explained in the following sections.

3.1 Hydrology

The original discharge values from the effective FIS were used as a starting point in this analysis. These values correspond to the flow magnitudes used in the original hydraulic modeling as evidenced in the HEC-2 card file. Over the effective FIS study reach, flows generally increase in a downstream direction with increasing drainage area and tributary confluences. Table 3-1 provides a summary of discharges from the effective FIS that were used for this study.

Table 3-1. Peak discharges used in LOMR analysis

River	Location	Drainage Area (sq mi)	Flood Frequency (Recurrence Interval) 10% (10-Yr)	2% (50-Yr)	1% (100-Yr)	0.2% (500-Yr)
Blackfoot River	At Gage #3400	2290	16800	22500	25000	31200
Clark Fork River	Above Blackfoot River	3668	15000	22500	26000	35500
Clark Fork River	*At Blackfoot River confluence**	*3668***	*31800**	*45000**	*51000**	*66700**
Clark Fork River	At Gage #3405 ab. Missoula	5999	27000	38200	42500	56000

* Coincident peak discharge is equal to sum of Blackfoot River at Gage #3400 and Clark Fork River Above Blackfoot River.

** Drainage area assumed same at confluence as 'Above Blackfoot River' drainage area reported in effective FIS.

In contrast to the non-coincident peak assumption used in the effective FIS, discharges for the CFR between the confluence with the BFR and the downstream tie-in point were assumed coincident and were calculated by adding the effective discharges for the BFR and CFR upstream of the confluence. The coincident discharge values are noted in Table 1 with an asterisk. The assumption that the peaks are coincident increases discharges at the confluence by up to 18% over the discharges used in the effective FIS (Table 3-2).

In order to determine Clark Fork River discharges for the effective FIS, a discharge-drainage area relationship was developed for Clark Fork drainage using the data from the four gages downstream of the study area. Three of the four gages used in the analysis have drainage areas that exceed two times the drainage area of the Clark Fork River at the confluence with the Blackfoot River. Development of the discharge predictions is documented in section 3.1 of the effective FIS (FEMA 1988).

Recent hydrologic analysis of long term gage data shows that discharges for the Blackfoot and CFRs are between 9% and 51% lower than those listed in the effective FIS (see Appendix B). At the downstream tie-in point, effective FIS cross-section DX, the CFR discharges revert to the discharges listed in the effective FIS which assumes that the flows are not coincident.

Table 3-2. Difference between peak discharges used in LOMR analysis and effective FIS

River	Location	Flood Frequency (Recurrence Interval)			
		10% (10-Yr)	2% (50-Yr)	1% (100-Yr)	0.2% (500-Yr)
Clark Fork River	At Blackfoot River confluence	4800	6800	8500	10700
Clark Fork River	At Blackfoot River confluence	16.3%	16.3%	18.2%	17.4%

3.2 Topography and Survey Data

The geometry for the post-project conditions hydraulic model was developed from a composition of multiple survey and terrain datasets as described herein.

3.2.1 Survey Horizontal Reference System and Vertical Datum

Elevations surveyed for this project are reported in North American Vertical Datum of 1988 (NAVD88). Horizontal and vertical reference system details are as follows:

- Horizontal: UTM with NAD83(CORS 96) datum, Zone 12, International Foot; Central Meridian 111d West
- Vertical: North American Vertical Datum of 1988 (NAVD88), US Foot
- Geoid Model: Geoid03

The primary control point used for GPS survey is NGS Cooperative Base Network Control Station RX0663 (DESIGNATION J 310). This point exceeds the minimum requirements for horizontal and vertical control as specified in FEMA Guidelines and Specification for Flood Hazard Mapping, Appendix A. The NGS data sheet for this point is provided in Appendix D.

3.2.2 Survey Data

Following dam removal and remediation, post-project site conditions were surveyed between 2009 and 2012 using various methods as described below. Additional surveys were conducted in 2011, 2012 and 2013 to collect water surface profile elevations that were used for hydraulic model calibration.

In 2009, 2010 and 2011 RDG surveyed the as-built site conditions as restoration construction progressed. Data collection included topographic survey of the constructed river channels and floodplain. RDG data collection efforts utilized a total station (Trimble 3303DR) with data collector and a survey-grade GPS (Trimble R8) system. RDG also established horizontal and vertical control benchmarks for use throughout the project area. In 2011, Light Detection and Ranging (LiDAR) data for the project area was collected by MT LiDAR. The LiDAR data quality report is included in Appendix D-5.

Cross-sections within the study area were re-surveyed near the locations of the original FEMA cross-sections in October and November 2012. Cross-sections that were re-surveyed are listed in Appendix D-5. Two additional cross-sections (RS 14370 and 15057) were surveyed on the Blackfoot River in the vicinity of bank erosion on MT Hwy 200 in October and November 2012. Survey-grade GPS (Trimble R8) and a total station (Trimble 3303DR) with data collector were used to complete the retracements.

The removal of Bonner Dam altered the river near FEMA cross-section N (Figure 3-1). In 2005, the superstructure of the dam was removed. In October and November 2012, cross-sections upstream and downstream of the former dam were re-surveyed capturing changes in the riverbed and banks that occurred subsequent to removal of the dam and remediation of the cooling pond. FEMA cross-section N, located near the remaining sill was not re-surveyed for safety reasons, and therefore, was not included in the LOMR hydraulic model. The remaining portions of the sill were removed in October and November 2013. The removal of the remainder of the sill was confined to the area upstream of FEMA cross-section M and downstream of O. As cross-section N was not included in the LOMR hydraulic model, the immediate effects of the removal will not affect the hydraulic analysis which was completed for the LOMR prior to removal of the sill.

Observations indicate that river adjustments resulting from higher flows following removal of the remaining portions of the Bonner Dam sill could include localized areas of bed degradation. These adjustments are unlikely to propagate upstream or downstream significantly due to the low height of the sill, the lack of stored sediment upstream of the sill, the existing coarse bed gradation, and the negligible effects of this work on the average reach-scale bed slope of the Blackfoot River. However, it is unknown whether future river adjustments resulting from higher flows following removal of the sill will affect the geometry of adjacent FEMA cross-sections, and how those adjustments will influence the revised water surface profiles.

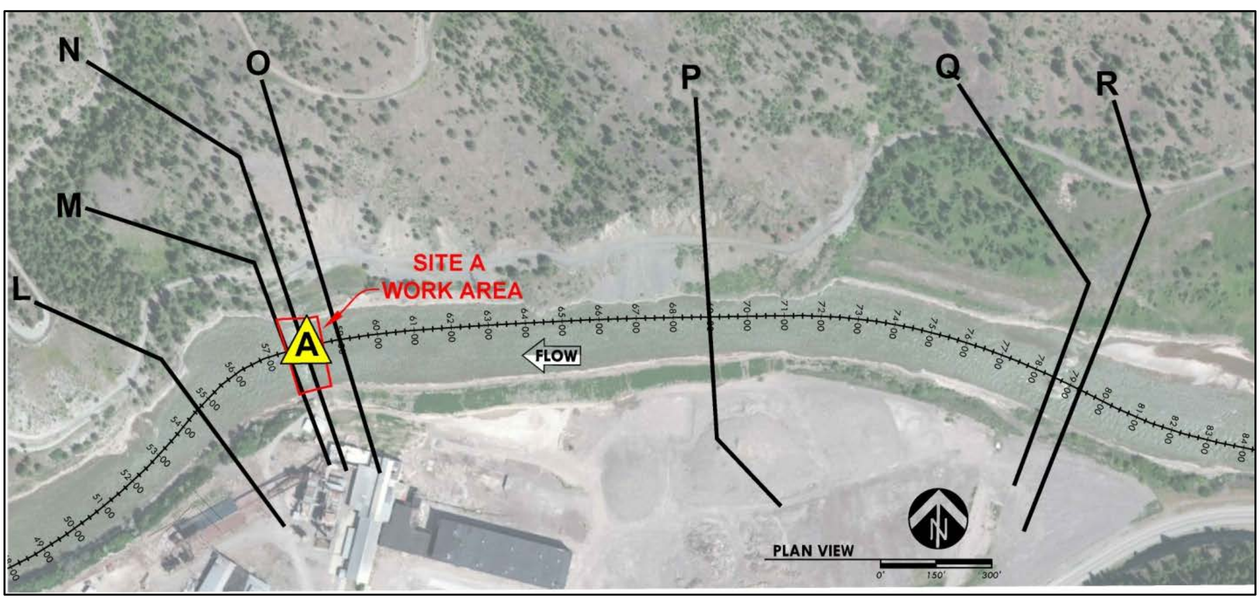


Figure 3-1. Location of Bonner Dam removal in relation to effective FEMA cross-sections.

There are five bridges located in the BFR reach modeled and one bridge in the CFR reach downstream of the confluence as discussed further in Section 3.3.4.4. Bridge superstructure and pier geometry was surveyed for all bridges in the project area except the two I-90 bridges. The center piers of the two I-90 bridges crossing the Blackfoot River which were retrofitted by USACE prior to the removal of Milltown Dam. As-built survey data from 2011 for the I-90 bridges crossing the Blackfoot River was provided by CH2MHILL. Cross-sections were surveyed in close proximity to the I-90 bridges to validate the retrofitted as-built condition and characterize the subsequent addition of riprap and center pier reinforcements.

In 2013 RDG surveyed additional cross-sections on the Blackfoot River near the confluence with the Clark Fork River. This survey was performed using single-beam hydroacoustic and topographic survey methods as described in the following section.

RDG integrated topographic, bathymetric and LiDAR surveys into a seamless terrain model of terrestrial bare earth and submerged bathymetry. Surveyed cross-sections were included in the LiDAR or as-built surface as 'ribbon surfaces'. Ribbon surfaces essentially represent a patch of bathymetric data outside of the contiguous bathymetric data extents. The ribbon surfaces were created by extending the survey points 25 feet upstream and downstream of the cross-section survey line. When viewed in plan form, this creates rectangular contours in the wetted portion of the channel where the topographic surface appears unnatural (Figure 3-2). Ribbon surfaces do not extend above the 1%-annual-chance WSEL to ensure that the floodplain boundary delineation only intersects the LiDAR or as-built portion of the topographic surface. The resulting elevation model of the project site allowed spatially-dense hydraulic modeling of post-project conditions. Summary tables identifying the source of data for each cross-section used in the study are provided in Appendix D-3.

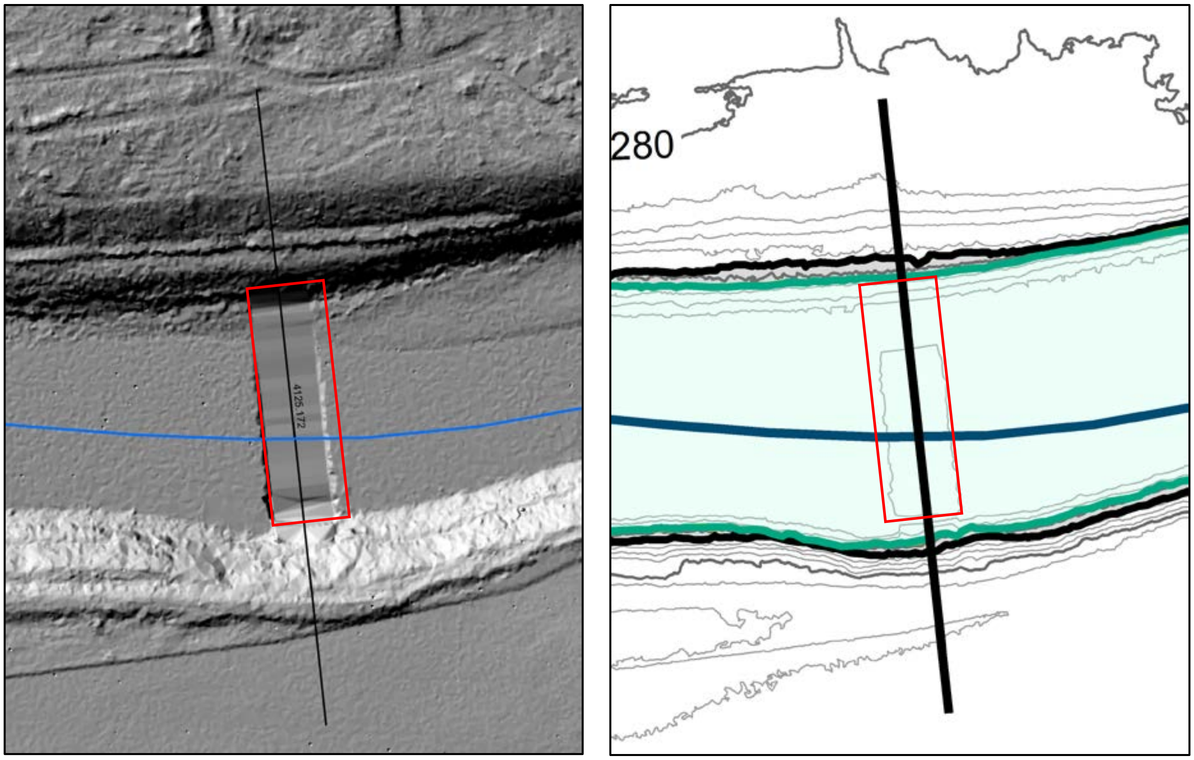


Figure 3-2. Example of LiDAR DEM hillshade (left) and contours (right) showing bathymetric patch ribbon surface outlined in red at BFR RS 4125.

3.2.3 Survey Field Operations

3.2.3.1 Topographic Data

Cross-sections points, topographic points and bridge structure elevations were collected using total station and survey-grade GPS equipment and RTK survey methods. GPS Receiver specifications are listed in Table 3. Cross-sections were surveyed across the active channel and up the river banks to tie in with the LiDAR or as-built surface. Bathymetric data was collected using hydrographic methods described below.

Table 3-3. GPS Receivers Specifications

Receiver	Serial Numbers	Antenna	Signals Tracked	RMS Accuracy
Trimble R8 Model 2	On File	Integrated	GPS LI & L2	H: +/- 10mm+1ppm V: +/- 20mm+1ppm

3.2.3.2 Hydrographic Data

Hydrographic data was collected using acoustic measurement techniques. Depth soundings were collected using a Seafloor Systems Sonarmite single-beam echo sounder with specifications listed in Table 3-4. To minimize errors in horizontal and vertical offsets, the GPS antenna was mounted directly above the echo sounder. GPS receiver elevations and water depth soundings were logged on Trimble Survey Controller 2 data collector using Trimble Access v1.9.

Table 3-4. Single-beam echo sounder specifications

Echo sounder	Serial Number	Transducer Freq. (kHz)	Beam Angle (deg.)	Depth Range (m)	Depth Accuracy (cm per % depth)
Seafloor Systems Milspec Sonarmite	SM16010712	200	4	0.3 to 75	1cm / 0.1% depth

3.2.4 Survey data processing and quality assurance

3.2.4.1 Topographic Data

Static GPS base station data was logged during RTK survey field operations and compared with CORS reference values to ensure accuracy of base station locations. GPS control point checks were performed to ensure integrity of elevation data. Topographic points not meeting vertical and horizontal thresholds were not utilized. Following the field effort all survey data was processed using Trimble Business center to check for Type I errors including instrument and rod height errors. The data files were reviewed manually to identify and remove any outliers during post-processing QA/QC review.

3.2.4.2 Hydrographic Data

Raw hydrographic data was filtered to remove points with depth values less than 1.0 ft for the Sonarmite echo sounder.. Corrections for sound velocity were made prior to survey. The depth values were then subtracted from the water surface elevation to generate the channel bed elevation points. The data files were reviewed manually to identify and remove any outliers.

3.2.5 Survey records

Field notebooks were maintained by each survey crew to track daily field operations and record pertinent information including sketches of bridge structures. Each field notebook is carefully prepared, identified, indexed, and preserved. Each notebook is numbered and marked with a brief description of the contents on the cover and each page is numbered. The first page used on each day of fieldwork is dated and lists the name of the survey crew members. Electronic field notes are archived and for GPS surveys, the survey control network is identified in each job report. Copies of the survey field notes for this project are included in Appendix D-1.

The survey control point used for this project (RX0663 as described above) is identified in Figure 1-3 and the maps in Appendix E.

3.3 Hydraulics

The following section describes the effective FEMA step-backwater model and the hydraulic models developed to represent post-project floodplain and floodway conditions.

3.3.1 Vertical Datum and Conversion Factors

Analysis for this project was performed and presented in the North American Vertical Datum of 1988 (NAVD88, Geoid03) to ensure consistency between flood elevations and the surveyed elevation data. Elevations presented in the effective FIS for Missoula County, Montana are provided in the National Geodetic Vertical Datum of 1929 (NGVD29). The NGVD29 datum is lower than the NAVD88 datum. Standard practice for FEMA flood studies is to develop an average conversion factor for each flooding source (FEMA 2010).

The US Army Corps of Engineers (USACE) computer program Corpscon6 (USACE 2004) was used to compute datum conversion factors within the study area. Corpscon6 employs the Vertcon program to convert orthometric heights between National Geodetic Vertical Datum of 1929 (NGVD29) and North American Vertical Datum of 1988 (NAVD88). To convert between NGVD29 and NAVD88 in the study area, there is an average datum shift of +3.50 feet for the BFR and +3.60 feet for the CFR (FEMA 2010). To insure consistency between flood elevations at the upstream and downstream tie-in points of the study extent, more precise conversion factors were utilized at select cross-section locations. A table of conversion factors for effective FIS cross-sections and Corpscon conversion reports are provided in Appendix D-4.

3.3.2 Current Effective Model

The effective FEMA flood hazard information for the BFR and CFR was first published in 1988 and is described in the Flood Insurance Study of Missoula County, Montana and Incorporated Areas (FEMA, 1988). The effective FIS is based on a 1979 study with HEC-2 card files available in scanned format. HEC-2 is a legacy computer software developed by the USACE that was used to calculate water surface profiles. HEC-2 card files contain the input variables and results necessary to replicate the original hydraulic modeling effort. The card files for the BFR and CFR are provided in Appendix F-4 and are being provided as a surrogate for the current effective models as previously described.

3.3.3 Duplicate Effective Model, Corrected Effective Model, and Pre-project Models

Duplicate Effective, Corrected Effective and Pre-project models are normally required for LOMR submittals. As previously described, due to the significant change in hydraulic characteristics of the study reach, it was agreed that these models would not be required for this submittal (see Appendix A-1, LOMR Procedures Memo, pg. 4, item 2). The hydraulic model submittal for this LOMR reflects only post-project conditions.

3.3.4 Post-Project Model

A new 1-dimensional steady-flow HEC-RAS model was developed for use in this LOMR analysis. The modeling program used for this evaluation was the Hydrologic Engineering Center River Analysis System (HEC-RAS), version 4.1.0, developed for the USACE (USACE 2009). A steady-state, subcritical, open-channel flow simulation was performed to model the BFR and CFR in the vicinity of Bonner, Montana. A single HEC-RAS model geometry file was developed with three reaches that represent the BFR and the CFR upstream and downstream of the confluence (CFR-US and CFR-DS). The HEC-GeoRAS utility, designed to be used as an extension of ArcGIS, was utilized for pre- and post-processing of geospatial data associated with the model (USACE 2012). The model was used to compute water surface profiles corresponding to the 10%, 2%, 1%, and 0.2%-annual-chance (10, 50, 100, and 500-year) floods, floodplain inundation limits for the 1% and 0.2%-annual-chance (100 and 500-year) events, and floodway boundaries for the 1%-annual-chance (100-year) flood. Model file names are listed in Appendix D-6 for reference.

3.3.4.1 Boundary Conditions

A fixed water surface boundary condition from the effective HEC-2 model was assigned at the downstream boundary on the CFR (FIS cross-section DW). The model was run under subcritical flow, and a fixed water surface elevation corresponding to the profile elevation in the effective FIS was specified for each flow profile evaluated. Elevations were converted from NGVD29 to NAVD88 at this location using the Corpscon program to ensure accuracy. The Corpscon conversion report is included in appendix D-4. The known water surface elevations taken from the effective FIS for the flows evaluated are listed in Table 3-5.

Table 3-5. Downstream boundary conditions used at Clark Fork River cross-section 962 (Effective FIS cross-section DW).

Flood Frequency (Recurrence Interval)	NAVD88 Downstream Boundary Elevation (ft)[1]
10% (10-Yr)	3231.20
2% (50-Yr)	3233.80
1% (100-Yr)	3234.75
0.2% (500-Yr)	3236.90

[1]The Vertcon vertical conversion factor from NGVD29 to NAVD88 for this location is 3.55 feet

3.3.4.2 Cross-sections

The Post-project Model geometry was developed using the best available topographic and river survey data through 2012 as described in section 3.2.2. A total of 45 surveyed cross-sections were used to represent the topography of the BFR and its floodplain. A total of 99 channel cross-sections were used to represent the topography of the CFR and its floodplain. The cross-sections were drawn to remain perpendicular to the expected flood flow lines for both small (10-yr, 50-yr) and large magnitude (100-yr, 500-yr) floods, sometimes requiring multiple inflection points. The cross-sections extend horizontally across the entire valley to capture the maximum potential inundation for 500-yr flood.

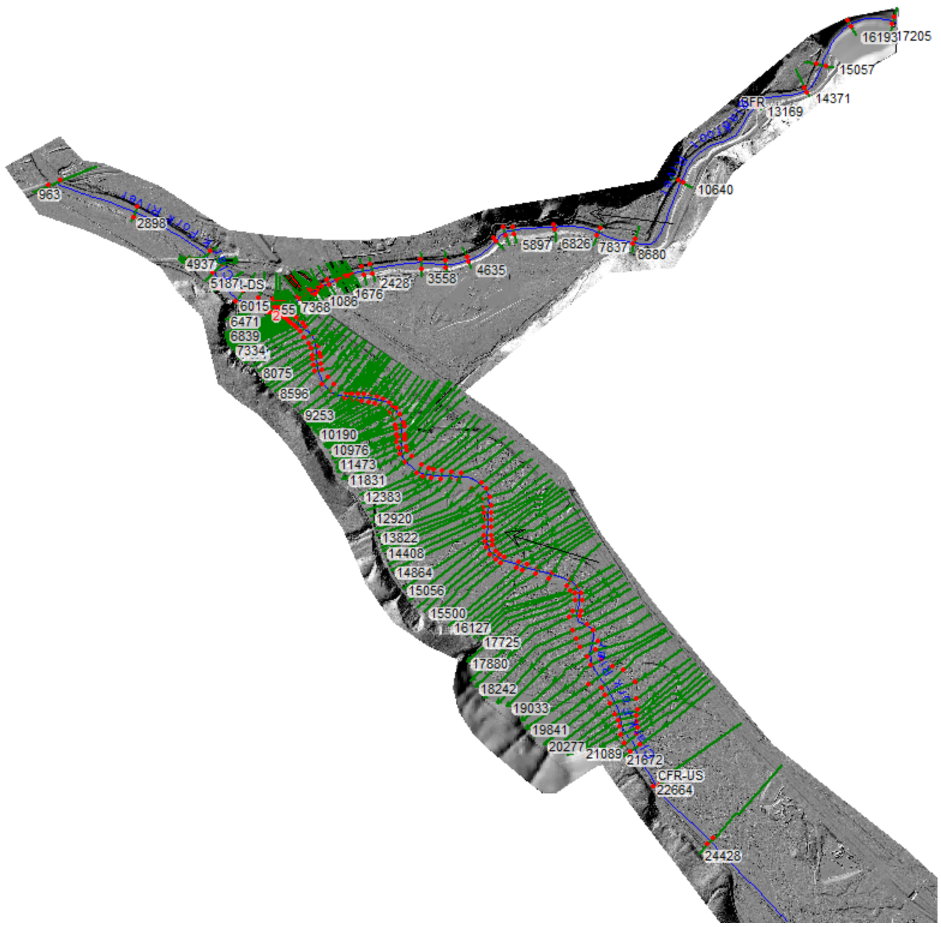


Figure 3-3. Plan-view layout of sections for Post-project model.

The cross-sections were sampled from an elevation model that was compiled from surveyed channel and floodplain elevation data, LiDAR floodplain elevation data, and USGS 10-m DEM floodplain elevation data as noted in Appendix D-3 The in-channel portion of all cross-sections were field surveyed as described above in Section 3.2.2. The surveyed channel data was merged with the floodplain elevation data to create a single terrain model (TIN) surface that represents the post-project conditions. Cross-sections were sampled from this surface using HEC-GeoRAS.

Distances between surveyed cross-sections for the BFR average approximately 382 feet with a maximum spacing of 2530 feet. Distances between surveyed cross-sections for the CFR average approximately 268 feet with a maximum spacing of 1763 feet. Cross-sections were interpolated in the calibration model geometry file in selected locations to allow calibration at points with observed water surface elevations. Spacing between cross-sections with and without the interpolated cross-sections are listed in Table 3-6. Interpolated cross-sections were removed from the model geometry used for the floodplain and floodway analysis to avoid conflicts between modeled and mapped floodway widths.

Table 3-6. Cross-section spacing

	Blackfoot River		Clark Fork River	
	Without Interpolated (ft)	With Interpolated (ft)	Without Interpolated (ft)	With Interpolated (ft)
Minimum	10.46	10.46	120.04	56.22
Maximum	2529.65	928.70	1763.72	992.22
Average	382.34	296.64	267.66	238.04

3.3.4.3 Junction

The BFR and CFR join together near Bonner, Montana. The post-project model reflects this confluence using a multi-reach model that joins together near the location of the former Milltown Dam. Cross-sections near the junction were split to best represent flow in the two rivers as it transitions to a single channel. Cross-sections locations in this area were chosen to ensure that the equal water surface elevation assumption used in the junction calculations would be accurate. Figure 3-4 shows the split in the sections separated by a lateral weir.

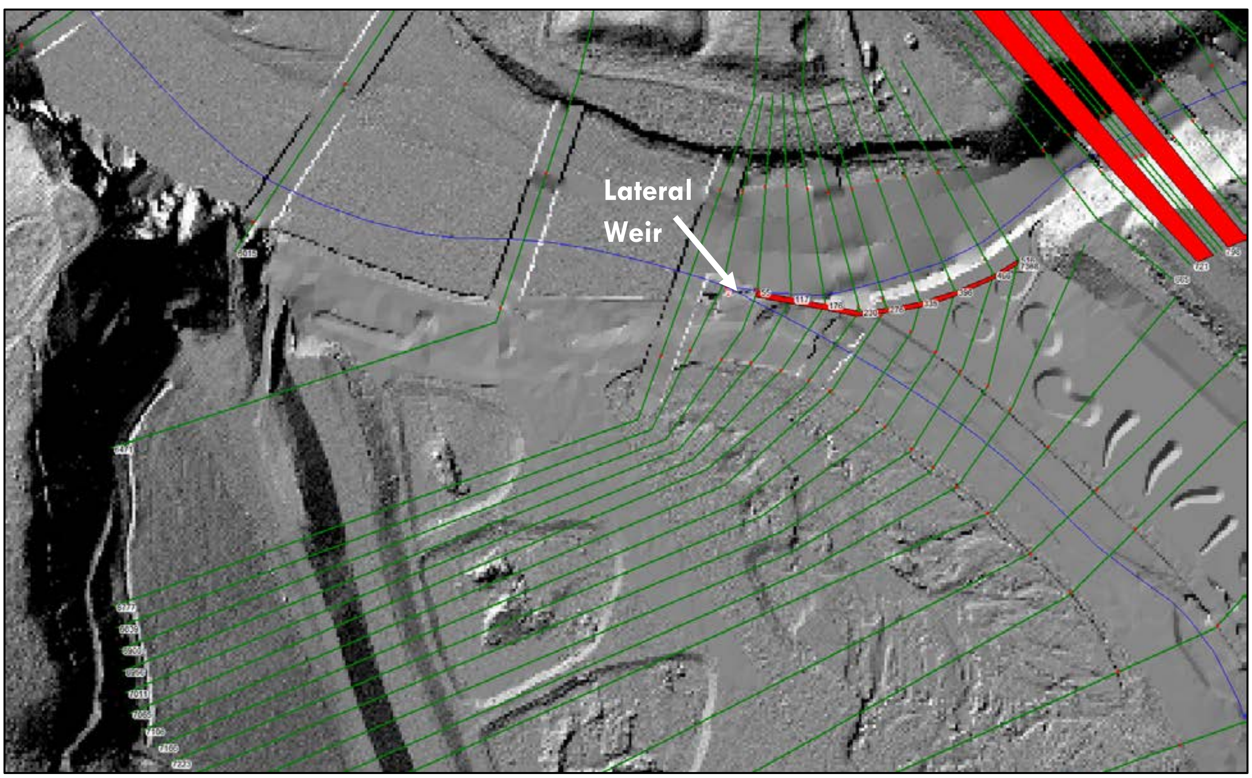


Figure 3-4. Plan-view layout of cross-sections and lateral weir in vicinity of junction.

Junction lengths were set to reflect the distance along the river centerline from the CFR cross-section downstream of the junction to next cross-section immediately upstream of the junction. Water surface elevations were calculated at the junction using the momentum option in the HEC-RAS junction editor. The momentum method option in HEC-RAS was tested and found to produce small improvements in the calibration results. Using the momentum method with an angle between the downstream reach of the CFR and the upstream reach of the Clark Fork of approximately 7 degrees produces a small difference in water surface elevation (+/- 0.1 ft) relative to the energy method. Using the momentum method with an angle between the BFR and downstream reach of the CFR of approximately 11 degrees produces an average difference in water surface elevation of approximately +0.5 feet with a maximum difference of +1.1 feet relative to the energy method. The momentum method of calculating water surface elevations at the junction was used for the analysis as it reproduced observed water surface elevation slightly better and produced a water surface profile that transitioned more smoothly through the bridges on the BFR.

Because the BFR and CFR confluence extends over a distance of approximately 500 feet, spans multiple cross-sections, and there is up to an 11 foot difference between the BFR and CFR channel invert elevations, it was necessary to add a lateral weir to balance water surface elevations through the confluence (Figures 3-4 and 4-3). The lateral weir structure extends 590 feet along the right bank of the CFR and allows flow to transfer between CFR cross-section 6899 to cross-section 7334 and BFR cross-section 55 to cross-section 516. Without the lateral weir, the model over predicts water surface elevations in the CFR and under predicts water surface elevations in the BFR near the junction. Lateral weir elevations were set at the elevation of the floodplain surface and do not project above the ground elevation. Flow between the adjacent cross-sections was balanced using the flow optimization option in the lateral structure editor. The weir coefficient controlling flow between the cross-sections was calibrated to minimize the difference between water surface elevations in adjacent cross-sections. A coefficient value of 0.8 was used to optimize the results for the 100-year profile (Figure 3-5).

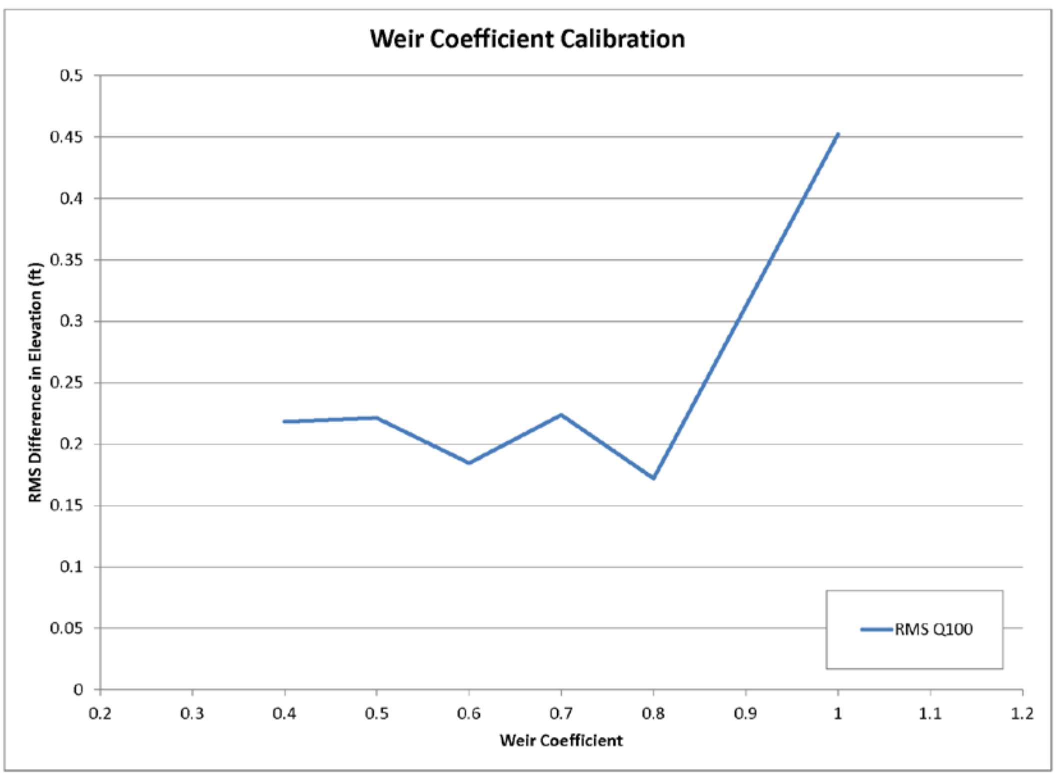


Figure 3-5. Weir coefficient calibration results.

3.3.4.4 Bridges

There are five bridges located in the BFR reach modeled and one bridge in the CFR reach downstream of the confluence (Figures 3-6 and 3-7). All bridges except the BFR I-90 bridges were modeled using the standard energy equation method to calculate energy losses through the bridge section. Conversely, the BFR I-90 bridges were modeled using the Yarnell equation option as it most closely approximated measured water surface elevations. The large center piers of the BFR I-90 bridges obstruct a considerable portion of the channel and cause an observable drop in water surface elevation at bankfull flow (Figure 3-8). The Yarnell equation is sensitive to the pier shape, pier obstructed area and velocity of water (USACE 2010). These factors appear to play the largest role in determining water surface elevations on the BFR in the vicinity of the I-90 bridges.

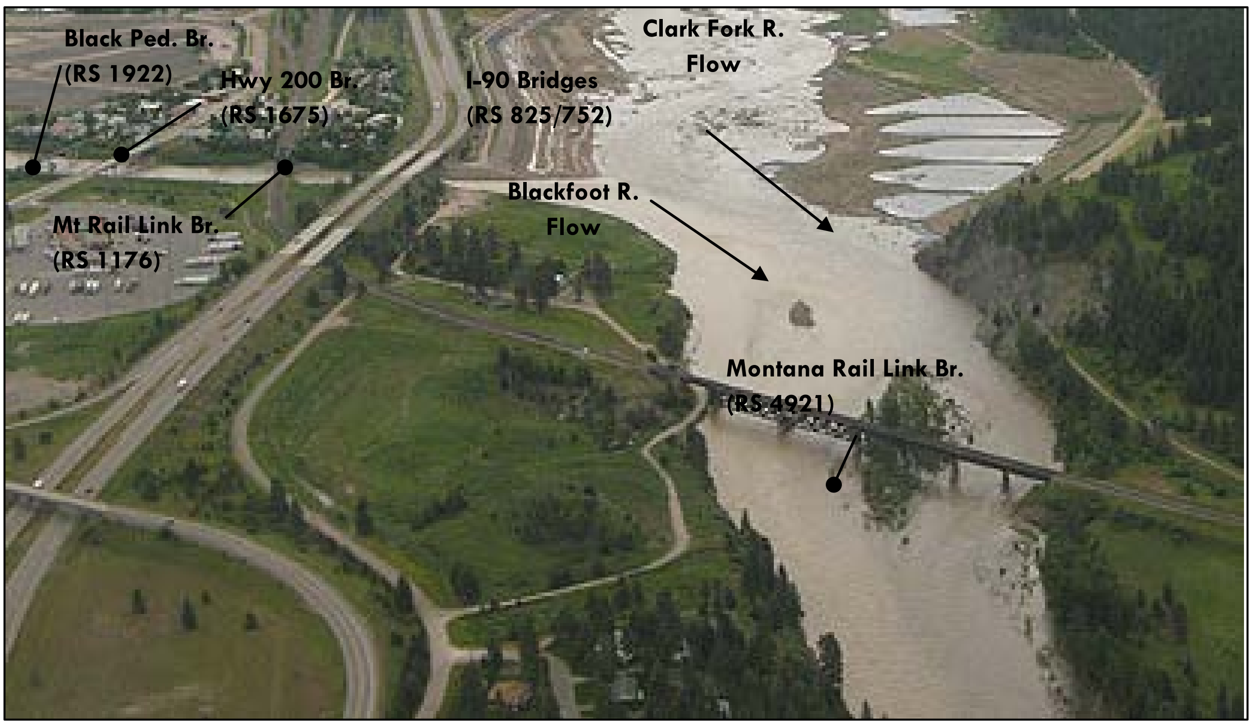


Figure 3-6. Bridge locations and HEC-RAS river stations.

Figure 3-7. View of five Blackfoot River bridges. Left photo looking upstream from confluence prior to completion of construction. Right photo looking downstream.

Figure 3-8. View of I-90 bridges and retrofitted center piers in Blackfoot River.

3.3.4.5 Ineffective Flow Areas

Ineffective flow areas (IFAs) were used for the CFR reach upstream of the junction to exclude conveyance from the portions of the constructed wetland ponds below floodplain elevation. The IFAs for the wetland ponds were set to permanent mode to prevent overestimation of conveyance area where cross-sections intersect wetland ponds. Bridge IFAs were set at high and low chord elevations upstream and downstream of bridge respectively. IFAs were added at the downstream end of the BFR between RS 55 and 516 to reflect hydraulic shadow of constriction of the I-90 Bridge embankment on the right bank of the BFR and smooth the transition to CFR floodplain.

3.3.4.6 Calibration

The hydraulic model was calibrated to match observed water surface elevation data as closely as possible while maintaining reasonable roughness values. Manning's n roughness values were back calculated from rating curves for three USGS gages: CFR at Turrah (Figure 3-9), CFR above Missoula (Figure 3-10), and BFR near Bonner (Figure 3-11). Piecewise linear fits were then used to interpolate roughness values for calibration and production run discharges (Figure 3-12).

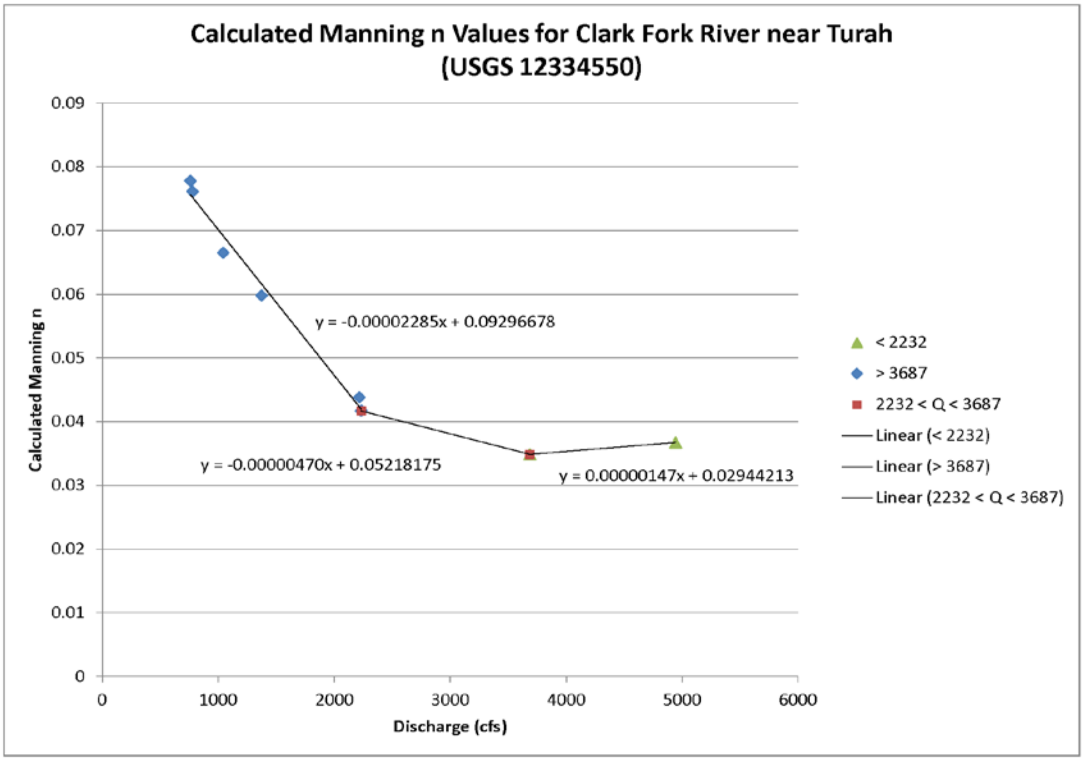


Figure 3-9. Manning n values calculated for USGS gage 12344550 Clark Fork River near Turah.

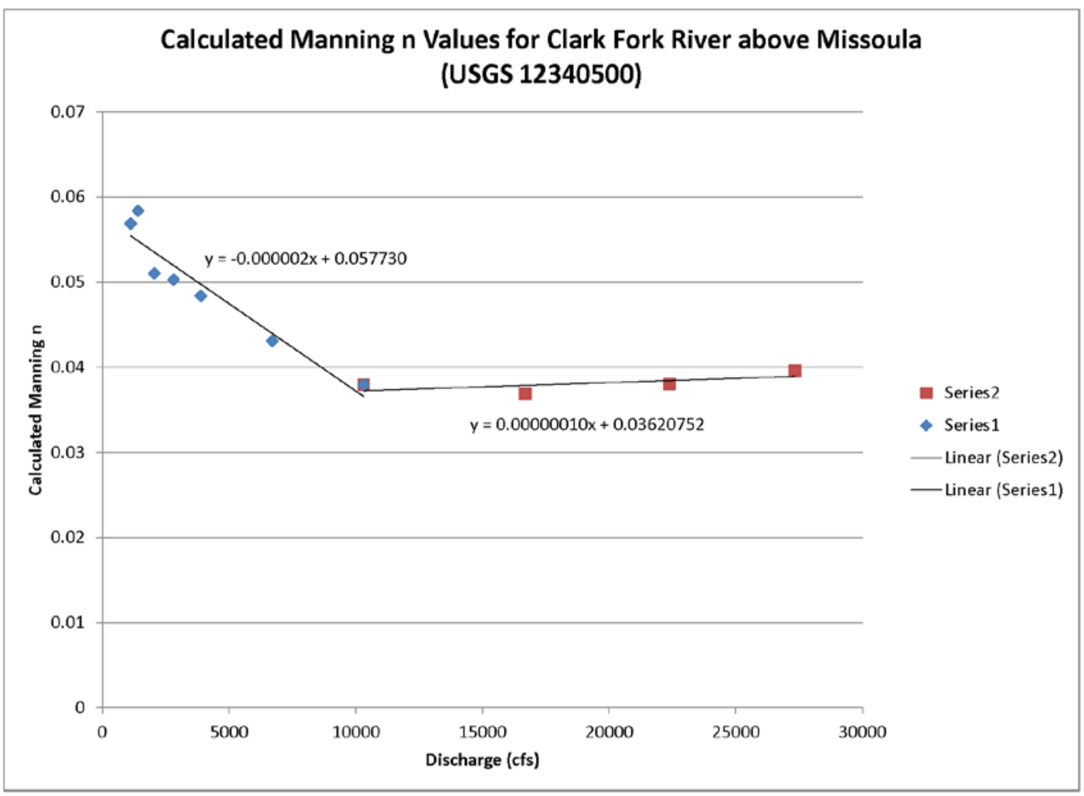


Figure 3-10. Manning n values calculated for USGS gage 12340500 Clark Fork River above Missoula.

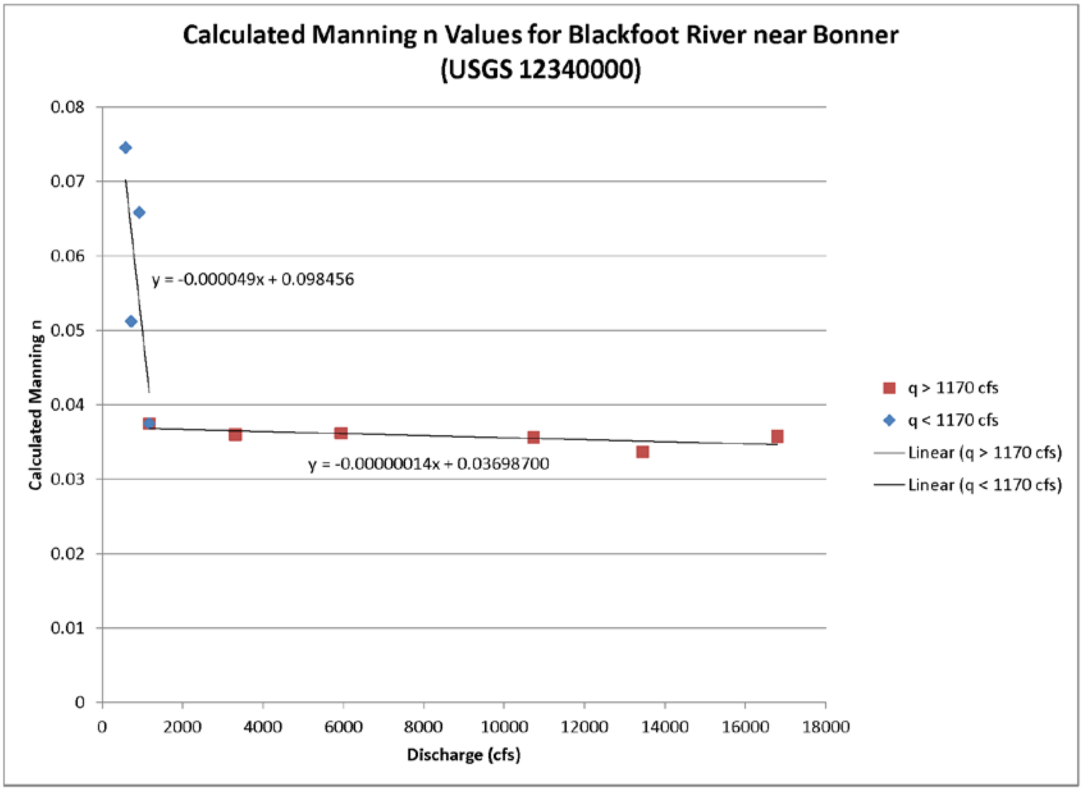


Figure 3-11. Manning n values calculated for USGS gage 12340000 Blackfoot River near Bonner.

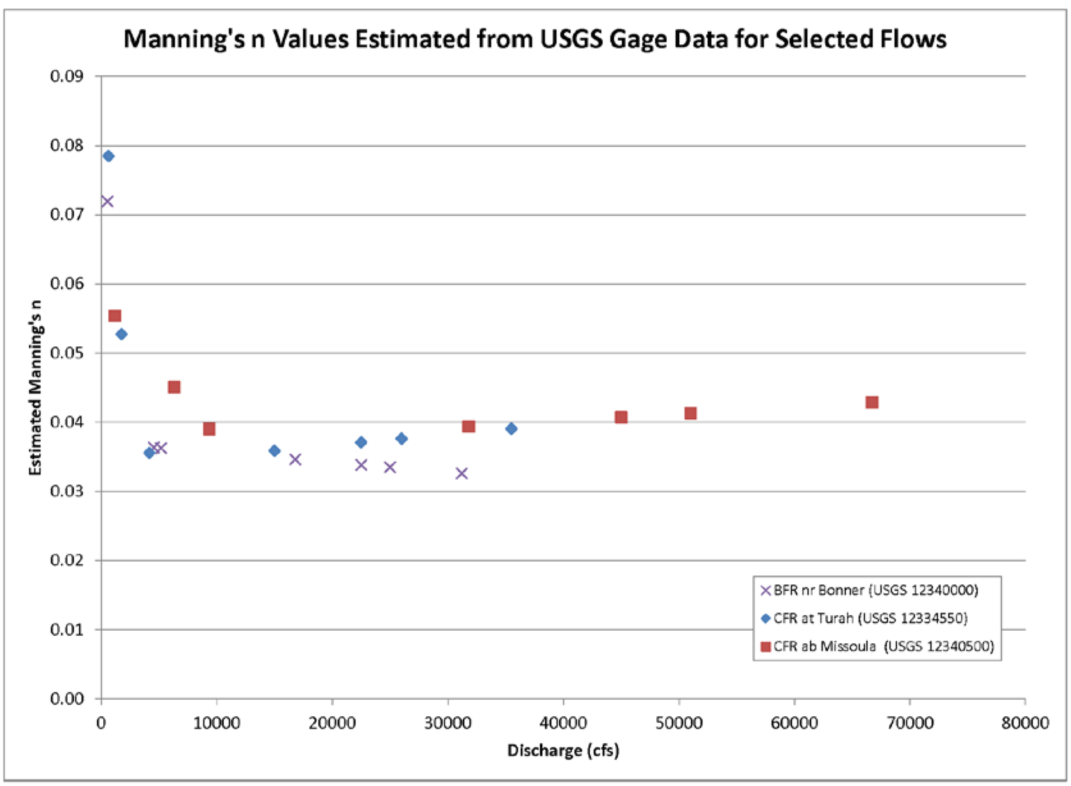


Figure 3-12. Manning n values estimated from USGS gage data.

Observed WSEL data was surveyed in 2011, 2012 and 2013 as described in section 3.2.2.2. Table 7 lists flows that correlate to the survey date which were used to calibrate the model. The 2011 and 2013 flows were both above bankfull stage on the Blackfoot River. The 2011 flow was above bankfull on the Clark Fork River.

Table 3-7. Calibration Flows

River	Location	RS	Event Date / Discharge (cfs)		
			7/13/2011	10/3/2012	6/7/2013
Blackfoot	Upstream of confluence	17205	5178	542	4561
Clark Fork	Upstream of confluence	24428	4167	634	1760
Clark Fork	Downstream of confluence[1]	6838	9345	1176	6321

[1]Flows at confluence of Blackfoot and Clark Fork rivers are considered coincident for purposes of this analysis (see section 3.1 above)

Manning n values were used to calibrate the model to match observed water surface elevation data surveyed in 2011, 2012 and 2013. Channel n values were calibrated to the observed data while maintaining overbank values as a percentage of the channel n value. Manning n values were held constant on the Blackfoot River through the bridges to RS 2220 which correlates to the higher hydraulic depth values shown in Figure 3-13 and corresponding calibration results in Figure 3-14. Manning n values were held constant on the Clark Fork River through the bridge up to RS 7586 which correlates to the spatial break in hydraulic depth values shown in Figure 3-15 and corresponding calibration results in Figure 3-16. The manning n values were normalized using a best fit curve to maintain reasonable values while minimizing error in the model. Manning n values used in the model are generally within the range of effective FIS model n values (Table 3-8). Lower n values in effective FIS model likely reflect reservoir effects modeled with low n values. The results of the calibration are presented in Appendix D-8.

Table 3-8. Comparison of Manning n Values from Effective FIS and LOMR

	Effective FIS		LOMR	
Flooding Source	Channel	Overbanks	Channel	Overbanks
Blackfoot River	0.032-0.042	0.045-0.060	0.030 - 0.045	0.050 - 0.062.
Clark Fork River	0.024-0.060	0.032-0.090	0.030 - 0.036	0.053 - 0.065

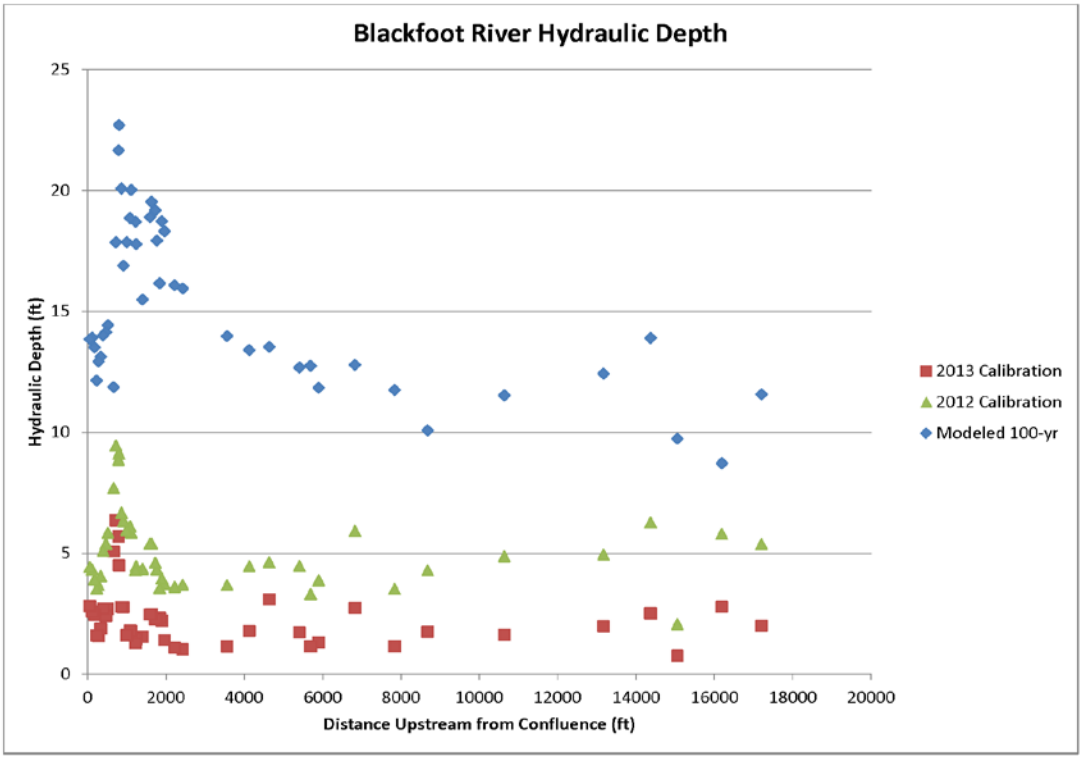


Figure 3-13. Hydraulic depth values for Blackfoot River.

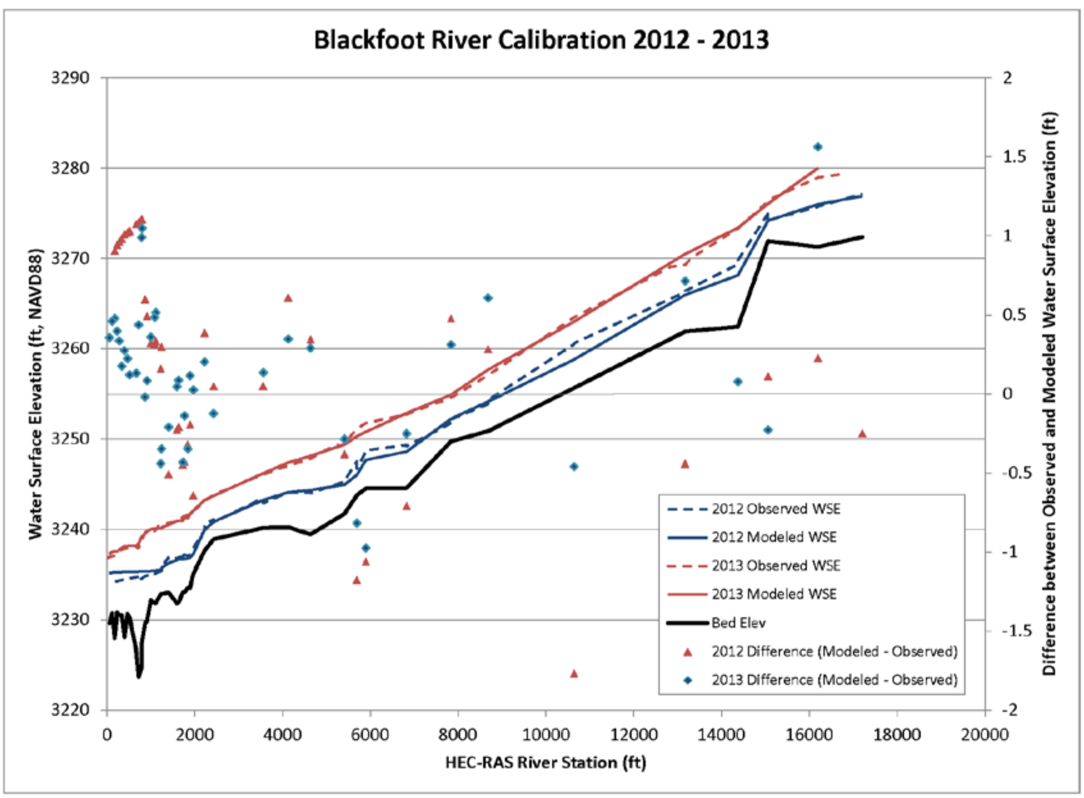


Figure 3-14. Calibration results for Blackfoot River.

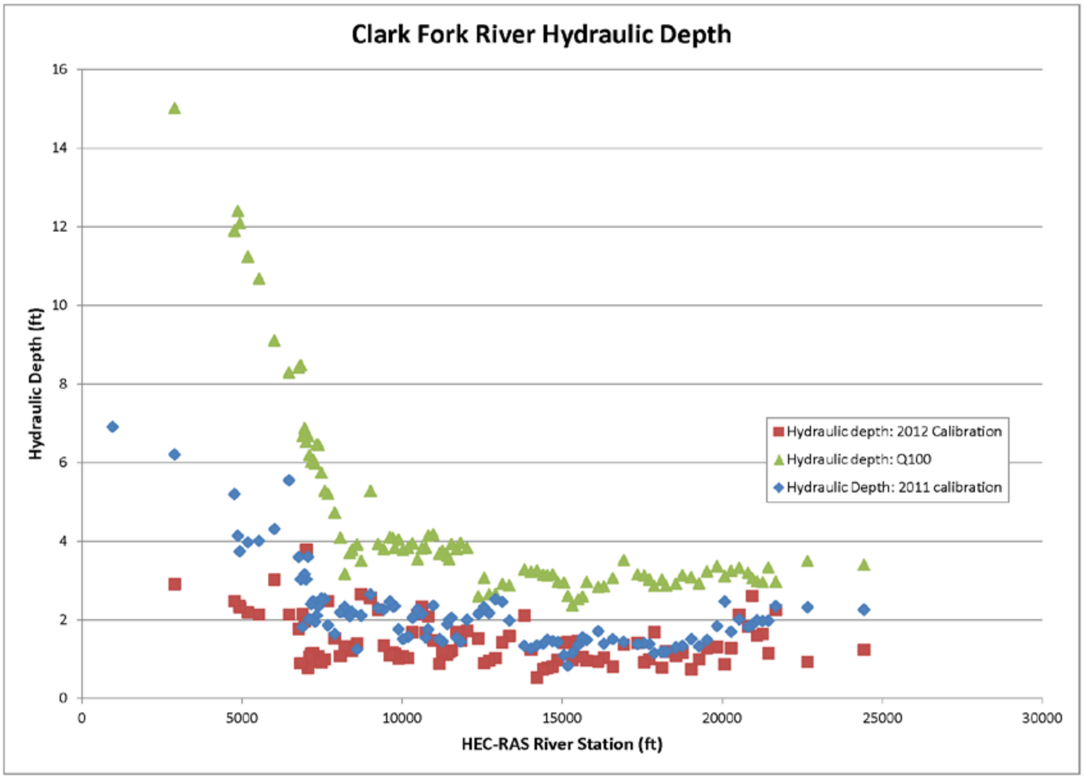


Figure 3-15. Hydraulic depth values for Clark Fork River.

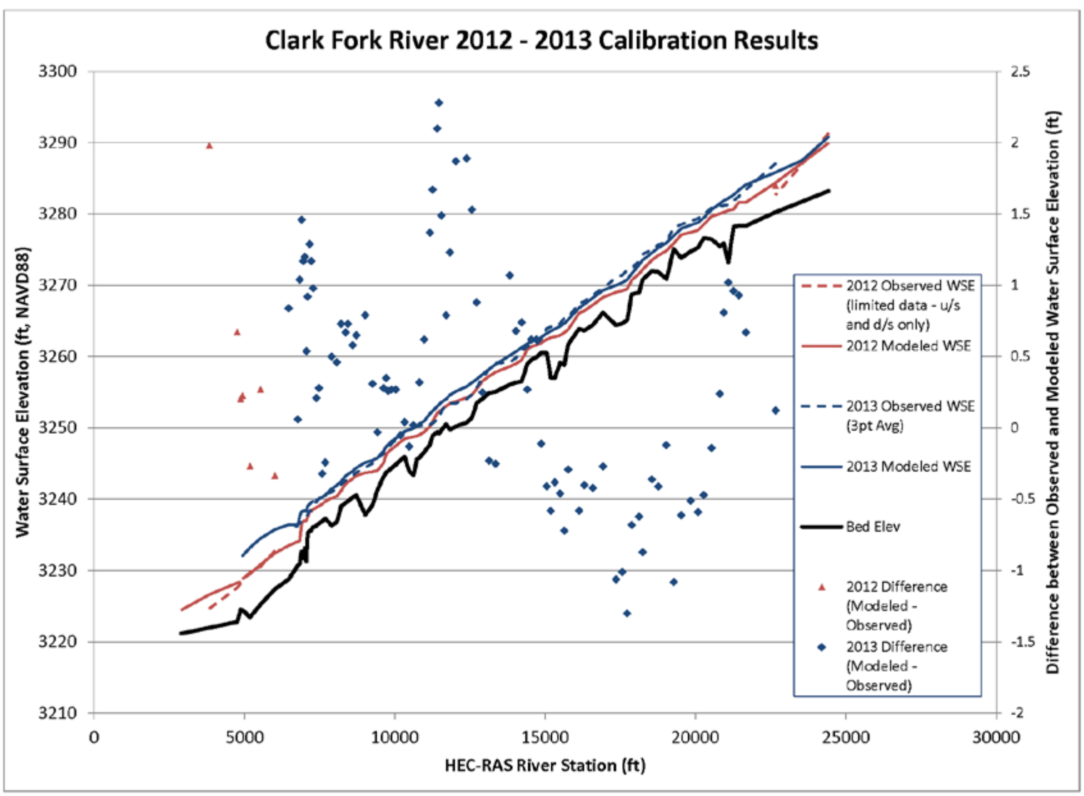


Figure 3-16. Calibration results for Clark Fork River.

3.3.4.7 Floodway Encroachment

An encroachment run was performed for the Post-Project Model, using encroachment method 4 in HEC-RAS 4.1.0, and then iterating using method 1 to attempt to match effective floodway stations in the effective FIRM near the upstream and downstream study limits. Encroachment method 4 was used initially in an attempt to maximize the conveyance relative to the un-encroached section without exceeding the 0.5 foot maximum rise allowable by the Missoula County (2004). Encroachment method 1 was then used to set the encroachment stations explicitly to track with geomorphic bank and terrace features. The floodway limits were then adjusted to smooth the floodway boundary. Results for the floodway encroachment runs are further described in Section 5.3 below.

3.4 Sediment Transport

The following section provides data related to sediment transport requested in the MT-2 Riverine Structures Form (MT-2 RS). The MT-2 RS defines 'channelization' as a structure type that requires specific data for processing of the LOMR.

Only minimal amounts of channel construction were completed for the BFR in the vicinity of the Bonner Dam and at the confluence. The in-channel work in the vicinity of Bonner Dam did not alter the overall dimensions of the channel and therefore is not expected to result in any changes to sediment transport through the remediation area. The confluence reach of the BFR downstream of the I-90 bridges was designed in conjunction with the CFR using methods described below.

The restoration of the CFR and its floodplain could be considered restoration and data is provided here as requested in section B of the MT2-RS form. The CFR bankfull channel was designed to maintain sediment transport continuity in the very coarse gravel to small cobble range. Specific sediment and debris loads in volumetric units of acre-feet are not available, nor is a definitive sediment transport rate in percent concentration by volume. However, the hydraulic geometry for the bankfull channel was sized to ensure transport rate continuity over the range of particle size classes present in the supply load. Methods used to design the channel are described below.

The design team used a combination of elements from several techniques that represent the best available methods for developing design criteria for restoration designs. As described in Section 3 of the Restoration Plan (NRDP 2005), analog, empirical, and analytical methods provided the basis for developing a range of design channel dimensions, and were used to predict the most probable cross-section, plan form and profile dimensions for the CFR and BFR. Multiple methods were used to complete the following analyses: a stable slope analysis; a critical velocity analysis; a hydraulic geometry assessment; a shear stress analysis; a sediment transport analysis; and a scour analysis. Details of these analyses and their results can be found in Appendix C of the Restoration Plan (NRDP 2005). The following sediment transport analysis methods were selected for their applicability to gravel bed rivers:

- Meyer-Peter and Müller (1948)
- Ackers and White (1973)

A scour analysis was completed for the proposed project reaches to evaluate general scour and bend scour using the following methods:

- U.S. Bureau of Reclamation (1984)
- Thorne (1997)
- Maynord (1996)
- U.S. Army Corps of Engineers (1994)

Final channel and floodplain lines and grades were determined through a trial and error process that included several iterations of channel stability analyses. The methods used to complete the channel stability analysis focused on refining the cross-section, plan form and profile dimensions until acceptable values were observed for each hydraulic parameter considered to influence the dynamic equilibrium of river hydraulics. Acceptable values were assumed to be a range of values that best achieved dynamic equilibrium among hydraulic parameters, anticipated sediment size and anticipated sediment supply.

4 RESULTS

4.1 Errors, Warnings, and Notes

For each plan evaluated in HEC-RAS, a summary of errors, warnings, and notes is produced. No errors were produced for the plans evaluated. The following warning messages were created. These warnings are usual and customary:

> *Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross-sections.*
>
> *Warning: The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than 0.7 or greater than 1.4. This may indicate the need for additional cross-sections.*
>
> *Warning: Divided flow computed for this cross-section.*

Additional warnings were generated for the BFR at RS: 752. The following warnings are acceptable as the final water surface profile at this cross-section is governed by backwater from the CFR:

> *Warning: The energy equation could not be balanced within the specified number of iterations. The program used critical depth for the water surface and continued on with the calculations.*
>
> *Warning: The flow regime calculated by the momentum equation shows class B flow. For the best solution, this profile should be run as a mixed flow problem.*
>
> *Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross-section. This may indicate the need for additional cross-sections.*
>
> *Warning: During the standard step iterations, when the assumed water surface was set equal to critical depth, the calculated water surface came back below critical depth. This indicates that there is not a valid subcritical answer. The program defaulted to critical depth.*
>
> *Warning: When the Manning's n value for the channel was composited, the computed n value was larger [smaller] than the largest [smallest] user entered n value. The n value has been set to the largest [smallest] entered value. The user may wish to examine this cross-section and enter a single n value for the entire channel.*

Additional warnings were generated at the confluence of the BFR (downstream of RS: 752) and the CFR (between RS 6899 and 7390) where cross-sections were drawn adjacent to each other. The following warning indicates that the cross-sections do not capture the flow, which is acceptable in this situation where the adjacent cross-section is connected with a lateral weir:

> *Warning: The cross-section end points had to be extended vertically for the computed water surface.*

4.2 Check-RAS

Each HEC-RAS model was run through CHECK-RAS v2.0.1 (FEMA 2012). CHECK-RAS is a program developed by FEMA that can be used to check the validity of input and output data from HEC-RAS. CHECK-RAS reports are included in Appendix D-6. Each message is addressed in the comments column. All messages generated are considered informational.

When reviewing the CHECK-RAS reports, messages are generated regarding length of overbank distances relative to channel distance. These messages result from use of cross-sections with one or more inflection points. Some cross-sections are concave/convex to accommodate side channels and other floodplain features. Downstream reach lengths have been checked and are set correctly. The following three messages refer to this situation and can be considered informational:

> *Message XS DT 01: Both the right overbank distance of rob and the left overbank distance of lob are longer than the channel distance of chl . Please review the creation of left overbank, channel and right overbank distances. The HEC-RAS geometry file may need to be recreated using a GIS program. Please resolve the differences among the distances.*
>
> *Message XS DT 02L: The Left overbank distance of lob is greater than the channel distance of chl by more than two times. The Left overbank distance may be in error. Please review the creation of left overbank, channel and right overbank distances. The HEC-RAS geometry file may need to be recreated using a GIS program. Please resolve the differences between the distances.*
>
> *Message XS DT 02R: The Right overbank distance of rob is greater than the channel distance of chl by more than two times. The Right overbank distance may be in error. Please review the creation of left overbank, channel and right overbank distances. The HEC-RAS geometry file may need to be recreated using a GIS program. Please resolve the differences between the distances.*

Messages were also generated for both the floodplain and floodway models regarding use of the junction option. Use of junction option is appropriate as flows at junction are considered coincident for purposes of this study. Junction lengths were checked are set correctly in junction editor. The momentum option is used as described in section 3.3.3.3. The following two messages refer to this situation and can be considered informational:

> *Message XS JT 01: The Junction option is used. For Flood Insurance Studies, this option should be used if the tributary and main stream can have coincident peaks. It is appropriate to use for approximate-studied streams; if the discharges at different time periods are known from the rainfall-runoff model; for loop analysis; and for unsteady flow analysis. The Junction should be removed if the above conditions are not satisfied. Refer to the Help section for information on how to remove a Junction. Sample XS JT 01 HEC-RAS files can be downloaded from http://www.fema.gov/library/viewR ecord.do?id=2300 under the Cross-section Check Data Sets section.*
>
> *Message XS JT 02: The name of the junction is $junctionname$. The length from the $riverreach1$ to the $riverreach2$ is equal to zero. Please insert the length across the junction in the Junction Data window in HEC-RAS if the junction can be considered.*

A message was generated for the floodway model regarding floodway discharges. Distribution of discharge at the confluence of the Clark Fork and Blackfoot River varies between BFR RS 55 - 466 and CFR RS 6899 - 7282. Flow between the adjacent cross-sections was balanced across the lateral weir using the flow optimization option in the lateral structure editor. The sum of discharges in adjacent cross-sections remains constant. See report section 3.3.3.3 for details. The following message refers to this situation and can be considered informational:

> *Message FW FD 01: The floodway discharge is not equal to the 1-percent-annualchance discharge. Please justify the use of different discharges for the 1- percent-annual-chance and floodway profiles.*

A message was generated for the floodway model regarding change in velocity head, conveyance ratio, depth ratio, top width ratio and channel length. Interpolated cross-sections were removed from floodway model to avoid mismatch between modeled and mapped encroachment stations. This results in a distance of 773 between BFR RS 4635 and the next cross-section upstream with a headloss of 0.6 feet. Coincidentally, this cross-section was surveyed at a wide and shallow location downstream of the scour pool located formed by the former Bonner dam resulting in a large change in top width and conveyance. This situation is not pathogenic to the floodway analysis. The following message refers to this situation and can be considered informational:

> *Message XS SP 01: Additional cross-sections may need to be added between River Station Up of $secnoup$ and River Station Dn of $secnodn$ because all of the following conditions are met for the 1%-annual-chance flood. 1.Change in HV > 0.5; 2.Conv_Ratio < 0.7 or Conv_Ratio > 1.4 ; 3.DEPTH Ratio < 0.9 or DEPTH Ratio > 1.1; 4.TOPWID Ratio < 0.5 or TOPWID Ratio > 2.0; 5.Length Chnl Up / 500 > 1.1. The HEC-RAS geometry file may need to be recreated using a GIS program.*

Additional messages were generated for the floodway model regarding encroachment methods in the vicinity of the bridges. Encroachment method 1 was specified for all model cross-sections. The following two messages that refer to this situation appear to be erroneous:

> *Message FW ST 01S2: This is Section 2 of a hydraulic structure. The Encroachment Method was not specified at this River Station. For Flood Insurance Studies, Encroachment Methods 4 and 1 should be used.*

> *Message FW ST 01S3: This is Section 3 of a hydraulic structure. The Encroachment Method was not specified at this River Station. For Flood Insurance Studies, Encroachment Methods 4 and 1 should be used.*

4.3 Water Surface Elevation Comparison

As would be expected, Post-Project modeled water surface elevations (WSELs) for the Clark Fork River show a significant reduction at and immediately upstream from the former Milltown Dam site as summarized in Figure 4-1. Upstream of the former reservoir, however, the WSELs are up to three feet higher than the effective profile. It appears that the river bed has aggraded up to three feet upstream of the impoundment over the course of three decades which is evidenced by the higher bed profile in this area. As an alternative explanation, it is possible that the thalweg of the effective FIS cross-sections EJ, EK, and EL may have been surveyed at geomorphic pool features. The regulatory water surface profiles converge to within 0.5' of the effective WSEL at Effective FIS cross-section EL (CFR RS 24429) which is further described in Section 5.2 below. Downstream from the former Milltown Dam, water surface elevations match reasonably well between the effective and post-project profiles.

Similar reductions in WSEL are evident on the BFR as shown in Figure 4-2. Tables comparing regulatory water surface elevations at the location of Effective FIS cross-sections and LOMR cross-sections are provided in Appendix D-9. The previous backwater extent on the BFR extended up to the former Bonner Dam location at BFR RS 5900. Following removal of the majority of Bonner Dam in 2005, a headcut propagated upstream to BFR RS 15000 (Epstein 2009). The difference in WSEL between the effective and revised profiles tapers to zero at RS 15057.

The downstream end of the BFR study reach is influenced by backwater from the CFR near the junction. The adjoining BFR and CFR cross sections were compared and the final flood profiles reflect the higher WSEL for each pair of adjacent cross sections (Figure 4-3). The extent of the backwater effect from the CFR extends up the BFR to the eastbound I-90 bridge at BFR RS 752.

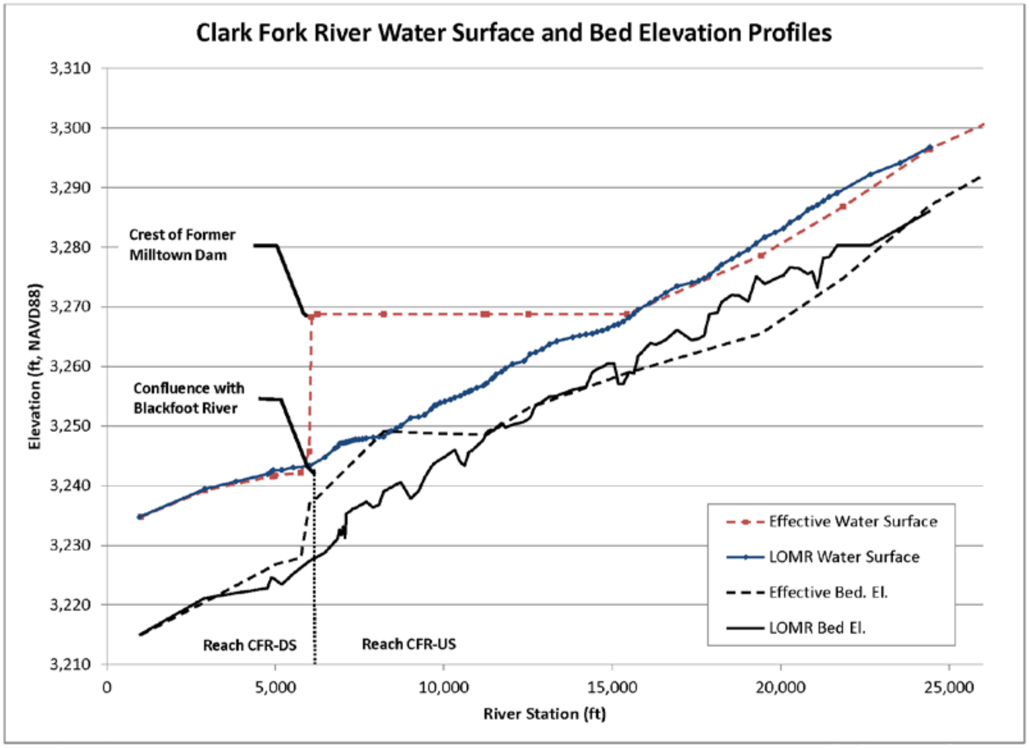


Figure 4-1. Comparison of Clark Fork River WSELs between Effective and Post-Project models. WSELs converge at upstream and downstream extents of study area.

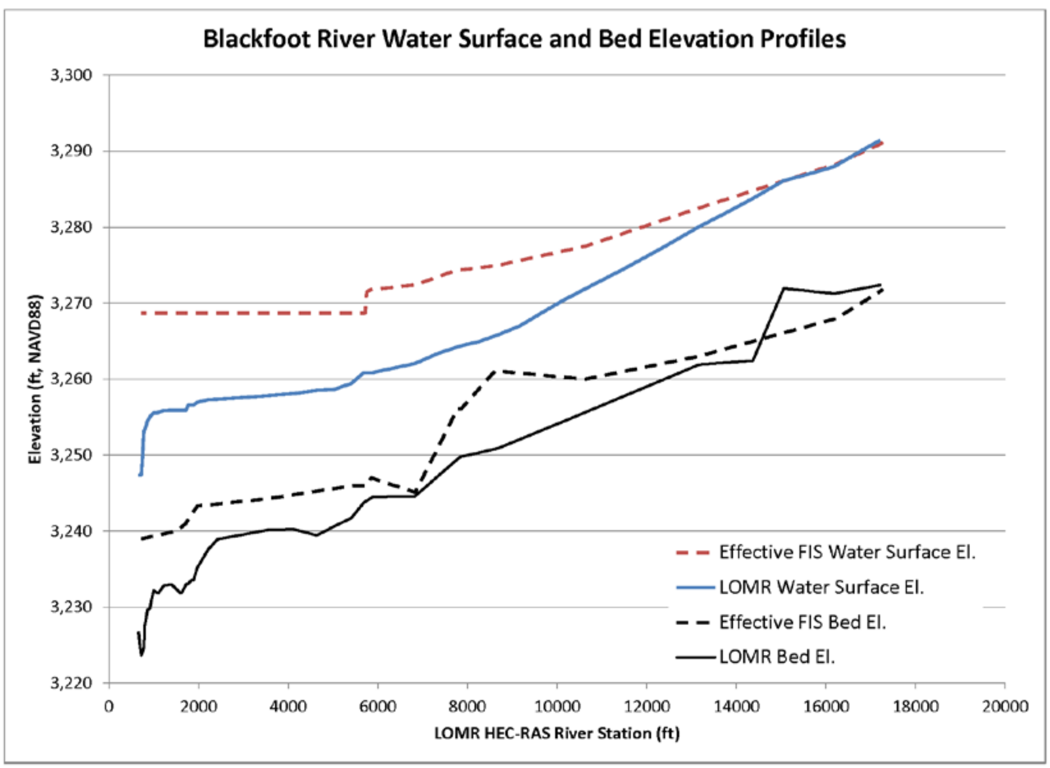


Figure 4-2. Comparison of Blackfoot River WSELS between Effective and Post-Project models. WSELs converge at upstream extents of study area.

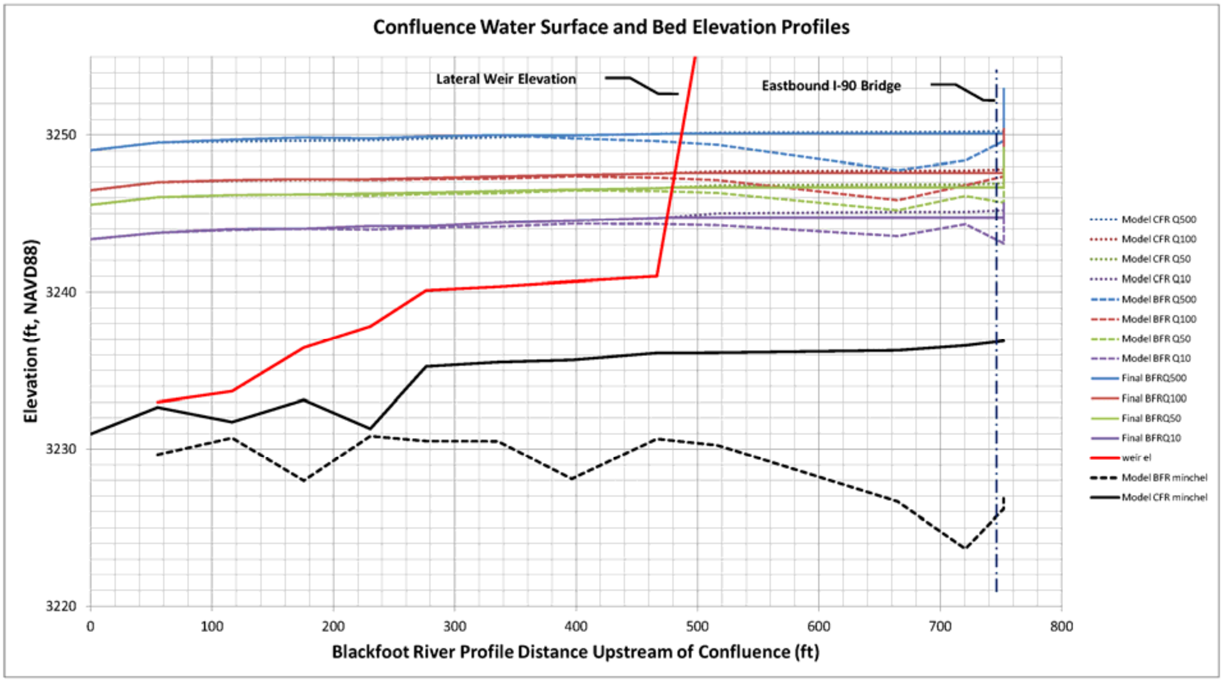


Figure 4-3. Comparison of Blackfoot River and Clark Fork River WSELS near confluence.

5 FLOODPLAIN MAPPING

5.1 Map Products

Maps of areas inundated by the 100-yr base flood and the 500-yr flood were created concurrent with the Hydraulic Analysis. ArcGIS software was used to create the inundation maps, which are illustrated over a certified topographic map and overlain on the effective FIRM's.

The maps include the stream centerlines, the HEC-RAS cross-sections, base flood elevation (BFE) contours, the 1% chance annual floodplain, and the 0.2% chance annual floodplain. Of the 145 cross sections used in the CFR/BFR model, 55 cross sections are not lettered to eliminate overly dense cross sections from appearing on the final FIRM. BFE lines were created using FEMA Guidelines and Specifications, Appendix C, Section C.6.6 (FEMA 2009).

One set of maps is shown overlain on a certified topographic map, and one set of maps is shown annotated on the effective FIRM panels received from FEMA. A third set of maps shows the tax lots and owner of record based on Missoula County tax assessor information. PLSS grid lines shown on all maps are from the Montana PLSS Map Service (Montana State Library 2010). The maps are included in Appendix E.

An internal audit of the floodplain boundaries using procedures suggested in the FEMA Floodplain Boundary Standard Audit Procedures Version 2.0 (FEMA 2007)found that 95% of the valid comparison points met the accuracy standard of less than +/- 1.0 foot difference between the regulatory flood and ground elevations. A shapefile of audit points tested (TEST_PTS_STUDYX .shp) are included in Appendix F-10 GIS Data.

5.2 Tie-In between New Mapping and Effective Mapping

The upstream and downstream ends of the CFR study reach tie into the effective reach of the CFR, which is Zone AE with mapped floodway. The revised regulatory WSELs at the upstream and downstream ends of the CFR study reach tie match effective FIS cross section elevations within 0.5 feet (Table 5-1).

Table 5-1. Clark Fork River Difference in Regulatory Water Surface Elevation Between Effective FEMA and LOMR Profiles at Tie-in Points

LOMR Data			Effective Data			Difference in Elev.
Cross-section	River Station (ft)	Regulatory Elev. (ft, NAVD88)	Cross-section	Distance (ft)	Regulatory Elev. (ft, NAVD88)	(ft)
DX	24428	3296.77	DX	228397	3296.50 [1]	0.27
GA	2898	3239.43	EL	249227	3239.20 [2]	0.23

[1]The Vertcon vertical conversion factor from NGVD29 to NAVD88 for this location is 3.55 feet.
[2]The Vertcon vertical conversion factor from NGVD29 to NAVD88 for this location is 3.53 feet.

The recommended tie-in point for the upstream end of the BFR is located at RS 15057 which is located 1136 feet downstream of effective cross section V (Figure 5-1). The difference in elevation between the LOMR model and the interpolated effective FIS elevation is 0.02 feet at this point (Table 5-2). This is also the upstream limit of LiDAR topographic data available for the BFR reach. The model was extended upstream about 2500 feet to effective cross section W using surveyed cross sections coupled with USGS 10-m DEM floodplain elevation data shown in Figure 5-1 as a dashed black line.

The difference in WSEL between the effective FIS and LOMR model for the BFR is less than 0.5 from RS 15057 upstream to 17205. Given the coarseness of the 10-m DEM elevation data, it is recommended that floodplain mapping not be completed for this area until finer resolution topographic data is available. It is recommended that profile distances for effective cross sections V and W (LOMR cross sections AF and AG) are revised to reflect the new centerline shown in figure 5-1 as the effective centerline intersects the right bank downstream of cross section W.

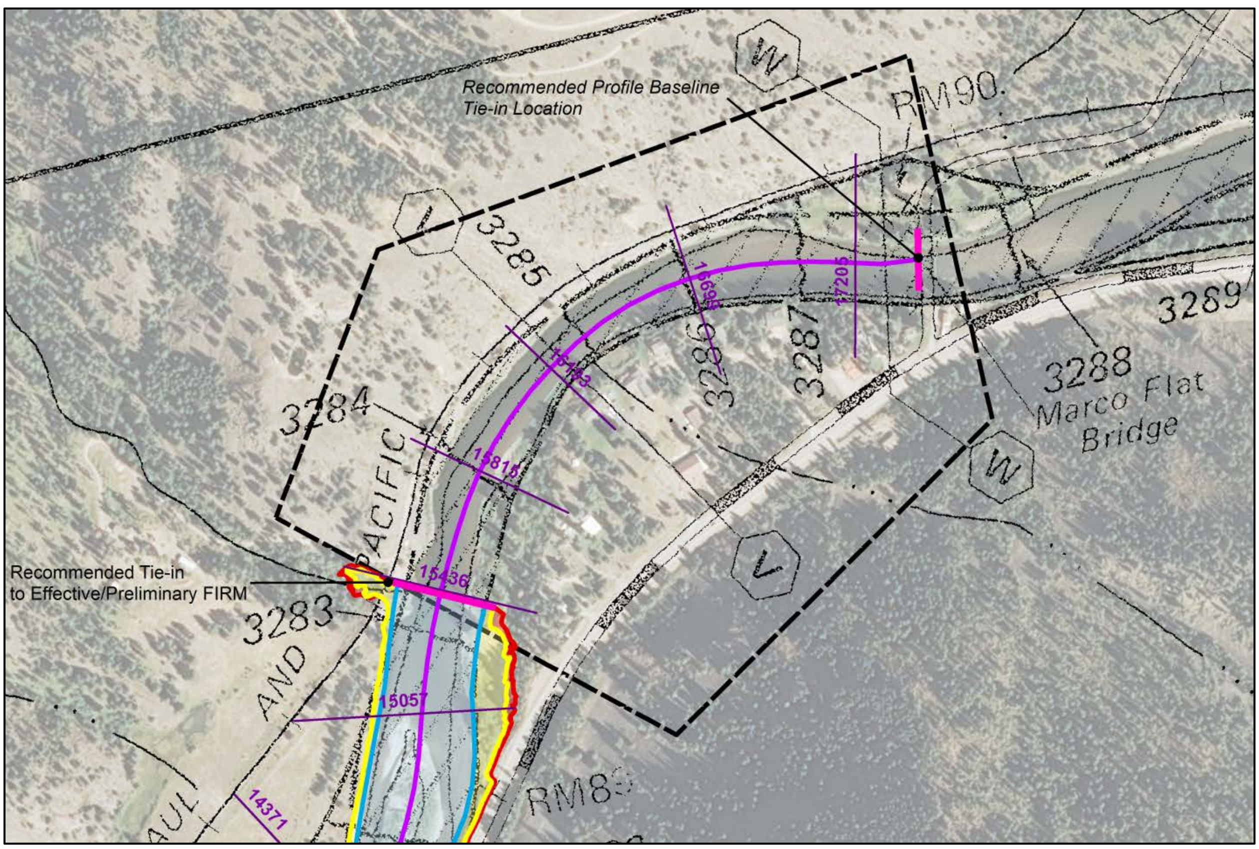


Figure 5-1. Recommended tie-in location at upstream end of Blackfoot River (2011 aerial photo with effective FIRM superimposed and USGS 10-m DEM elevation data outlined with a dashed black line).

Table 5-2. Blackfoot River Difference in Regulatory Water Surface Elevation Between Effective FEMA and LOMR Profiles at Tie-in Points

LOMR Data			Effective Data			Difference in Elev.
Cross-section	**River Station** (ft)	**Regulatory Elev.** (ft, NAVD88)	**Cross-section**	**Distance** (ft)	**Regulatory Elev.** (ft, NAVD88)	(ft)
AE	15057	3,286.08	N/L	14,571	3,286.10 [1]	0.02
AG	17205	3,291.40	W	16,748	3,290.90 [1]	0.50

[1]The Vertcon vertical conversion factor from NGVD29 to NAVD88 for this location is 3.55 feet.

5.3 Floodway Mapping

An encroachment run was performed on the post-project model to re-evaluate the regulatory floodway post-project. The encroachment run was performed for the Post-Project Model, using encroachment method 4 in HEC-RAS 4.1.0, and iterating using Method 1 to attempt to match floodway boundary locations shown in the effective FIRM where possible. Note that extensive modification within the effective floodway occurred during the project, making identical replication of the previous floodway results impractical.

Negative surcharge values occurred at several locations in the floodway run. Attempts to eliminate the negative values resulted in floodway boundaries that did not meet the smoothness criteria required to pass the Check-RAS floodway review. Negative surcharge values were minimized to the extent possible. Table 5-3 lists cross-sections with negative surcharge values.

Table 5-3. Negative surcharge values

Reach	River Station (ft)	Surcharge value (ft)
BFR	7837	-0.01
BFR	6826	-0.02
CFR-US	9778	-0.03

The cross-section on the Clark Fork River with a negative surcharge value is shown as 'N/L', or not lettered on the workmap. An exception is requested to allow the Blackfoot River cross-sections with negative surcharge values to be shown on the FIRM. Showing these sections as not lettered would result in a distance of 2782 feet with no cross-section on the Blackfoot River profile and workmap. It is recommended that the surcharge values for these sections be rounded to 0.0 as shown in the proposed floodway data table in Appendix D-11 .

6 FLOOD INSURANCE STUDY REPORT

6.1 Recommended FIS Text

6.1.1 Blackfoot River

The cross-section data for the Blackfoot River was taken from field surveys and topographic mapping prepared by River Design Group, Inc. Revised water-surface elevations for floods of selected recurrence intervals were computed using HEC-RAS 4.1.0. The 100-year floodplain boundary was delineated using water-surface elevation determined at each modeled cross-section. Between cross-sections, the 100-year floodplain was interpolated using topographic mapping at a scale of 1:2,400, with contour intervals of 4 feet.

Channel and overbank roughness factors (Manning's "n") used in the hydraulic analyses were based on engineering judgment. The channel roughness factors used to model the Blackfoot River ranged from 0.030 to 0.045 and overbank roughness factors range from 0.050 to 0.062.

6.1.2 Clark Fork River

The cross-section data for the Clark Fork River was taken from field surveys and topographic mapping prepared by River Design Group, Inc. Revised water-surface elevations for floods of selected recurrence intervals were computed using HEC-RAS 4.1.0. The 100-year floodplain boundary was delineated using water-surface elevation determined at each modeled cross-section. Between cross-sections, the 100-year floodplain was interpolated using topographic mapping at a scale of 1:2,400, with contour intervals of 4 feet.

Channel and overbank roughness factors (Manning's "n") used in the hydraulic analyses were based on engineering judgment. The channel roughness factors used to model the Clark Fork River ranged from 0.030 to 0.036 and overbank roughness factors range from 0.053 to 0.065.

6.2 Revised Flood Profiles

Revised flood profiles were generated using the FEMA computer program RASPLOT v3.0 (FEMA 2013) to illustrate the 10-, 50-, 100-, and 500-year water surface elevations. Revised flood profiles for the Blackfoot River and Clark Fork River study reaches are provided in Appendix D-10. Data used to generate the profiles is included in electronic format in Appendix F-4, Hydraulic Computations.

6.3 Revised Floodway Data Tables

Revised floodway data tables were generated using the FEMA computer program RASPLOT v3.0 (FEMA 2013). Revised floodway data tables for the Blackfoot River and Clark Fork River study reaches are included in Appendix E-11. The data tables provide regulatory water surface elevations and increases in elevation resulting from floodway surcharge. Data used to generate the floodway data tables is included in electronic format in Appendix F-4, Hydraulic Computations.

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