Hydraulic Analysis Report

Junction Creek Detailed Floodplain Study
Beaverhead County, MT

August 2018

Contract Number: WO-MM-155
Mapping Activity Statement No. 2016-01

Junction Creek Detailed Floodplain Study

Hydraulic Analysis Report

Beaverhead County, Montana

PREPARED FOR:

Montana Department of Natural Resources and Conservation

Federal Emergency Management Agency

August 17, 2018

PREPARD BY:

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I hereby certify that all work products (maps, reports, etc.) prepared for this project were done so under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

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1.0 Introduction and Background

Morrison-Maierle has completed the hydraulic analysis of Junction Creek within Beaverhead County, Montana, as part of the Mapping Activity Statement (MAS) 2016-1 Beaverhead County Modernization Project, Phase II (FEMA 2016d). This Flood Risk Project was initiated by the Montana Department of Natural Resources and Conservation (DNRC) in partnership with the Federal Emergency Management Agency (FEMA). The purpose of this report is to document the hydraulic analysis and to provide results for incorporation into floodplain mapping and a Flood Insurance Study (FIS).

The study includes varying Study Levels. Junction Creek is an Enhanced Analysis study and includes a floodway. Alder Creek, Gleed Ditch, and Junction Creek Overflow are Enhanced Analysis studies without a floodway (FEMA 2016b).

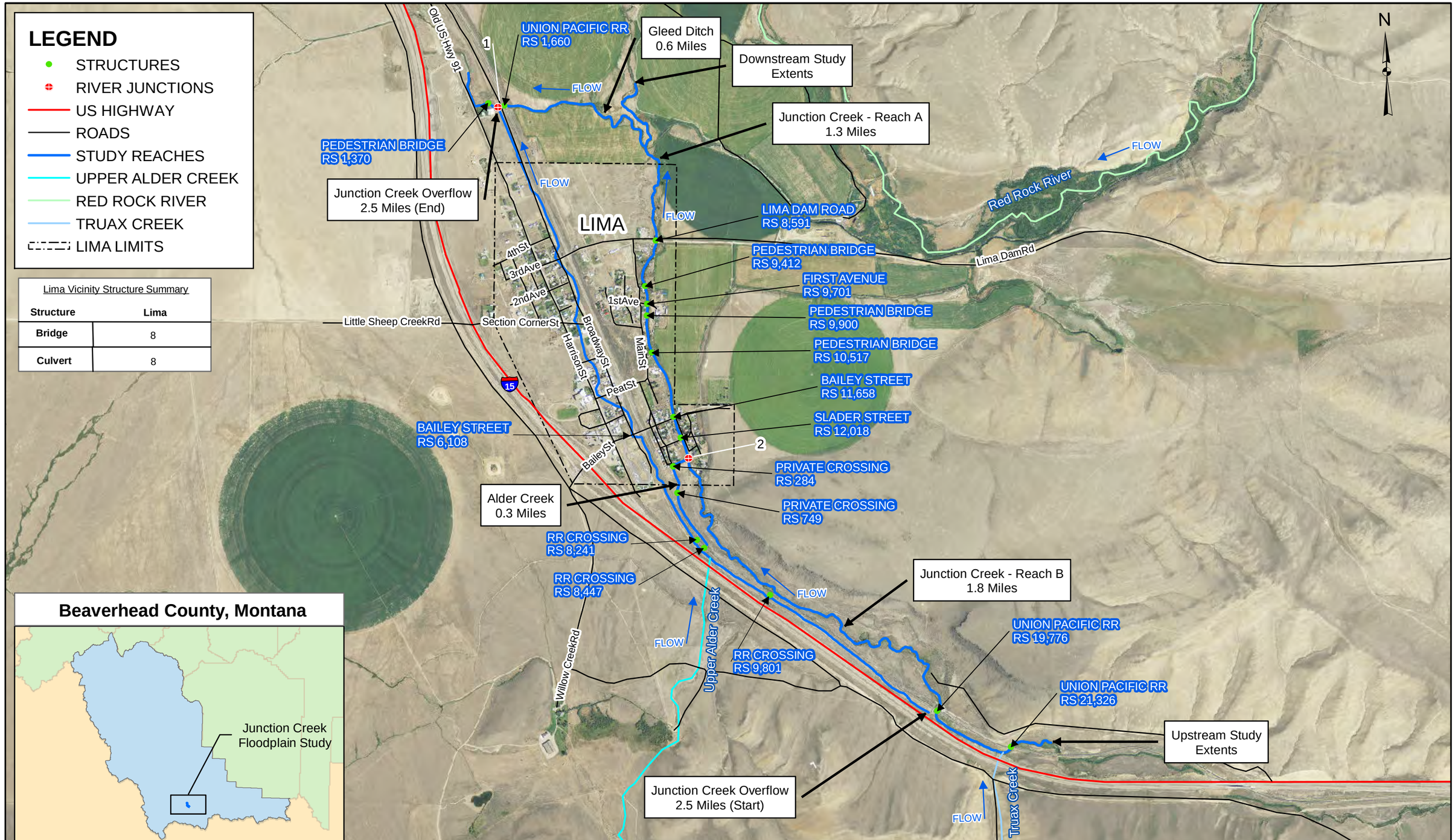
1.1 Study Limits

The study limits, as shown on Figure 1, consists of three segments through the town of Lima, Montana and one segment north of the town of Lima along Gleed Ditch. Junction Creek is the primary segment. Three split flow segments consisting of Junction Creek Overflow, Alder Creek and the Gleed Ditch occur within the floodplain study limits. The lengths of each segment are summarized below in Table 1.

Table 1: Study Reach Segments

No.	Segment	Reach Length (miles)	Total Length (miles)
1	Junction Creek Reach A	1.3	3.1
	Junction Creek Reach B	1.8	
2	Junction Creek Overflow	2.5	2.5
3	Alder Creek	0.3	0.3
4	Gleed Ditch	0.6	0.6
Total			6.5

This Hydraulic Summary Report presents the information and methods used to develop the one-percent-annual-chance (100-year) and 0.2-percent-annual-chance (500-year) floodplains. This study is based on the best available information including LiDAR, bathymetry survey, structure survey, and a new hydrologic analysis developed specifically for this mapping update. The LiDAR was obtained by Quantum Spatial Inc. (QSI) in 2017 (QSI, 2017). The hydrologic analysis for Junction Creek was completed by the DNRC in 2017 (DNRC, 2017) and was approved by FEMA in 2017. The hydraulic bathymetric and structure surveys were completed by Morrison-Maierle in the spring of 2017 (M-M, 2017) and submitted to FEMA in May 2017.



Lima Vicinity Structure Summary

Structure	Lima
Bridge	8
Culvert	8

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DATE: 5/2/18

Beaverhead County **Junction Creek Detailed Floodplain Study** MT

PROJECT NO. 1447.046

Project Loction & Study Limits

FIG. 1

The hydraulic analysis for Junction Creek within Beaverhead County, MT is summarized in this report. The flood study includes the 10%, 4%, 2%, 1%, 1%+ and 0.2% annual-chance (AC) flood events. The DNRC and Morrison-Maierle, the professional service contractor, have completed this study using guidelines and standards published in the FEMA Resource and Document Library to ensure the study complies with the National Flood Insurance Program.

1.2 Watershed Description

Junction Creek originates in the mountains south of the town of Lima, Montana and flows north through the corporate limits of the town of Lima. Junction Creek discharges to the Red Rock River approximately 1.4 miles north of the corporate limits. At its mouth, the drainage area of Junction Creek is approximately 139 square miles (DNRC 2017). Junction Creek lies in one of the intermontane valleys in the Beaverhead River Basin within the Red Rock HUC-8 Watershed (10020001) in southwest Montana. The soils in these valleys consist of deep tertiary sediments in the upland terraces and benches and river terrace soils (alluvial sand, gravel, silt and clay) in the inner valley (DNRC 2017).

2.0 Previous Mapping

The effective FIS Report is dated January 5th, 1982 and is the result of community support for floodplain mapping, floodplain insurance, and floodplain development and management as discussed in a meeting held in Dillon, MT on June 23rd, 1977. Flood Insurance Rate Map (FIRM) panels were completed and published on September 30th, 1982 for the unincorporated areas of Beaverhead County and on March 4, 1986 for the town of Lima.

Flood hazard zone designations currently mapped for Junction Creek are Zones A, A1, A2, AO, and B for approximately 4.5 river-miles within Beaverhead County, Montana. Zone A1 mapping is available for approximately 2.0 river-miles of Junction Creek within the town of Lima. Zone A mapping is available for approximately 0.3 river-miles of Alder Creek. Zone B is available for approximately 1.1 river miles of Junction Creek Overbank through the town of Lima. Zones A2 and AO are available for approximately 1.0 river-miles of Junction Creek Overbank south of the town of Lima.

Zone A is a flood hazard designation without supporting detailed hydraulic modeling and base flood elevation data. Zones A1 and A2 are flood hazard designations with supporting detailed hydraulic modeling and base flood elevation data. AO zones are areas of the 1% AC flood with depths of one to three feet (typically sheet flow on sloping terrain) and the average depths of inundation are noted on the FIRM panels. B zones are areas of the 1% AC flood and 0.2% AC flood; or certain areas subject to 1% AC flooding with an average depth less than one foot or where the contributing drainage area is less than one square mile; and areas protected by levees from the base flood. This floodplain study will change all special flood hazard area zone designations on the maps of Junction Creek to Zone AE for Beaverhead County, Montana.

The effective study includes base flood evaluation data along Junction Creek and the Junction Creek Overbank through the town of Lima west of the Union Pacific Railroad that is based on a detailed study analysis. Alder Creek flood risks were assessed using approximate methods. The effective study limits were south of the confluence with Gleed Ditch near the northern corporate limits of the town of Lima. The effective study hydrologic and hydraulic analyses flow data are summarized in Table 2 below. Junction Creek was the sole source for flooding in the effective study.

Table 2: Effective Flood Insurance Study Summary of Discharges

Flooding Source	Location	1% AC Flood (cfs)	0.2% AC Flood (cfs)
Junction Creek	Above First Railroad Crossing One Mile Southeast of Lima	700	910
	Below Second Railroad Bridge	455	500
	Below Alder Creek	607	672
Junction Creek Overbank*	Below Second Railroad Bridge	245	410
	Below Alder Creek	93	238

* Junction Creek Overbank flooding source is split flow from Junction Creek. It has no independent flooding source.

In the effective study, Manning's "n" roughness value assignments within the channel banks for Junction Creek and Junction Creek Overbank range from 0.04 to 0.05. Roughness values

for the overbanks ranged from 0.04 to 0.07 for both stream reaches. The FIS report indicates a floodway was computed for both Junction Creek and Junction Creek Overbank reaches. However, the currently effective FIRM (dated 3/4/1986) for the incorporated area of the town of Lima does not include floodway delineation along the Junction Creek Overbank reach.

The local community, Beaverhead County, and the State of Montana identified the project area as a priority for update and revision of flood risk data. The purpose of this project is to update the existing FIS report and FIRM panels along Junction Creek within the town of Lima and adjacent unincorporated area in southern Beaverhead County, Montana. The effective flood study is based on outdated hydrologic data, hydraulic modeling, and floodplain mapping technology. Additionally, the community has experienced flooding since the date of the effective flood study. Flooding that has occurred subsequent to the effective study and related flood mitigation activities have altered the flood characteristics, flood risk, and related flood conveyance of Junction Creek and related split flow reaches.

This study includes a hydrologic flood flow analysis which meets current engineering standards and incorporates an additional thirty years of climatic data. Hydraulic modeling and floodplain mapping are supported by recently collected field survey and LiDAR topographic data acquisition. The new ground information captures changes to structures and development within the floodplain since the last study was completed. The LiDAR topography data also improves the resolution of ground information for floodplain boundary delineation. While the current hydraulic model applies the same basic step-backwater approach as the previous flood study, the representation of structure crossing complexity and floodplain information is improved in the modern numerical model.

3.0 Hydrology

This enhanced flood study, as shown on Figure 1, covers approximately 3.1 stream-miles of Junction Creek, 2.5 stream-miles of Junction Creek Overflow, 0.3 stream-miles of Alder Creek and 0.6 stream-miles of Gleed Ditch within Beaverhead County, MT (Figure 1). The hydrologic analyses for Junction Creek was completed as part of the Beaverhead County Modernization Project, Phase II by the DNRC (DNRC, 2017).

Junction Creek is an ungaged stream. Four methods for estimating flood frequency discharge were analyzed in the study including the following methods:

- USGS Montana Regression Equations,
- USGS Idaho Regression Equations,
- Weighted USGS MI-ID Regression Equations, and
- Regional Regression Analysis

A description of the methods and how they apply to the estimate of flood frequency discharges is provided in the hydrology report (DNRC, 2017). The Recurrence Interval is reported as % Annual Chance or % AC.

Due to the short reach length and lack of significant change in tributary area, no flow changes based on hydrologic analysis are recommended within the study reach. A summary of peak flow estimates for each method on the Junction Creek flooding source in Beaverhead County, Montana is presented in Table 3.

Table 3: Summary of Discharge Estimates for Junction Creek

Recurrence Interval (% Annual Chance)	Discharge Estimates (cfs)			
	MT Regression Equations	ID Regression Equations	Weighted MT-ID Regression Equations	Regional Regression Analysis
10%	690	430	**540**	410
4%	880	580	**720**	530
2%	1,020	690	**850**	630
1%	1,170	830	**1,000**	720
0.2%	1,540	1,160	**1,360**	950

Selected discharges are shown in RED.

The DNRC recommended using the weighted USGS Montana and Idaho Regression Equations (DNRC 2017). The DNRC concluded that the USGS Montana Regression Equations alone are not representative of the Junction Creek basin due to the variability in gages used between the southern and northern portion of the Southwest Region. They

also observed that the Junction Creek drainage basin lies along the southern border of the Southwest Region, which is also the state border of Montana and Idaho. Furthermore, Idaho's Region 6_8 encompasses this boundary and overlaps into Montana. Montana's Southwest region and Idaho's Region 6_8 have similar hydrologic characteristics, and a weighted estimate was judged to be the most representative of the Junction Creek basin.

The DNRC evaluated whether a flow node change on Junction Creek at its confluence with the Gleed Ditch (Figure 1) was appropriate. The typical irrigation flow rate and potential timing of Junction Creek flooding as well as Red Rock River flooding at the Gleed Ditch point of diversion were investigated. After evaluation, the DNRC determined a flow change at the confluence between Junction Creek and Gleed Ditch was not appropriate (see Appendix H).

The uncertainty in the 1-percent discharge estimate was represented by calculating the 84% confidence interval and adding the error to the 1% AC discharge to develop the 1%+ AC flood frequency. A comparison of the recommended flood frequency discharge estimates and the currently effective discharges for the Junction Creek flood source is provided in Table 4 below.

Table 4: Selected Discharges

Location	Drainage Area (mi^2)	Selected vs. Currently Effective	Discharge Estimates (cfs)					
			10%	4%	2%	1%	1%+	0.2%
Junction Creek at upstream study limits	132	Selected	540	720	850	1,000	1,930	1,360
		Current Effective	420	620	-	700	-	910

Note for this study the 1%+ AC flood event is larger than the 0.2% AC event due to the relatively large uncertainty in the computation and assessment of the peak flows. This is due, in part, to the lack of gage data for Junction Creek and the lack of gage data for similarly sized watersheds in the general area to improve confidence in the hydrologic analysis.

While there are no flow change nodes recommended based on hydrologic analysis, the Junction Creek flood source does split into several different reaches. The flood flow rates for each of the split flow paths are documented in Section 4.11, "Worst Case Scenarios" and Appendix G.

4.0 Hydraulics

The methods and techniques used to complete the hydraulic analysis for Junction Creek in Beaverhead County, Montana are presented in the following sections. The analysis utilized the LiDAR topography mapping, bathymetric surveys, and hydraulic structure surveys to develop 1% AC zone AE, floodway, and 0.2% AC zone X mapping.

4.1 Hydraulic Analysis

This floodplain study of Junction Creek within Beaverhead County, Montana, as shown on Figure 1, consists of four segments; Junction Creek, Junction Creek Overflow, Alder Creek, and Gleed Ditch. Analysis for Junction Creek begins approximately one river-mile south of the confluence with the Red Rock River and extends south, or upstream, approximately 3.1 river-miles (Figure 1). Analysis for Junction Creek Overflow begins at the confluence with Gleed Ditch and extends south, or upstream, approximately 2.5 river-miles to the diversion point from Junction Creek (Figure 1). Analysis for the Alder Creek segment begins at its confluence with Junction Creek, in the town of Lima, and extends 0.3 river-miles upstream to a location near the crossing of Interstate Highway I-15 (Figure 1). Analysis for Gleed Ditch begins approximately 0.2 river-miles above the old US Hwy 91 crossing and extends 0.6 river-miles upstream to the confluence with Junction Creek (Figure 1). The length of each stream reach is summarized in Table 1.

Guidance provided in the document *FEMA Guidance for Flood Risk Analysis and Mapping of One-Dimensional Hydraulics* (FEMA 2016c) were followed for the hydraulic model development. The water surface elevations (WSEL's) were calculated with HEC-RAS, Version 5.0.3 hydraulic modeling software (USACE 2016a). HEC-RAS computes the steady flow analysis using the standard step energy balance calculation between cross sections starting at the most downstream cross section and moving upstream for subcritical analysis.

Cross sections were placed with the GeoHECRAS hydraulic computer modeling software (GeoHECRAS, 2016) at stream profile baseline reach lengths ranging from approximately 50 to 500 feet and at structures located within the floodplain study reach.

4.2 Site Data Acquisition

4.2.1 Field Survey

Field Survey data was collected by Morrison-Maierle staff in November and December of 2016. Structure and bathymetric surveys were completed using Global Navigation Satellite System (GNSS) real-time kinematic (RTK) methods of survey. Cross section and structure data were collected using the feature codes and guidelines outlined in FEMA Data Capture Technical Reference, November 2016. The Field Survey data coordinates were Montana State Plane coordinate system referenced to the North American Datum of 1983 (NAD83-2011) and the North American Vertical Datum of 1988 (NAVD88), for the horizontal and vertical datum, respectively. Horizontal coordinate system units were International Feet and vertical units were US Survey Feet. Survey-grade GNSS equipment capable of 3-centimeter horizontal and vertical accuracy was used to collect the field survey data.

The Field Survey included a hydraulic structure survey for all model reaches. The hydraulic structure survey included a stream channel survey in the vicinity of the structure. The Field Survey for the Junction Creek main channel included a hydraulic structure survey with an associated stream channel survey. A bathymetric survey was collected for the Junction Creek main channel at approximately 1,000 foot intervals along the floodplain where the distance between hydraulic structures was greater than 1,000 feet. A summary of the hydraulic structure and bathymetric surveys is provided in Table 5 below.

Table 5: Survey Data Collected for the Junction Creek Flood Study

Reach	Hydraulic Structures	Bathymetric Cross Sections
Alder Creek	5	-
Gleed Ditch	3	-
Junction Creek Overflow	-	-
Junction Creek	12	14
Truax Creek*	2	-
Total	**22**	**14**

* Truax Creek was not scoped for inclusion in the Floodplain Study

4.2.2 LiDAR Topography

The DNRC contracted with Quantum Spatial, Inc. to acquire topographic Light Detection and Ranging (LiDAR) data for the project area. The LiDAR topographic data was collected on April 11, 2017 and published for use May 12, 2017. The LiDAR topography was collected at a mean vertical accuracy of 0.081 feet. The LiDAR deliverables included 3-feet grid bare earth digital elevation models (DEM) for the entire length of the Junction Creek corridor (QSI, 2017). The LiDAR data was collected with the following specifications:

Projection:	Montana State Plane	Units
Datum:	Horizontal – NAD83 (2011) FIPS 2500	International Feet
	Vertical – NAVD88, Geoid 12A	US Survey Feet

NAD: North American Datum
NAVD: North American Vertical Datum

Flood control measures appear to have been constructed along Junction Creek at multiple locations within the town of Lima based on field reconnaissance of the study reach and review of the field survey and LiDAR topographic data. These flood control measures include a deepened, prismatic channel with narrow channel bank extension berms of varying height that extend as much as three feet above natural ground. The extension berms are sporadic on both sides of the Junction Creek channel and vary in thickness as well as construction materials.

The altered channel is incised and disconnected from the natural floodplain. The updated regulatory flood flow for Junction Creek is approximately 165% of the effective flood flow rate through the town of Lima. The existing modified Junction Creek channel generally has

capacity for the effective flood flow rate of 607-cfs, which is similar to the updated 10% AC flood event flood flow rate of 540-cfs.

An early modeling approach evaluated considering the areas of modified and extended banks as flood control features, setting the cross-section overbanks as ineffective flow area, and computing a constrained flood profile. This approach was rejected due to the sporadic extended bank construction and insufficient flood flow conveyance within the modified Junction Creek channel. Therefore, the narrow berms along the channel were ignored and flood elevations were calculated assuming the entire wetted cross section was conveying flow (natural high ground and isolated depressions excluded).

The incised channel, narrow berms, and development within the natural Junction Creek floodplain through the town of Lima created challenging parameters for a one-dimensional hydraulic model in locations where relatively dense development has been completed. See the Section 4.6 “Hydraulic Structures” for discussion of these challenging locations and the approaches implemented for this floodplain study.

4.3 Profile Baseline

The Junction Creek Profile Baseline is coincident with the stream channel centerline and the profile stationing is referenced in feet above the confluence with the Red Rock River. The Alder Creek Profile Baseline is coincident with the stream channel centerline and the profile stationing is referenced in feet above the confluence with Junction Creek. The Gleed Ditch Profile Baseline is coincident with the ditch channel centerline and its stationing is referenced in feet above the old US Highway 91 crossing since the Gleed Ditch floodplain does not intersect a receiving water course. The Junction Creek Overflow Profile Baseline was developed based on the topographic low point along the overflow path and profile stationing is referenced in feet above the confluence with Gleed Ditch. Profile Baselines are shown on the Work Maps included in Appendix A. Profile Baselines were created using LiDAR aerial imagery (QSI, 2017). The summary of key features along each reach are presented in Tables 6, 7, 8, and 9, respectively.

Junction computation elements were used at locations where stream reaches joined (eg. Alder Creek confluence with Junction Creek) in the HEC-RAS model. HEC-RAS hydraulic modeling logic requires each stream reach to have a unique name. For streams that connected with another stream at a junction, the primary stream reaches were named alphabetically from downstream to upstream.

Table 6: Key Features along Junction Creek Profile Baseline

River Station	Feature	Description	1% AC Discharge* (cfs)
5,455	Downstream Limit of Study	Beginning of Reach A – approximately one-river-mile above confluence with the Red Rock River.	973
6,808	Flow Change Location	Worst Case flow down lower portion of Junction Creek Reach A	973
6,823	Irrigation Check	Structure JNC 030 – check structure to divert flow to Gleed Ditch, total span approx. 20-feet – *Gleed Ditch Worst Case Scenario flow reported*	683
6,946	Diversion Location	Lateral weir – outflow to Gleed Ditch.	
8,591	Lima Dam Road	Structure JNC 040 – clear span concrete structure with concrete deck, abutments, and wing walls, total span approximately 25-feet.	1,000
9,412	Pedestrian Bridge	Structure JNC 060 – two span wood structure with wood deck, total span approximately 48-feet.	1,000
9,701	First Avenue Bridge	Structure JNC 070 – clear span steel structure with gravel deck, total span approximately 24-feet.	1,000
9,900	Pedestrian Bridge	Structure JNC 072 – clear span steel structure with wood deck, total span approximately 31-feet.	1,000
10,517	Pedestrian Bridge	Structure JNC 075 – clear span wood structure with wood deck, total span approximately 28-feet.	1,000
11,658	Bailey Street Bridge	Structure JNC 080 – clear span concrete structure with concrete deck, abutments, and wing walls, total span approximately 20-feet.	1,000
12,018	Slader Street Bridge	Structure JNC 090 – clear span wood structure with wood deck, total span approximately 17-feet.	1,000
12,370	Confluence Junction	Confluence with Alder Creek	1,000
15,192	Flow Change Location	Inflow from Junction Creek Overflow.	1,000
19,719	Flow Change Location	Worst Case flow for Junction Creek	998
19,776	Union Pacific Railroad Crossing	Structure JNC 110 – 72-inch diameter CSP and 6-foot span x 8-foot rise masonry culvert crossings. – *Junction Creek Overflow Worst Case Scenario flow reported.*	797
19,800	Flow Change Location	After outflow to Junction Creek Overflow – *Junction Creek Overflow Worst Case Scenario flow reported.*	797
19,846	Diversion Location	Lateral weir – outflow to Junction Creek Overflow.	
21,326	Union Pacific Railroad Crossing	Structure JNC 120 – 84-inch diameter CSP and 4.6-foot span x 7.5-foot rise masonry culvert crossings.	1,000
21,831	Upstream Limit of Study	End of Reach B – at upstream study extents.	1,000

* Regulatory flows reported for Junction Creek worst case scenario except as noted when regulatory flow and water surface elevation is governed by alternate worst case scenario.

Table 7: Key Features along Junction Creek Overflow Split Flow Profile Baseline

River Station (feet)	Feature	Description	1% AC Discharge* (cfs)
0	Downstream Limit of Study	Beginning of model reach – Junction 1 to Gleed Ditch.	77
2,683	Third Avenue West Overtopping	No hydraulic structure below road surface	77
3,842	W Section Corner Street Overtopping	No hydraulic structure below road surface	77
4,491	Keller Street Overtopping	No hydraulic structure below road surface	77
5,148	Peat Street Overtopping	No hydraulic structure below road surface	77
6,108	Bailey Street Overtopping	No hydraulic structure below road surface	77
7,662	Diversion Location	Lateral weir – railroad overtopping greater than 1% AC	
8,240	Diversion Location	Lateral weir – railroad overtopping greater than 1% AC	
8,241	Flow Change Location	After outflow to Alder Creek.	77
8,530	Railroad Crossing (Diversion Location)	Lateral weir – ALD 100 48-inch diameter RCP and ALD 102 24-inch diameter DI culvert crossings of railroad embankment.	
9,737	Flow Change Location	After outflow to Junction Creek.	172
9,801	Railroad Crossing (Diversion location)	Lateral weir – ALD 104 24-inch diameter DI culvert crossing of railroad embankment.	
13,090	Upstream Limit of Study	End of model reach – immediately downstream from lateral overflow from Junction Creek.	203

* Regulatory flows reported for the Junction Creek Overflow worst case scenario.

Table 8: Key Features along Alder Creek Split Flow Profile Baseline

River Station (feet)	Feature	Description	1% AC Discharge* (cfs)
0	Downstream Limit of Study	Beginning of model reach – Junction 2 to Junction Creek.	95
284	Private Crossing	Structure ALD 095 – 36-inch diameter CSP culvert crossing.	95
313	Flow Change Location	After lateral weir – railroad overtopping greater than 1% AC	95
749	Private Crossing	Structure ALD 096 – triple 36-inch diameter CSP culvert crossing.	95
1,550	Flow Change Location	After Lateral Weir discharge from ALD_100 48-inch RCP culvert	95
1,739	Flow Change Location	After Lateral Weir discharge from ALD_102 24-inch DI culvert	48
1,847	Upstream Limit of Study	End of model reach – lateral weir overflow from Junction Creek Overflow.	0

* Regulatory flows reported for the Junction Creek Overflow worst case scenario.

Table 9: Key Features along Gleed Ditch Split Flow Profile Baseline

River Station (feet)	Feature	Description	1% AC Discharge* (cfs)
1,183	Downstream Limit of Study	Beginning of model reach – approximately 0.2-river-miles above old US Hwy 91 crossing.	131
1,370	Pedestrian Bridge	Structure JNC 010 – clear span wood structure with wood deck, total span approximately 20-feet.	131
1,379	Flow Change Location	After outflow to fields north of Gleed Ditch for events greater than 1% AC.	131
1,500	Diversion Location	Lateral weir – overflow of Gleed Ditch	
1,517	Flow Change Location	Just downstream of Junction 1 – confluence with Junction Creek Overflow	131
1,660	Union Pacific Railroad Crossing	Structure JNC 020 – twin 43-inch span x 27-inch rise CSPA culvert crossing.	131
1,683	Flow Change Location	After outflow to fields north of Gleed Ditch.	131
1,950	Diversion Location	Lateral weir – overflow of Gleed Ditch.	
1,963	Flow Change Location	After outflow to fields north of Gleed Ditch.	297
2,440	Diversion Location	Lateral weir – overflow of Gleed Ditch.	
2,452	Flow Change Location	After outflow to fields north of Gleed Ditch for events greater than the 1% AC.	317
2,680	Diversion Location	Lateral weir – overflow of Gleed Ditch.	
4,686	Upstream Limit of Study	End of model reach – gated structure and overland inflow from Junction Creek.	317

* Regulatory flows reported for the Gleed Ditch worst case scenario.

This study does not include split flow junctions. Flow splits were modeled using the lateral weir approach since the split flow conveyance area is separated from the source stream channel by natural high ground or embankments generally oriented parallel to the source stream flood flow direction.

4.4 Boundary Conditions

To perform the hydraulic analysis, HEC-RAS requires boundary condition input data at the most downstream cross section of the model reach. Per FEMA's One-Dimensional Hydraulics Guidance for Flood Risk Analysis and Mapping (FEMA 2016c), the downstream boundary condition in a one-dimensional, steady flow, step-backwater model should be taken from a previously established water-surface elevation, if available. This information is not available for the Junction Creek floodplain study. Therefore, normal depth energy slopes for water surface elevations (WSELs) calculations were used for the starting downstream boundary condition for Junction Creek and the Gleed Ditch. Normal depth slopes were developed by querying the topographic surface at and just below the downstream study limit and calculating the average slope for the stream channel along the profile baseline between points approximately 1,000 feet apart.

The downstream boundary conditions for other reaches occur at junctions, which establish the downstream boundary condition for those reaches. Junctions have been removed in the regulatory plan included in the submission due to the lack of mass-balance of flows resulting from the worst case split flows for the overflow reaches. Please see Section 4.11 "Worst Case Scenarios" for additional information.

A summary of the boundary conditions established for each model segment for the Junction Creek floodplain study in Beaverhead County are summarized in Table 10. Junction locations are shown in Figure 1.

Table 10: Boundary Condition Summary

Segment	Boundary Condition Source
Junction Creek Reach A	Normal Depth Slope = 0.006772 ft/ft
Junction Creek Reach B	WSELs across Junction 2
Junction Creek Overflow	WSELs across Junction 1
Alder Creek	WSELs across Junction 2
Gleed Ditch	Normal Depth Slope = 0.004705 ft/ft

4.5 Cross Section Development

The terrain data in the GeoHECRAS (GeoHECRAS, 2016) model was based on the LiDAR data. Utilizing the cross section module tool within GeoHECRAS, cross sections were placed perpendicular to flow and along estimated equipotential lines. End points for all cross sections were established as required to capture the boundaries of the 0.2% AC floodplain. When feasible, the cross section end points were extended to capture the 1%+ AC water surface elevations since the flow rate was greater than the 0.2% AC flow and water surface elevations. Cross sections were placed at key locations along the reach including: breaks in channel slope, abrupt changes in floodplain width, and at bridge and diversion structure

locations. Cross sections were filtered to less than 500 points per cross section as required by HEC-RAS.

The Junction Creek study reaches include stream channel bathymetry survey completed by Morrison-Maierle in 2017 (M-M 2017) which was combined with LiDAR data using the GeoHECRAS 'Conflate Point Data' tool to replace the LiDAR data with the stream channel bathymetry survey. Where additional cross-sections were required in the modeling process, a low-flow channel was approximated based on the available bathymetry survey in the bounding cross sections.

Cross sections were generally placed at a maximum spacing of 500 feet along the channel centerline throughout the study. Occasionally, the channel distance exceeds 500 feet due to profile baseline meander. At these locations, the flood flow path between cross sections is less than 500 feet (see Table 11).

Table 11: Cross Section Channel Reach Length Over 500-feet

Stream	River Station	Channel Length	Flood Flow Length
Junction Creek	18,126	599	≈450
Junction Creek	18,655	530	≈440

Cross section were placed densely to calculate hydraulic flow complexity in some areas of the hydraulic model (eg. dense cross section placement from Junction Creek river station (RS) 9,374 thru RS 9,925 due to structures crossing the stream). The density of cross sections would obscure the floodplain mapping due to the map scale. Not all modeled cross sections have been displayed on the hydraulic work maps for clarity. Node names have been recorded in the model to assist the user when reviewing the model and the work maps; lettered cross sections are named with the appropriate letter label; mapped non-lettered cross sections are noted as NL - not labeled; non-lettered, non-mapped cross sections are noted as NL/NM - not labeled/not mapped. Cross sections are shown on the hydraulic work maps provided in Appendix A.

4.6 Hydraulic Structures

A field survey of the hydraulic structures for the Junction Creek study was completed by Morrison-Maierle in 2017 (M-M 2017). The geometries of hydraulic structures were modeled with the data obtained from this survey. Eleven bridge structures exist within the study limits. The structures range from street and roadway crossings within the town of Lima to private access structures.

Expansion and contraction coefficients assignments at the two upstream and one downstream cross sections at bridge/culvert/diversion constrictions generally were increased from the natural channel values of 0.1 and 0.3, to 0.3 and 0.5, respectively. This standard hydraulic modeling practice was employed to account for the increased head loss associated with the relatively abrupt transitions and varying velocities that accompany the expansion and contraction of flows at hydraulic conveyance structures, and is recommended in the HEC-RAS model documentation and reference manuals.

The bridge modeling approach was set for both high and low flow methods based on the bridge configuration. High flow methods were either the Energy (Standard Step) or Pressure/Weir flow. The Energy method (Standard Step) was utilized when there was freeboard to the bridge low chord and/or when the road elevation approaching the bridge was lower than the crossing and the bridge was perched above the roadway elevation in the overbanks. The Pressure/Weir flow method was the high flow method used when flood waters would impact and/or overtop the bridge structure.

Low flow methods included Energy, Momentum, and Yarnell methodologies. The energy method was utilized for clear-span bridges with no piers. The Momentum Balance and Yarnell routines were used on structures with mid-span piers. The Momentum and Yarnell methods are low flow methods used to account for the hydraulic losses due to water moving around the piers. The momentum method required an input for the Drag Coefficient (CD), and the Yarnell equation required a pier shape coefficient (K).

Pier shapes for the bridge structures studied consist of square piers or elongated piers with a triangular nose. The CD and K coefficients used for the different pier shapes are summarized in Table 12.

Table 12: Pier CD and K Coefficients

No.	Pier Shape	C_D	K
1	Square Nose Piers	2.0	1.25
2	Triangular Nose Piers	1.39	1.05

A summary of the bridge structures and hydraulic model settings for each structure are summarized in Tables 13 and 14, respectively.

Culvert crossings were modeled using field measurements of culvert barrel inverts, culvert infill when applicable, and roadway overtopping information. Overbank data was extracted from the LiDAR terrain data. In this study, culvert barrel inverts were commonly below the bounding channel elevations, with localized scour adjacent to their ends more closely matching the invert elevations. Internal hydraulic structure cross sections were adjusted to represent the local scour at the culvert ends while the bounding sections were set to the bathymetric survey. This approach provided reasonable backwater elevations caused by the channel elevations bounding the structure without artificially reducing barrel conveyance area at the culvert ends.

Culvert crossings beneath the Union Pacific Railroad presented a somewhat unusual relationship between the overtopping deck width and the culvert length. This was particularly true for those crossings with an access road adjacent to the railroad track. In those cases, the overtopping deck width was considerably shorter than the culvert length since the deck width was equivalent to the portion of the railroad grade controlling flow at an approximately constant elevation across its width.

A summary of the culvert data is provided in Table 15. Photographs 1 and 2 show typical roadway hydraulic conveyance structures and Photographs 3 and 4 show pedestrian bridge structures. Photographs of all the modeled bridge and culvert structures are provided in Appendix C.

Photograph 1: Lima Dam Road Bridge JNC 040 (evaluated as a culvert).

Photograph 2: First Avenue Bridge JNC 070.

Photograph 3: Pedestrian Bridge JNC 060.

Photograph 4: Pedestrian Bridge JNC 075.

Table 13: Summary of Bridge Structures

ID No.	Roadway	Model Segment	River Station	Spans	Total Span (feet)	Deck Width (feet)	Deck Thickness (feet)	Pier Width (feet)	Appendix C Photo Page
JNC 010	Pedestrian Bridge	Gleed Ditch	1,370	1	20.0	8.3	0.80	–	3
JNC 040	Lima Dam Road *	Junction Creek - A	8,591	1	25.5	30.0	2.70	–	5
JNC 060	Pedestrian Bridge	Junction Creek - A	9,412	2	48.0	6.0	1.00	2.0	6
JNC 070	First Avenue Bridge	Junction Creek - A	9,701	1	23.8	18.0	1.80	–	7
JNC 072	Pedestrian Bridge	Junction Creek - A	9,900	1	31.0	3.0	0.90	–	8
JNC 075	Pedestrian Bridge	Junction Creek - A	10,517	2	28.0	4.5	0.75	0.5	9
JNC 080	Bailey Street *	Junction Creek - A	11,658	1	20.0	33.0	2.00	–	10
JNC 090	Slader Street	Junction Creek - A	12,018	1	16.5	15.0	1.60	–	11

* Modeled as box culvert for the type of constructed bridge structure.

Table 14: Summary of Bridge Model Settings

ID No.	Roadway	Model Segment	River Station	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
JNC 010	Pedestrian Bridge	Gleed Ditch	1,370	0.3	0.5	Energy	Energy***
JNC 040	Lima Dam Road *	Junction Creek - A	8,591	0.3	0.5	Energy	Energy
JNC 060	Pedestrian Bridge	Junction Creek - A	9,412	0.1**	0.3**	Energy, Momentum, Yarnell	Energy***
JNC 070	First Avenue Bridge	Junction Creek - A	9,701	0.1**	0.3**	Energy	Energy***
JNC 072	Pedestrian Bridge	Junction Creek - A	9,900	0.1**	0.3**	Energy	Energy***
JNC 075	Pedestrian Bridge	Junction Creek - A	10,517	0.3	0.5	Energy, Momentum, Yarnell	Energy***
JNC 080	Bailey Street *	Junction Creek - A	11,658	0.3	0.5	Energy	Energy
JNC 090	Slader Street	Junction Creek - A	12,018	0.3	0.5	Energy	Pressure/Weir

* Modeled as box culvert for the type of constructed bridge structure.
** Significant overbank conveyance with no roadway embankment and lack of channel encroachment by structure abutments
*** Energy only recommended due to at least one of the following: Perched Bridge, Lack of Roadway Embankment, Overbank Conveyance

Table 15: Summary of Culvert Crossings

ID No.	Roadway	River Reach	River Station	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Appendix C Photo Page
JNC 020	Union Pacific Railroad Crossing	Gleed Ditch	1,660	61.0	CSPA	Twin Arch	3.58 x 2.25	4
ALD 095	Private Crossing	Alder Creek	284	40.0	CSP	Round	3	12
ALD 096	Private Crossing	Alder Creek	749	12.0	CSP	Triple Round	3	13
ALD 100	Railroad Crossing*	Junction Creek Overflow	8,530	43.0	RCP	Round	4	14
ALD 102	Railroad Crossing*	Junction Creek Overflow	8,530	37.0	DI	Round	2	15
ALD 104	Railroad Crossing*	Junction Creek Overflow	9,801	38.0	DI	Round	2	16
JNC 110	Union Pacific Railroad Crossing	Junction Creek - B	19,776	40.0	CSP	Round	6	17
				30.5	MCPA	Arch	6 x 8	
JNC 120	Union Pacific Railroad Crossing	Junction Creek - B	21,326	48.0	CSP	Round	7	18
				28.0	MCPA	Arch	4.6 x 7.5	

* Culvert within Lateral Structure.

Culvert Types:
CSPA – Corrugated Steel Pipe Arch
CSP – Corrugated Steel Pipe
RCP – Reinforced Concrete Pipe
DI – Ductile Iron Pipe
MCPA – Masonry Constructed Pipe Arch

4.6.1 Junction Creek RS 6,823 Diversion Structure (JNC 030)

The study reach included one diversion structure located at RS 6,823 of Junction Creek. This structure is used to maintain a backwater condition for a headgate structure diverting flow into the Gleed Ditch.

Photograph 5: Diversion JNC 30 Check Structure (RS 6,823)

Photograph 6: Turnout JNC 30 Headgate Structure (RS 6,823)

The diversion structure shown in Photograph 5 was modeled as an inline weir. The Gleed Ditch confluence/diversion from Junction Creek is composed of a high earthen berm located along the down-gradient bank of Gleed Ditch. The embankment would be overtopped for flows larger than the 1% AC event when flow is constrained through the narrow check structure opening. The flow regime would be expected to pass through critical depth due to both the anthropogenic impedance to natural floodplain flow and the natural valley ground forms in the vicinity of the check structure and the embankment.

The Gleed Ditch embankment does not have a plan form that is conveniently modeled in a one-dimensional environment. The embankment was evaluated by estimating the average embankment elevation across the inundated area and manually entering the inline weir elevations to represent the embankment. All flow immediately upstream of the embankment would also be obstructed, therefore, a blocked obstruction was added to the cross section at RS 6,841 to represent the flow impedance caused by the embankment.

A sensitivity analysis was performed to evaluate the effect on water surface elevations upstream and downstream of the structure. The sensitivity analysis included evaluation of the following model parameters and geometry alterations at JNC 030:

- Model regime analysis (Subcritical & Mixed Flow)
- Structure modeling approach
    - Cross sections only
    - Inline Structure
    - Bridge Structure
- Manning's 'n' roughness variation
- Total cross sections
- Cross section location and density
- Bank stations

The larger flood flow profiles are at critical depth for less than 30-feet of stream reach immediately downstream of the irrigation canal embankment and check structure for reasonable model variable combinations in the sensitivity analysis.

The mixed flow regime model analysis was evaluated but rejected. The mixed flow regime would allow calculation of a lower water surface profile over this short section that is less than the critical depth, resulting in a lower reported flood water surface elevation. Additionally, running the model in mixed flow regime caused other invalid and less conservative results at other structure locations in the study area. The selected approach produced results that are a reasonable representation of the hydraulic conditions at this location.

Water surface elevations at the upstream face of the structure and upstream of the structure were relatively insensitive to the structure and embankment modeling approach. Elevations varied about a tenth of a foot at the upstream face cross section when the cross section only approach, the inline weir approach, or the bridge approach and associated geometry were used to evaluate the structure.

The modeled water surface upstream of the embankment was relatively insensitive to changes in roughness, the number and frequency of cross-sections, and bank station

assignment along the cross-section. The sensitivity analysis was performed for cross section variations within 140-feet downstream of the structure to a cross section upstream of the structure where flood flows begin to contract. Based on the sensitivity analysis and the knowledge that the flow regime would pass through critical depth due to the constriction and weir overtopping, the critical depth computations were allowed to remain in the model for the short section downstream of the structure for the 1% AC flood profile.

Water surface elevations upstream of the structure would be less than presented due to failure of the earthen embankment forming the northern bank of the Gleed Ditch. However, the hydraulic model and flood map reflect reasonable worst case scenario water surface elevations caused by the irrigation embankment impedance to flood flows prior to failure. Please see the Section 4.11 “Worst Case Scenarios” for additional discussion.

The headgate turnout for Gleed Ditch was modeled using a lateral weir with gates for the overtopping overland flow and channel flows. The flow optimization module in HEC-RAS was used to determine the flow split between the two flow directions. As noted, the Gleed Ditch embankment is continuous along the Gleed Ditch northern bank.

4.6.2 Junction Creek RS 8,591 Crossing (JNC 040)

The Lima Dam Road crossing may be a precast concrete bridge or may be a three or four-sided concrete box culvert. The crossing includes concrete wing walls similar to those commonly included with reinforced box culvert construction. The bottom of the crossing is gravel and cobble infill similar to the adjacent streambed. A culvert hydraulic modeling approach was selected to represent this crossing in the analysis. As constructed, the structure would perform more similarly to a culvert than a bridge during flood flows. Therefore, the culvert modeling routine was a more appropriate way to represent this crossing.

4.6.3 Junction Creek RS 9,412, 9,701, & 9,900 Crossings (JNC 060 thru JNC 072)

As discussed in Section 4.2 “Topographic Data Acquisition” above, this area of Junction Creek has relatively dense development adjacent to the creek channel and within the floodplain. The creek channel is incised and appears to have been deepened both by lowering the channel bottom as well as sporadic channel bank extension with narrow berms of varying height above natural ground. While the creek channel cannot convey the entire regulatory flood flow, the majority of this flow is confined to the channel banks with velocities three to six times greater than those found in the overbank areas.

All three structures crossing the Junction Creek channel and floodplain have no discernable embankment across the floodplain. They are perched structures and are modeled in accordance with the HEC-RAS 5.0.3 Reference Manual with the energy approach for high flows. Flood waters that spill from the channel to the floodplain are not constrained by a raised roadway embankment and do not contract or expand due to structure and embankment features. Therefore, the typical floodplain expansion and contraction coefficients (0.1 and 0.3) were specified for the cross-sections bounding these structures.

The structures have minor encroachments into the Junction Creek channel. These encroachments are caused by narrowed channel banks and bridge structure features. Due to the large portion of flow conveyed in the Junction Creek channel at high velocities, small

encroachments result in increased energy required to pass through the structure. This results in an increased water surface within the channel along with the typically expected increase in velocity. In a one-dimensional model, the increased water surface is applied to the entire cross section, resulting in wide wetted areas upstream of the structure where no roadway embankment exists to retain the flood flow. Once the effects of the minor encroachment into the channel are removed in the cross-sections downstream of the structure, the channel capacity at a lower relative water surface elevation increases and the one-dimensional model applies conveyance calculations without considering the water spilled into the overbanks upstream of the structure. The resulting floodplain is hour-glass shaped and the conveyance top width change is not consistent with local topography.

To address the one-dimensional model limitations, ineffective flow areas were set above natural ground in the overbanks of most of the cross-sections throughout this reach to eliminate model conveyance calculations for wetted areas in the floodplain fringe. The area at the outer edge of the cross sections was represented as ponded storage as it would be poorly connected to floodplain conveyance for flood events through the 1% AC flood. The ineffective area cross section stations were developed by evaluating potential flow expansion (2:1) and contraction (1:1) with consideration of connected low topography conveying spill flood flows as well as the narrow “hourglass” floodplain neck immediately downstream of the structures.

Limiting flood fringe conveyance improved model stability, profile relationships for modeled flood events, and floodway negative surcharge calculations. The resulting regulatory flood elevations reasonably represent flood risk to properties adjacent to the hydraulic crossings.

4.6.4 Junction Creek RS 11,658 Crossing (JNC 080)

The Bailey Street crossing may be a precast concrete bridge or may be a three or four-sided concrete box culvert. The crossing includes concrete wing walls similar to those commonly included with reinforced box culvert construction. The bottom of the crossing is gravel and cobble infill similar to the adjacent streambed. A culvert hydraulic modeling approach was selected to represent this crossing in the hydraulic analysis. As constructed, the structure would perform more similarly to a culvert than a bridge during flood flows. Therefore, the culvert modeling routine was a more appropriate way to represent this crossing.

The channel upstream and immediately downstream of the Bailey Street crossing is incised with narrow berms constructed to extend the channel banks. Immediately above the roadway crossing, all flow would be constrained within the channel through the 1% AC flood. The HEC-RAS culvert routine indicated a drawdown in water surface elevation and an increase in flow velocity would result immediately upstream of the culvert. This yields unreasonable flood profiles with the 1% AC flood profile passing below the 2% AC flood profile at the culvert inlet. Minor alterations to the selected input parameters eliminated the crossing profile, but resulted in an unreasonable 1% AC flood profile with water surface elevations overtopping the roadway at a higher elevation than the three upstream step-backwater calculation nodes.

A sensitivity analysis was conducted to evaluate model response to input parameters and modeling approaches at the Bailey Street crossing to eliminate the drawdown and crossing profile which included:

- Varying channel and culvert roughness values in various combinations between 0.012 and 0.3
- Modeling the structure variously as a culvert or a bridge
- Varying bridge calculations methodology for high-flow analysis
- Varying ineffective flow area locations and elevations
- Varying culvert inlet loss coefficients

The flood profiles were very sensitive to downstream cross section and culvert roughness variations, structure modeling approach, bridge calculation methodology, and ineffective flow area elevations. The flood profiles were moderately sensitive to the culvert inlet loss coefficient variation and insensitive to the upstream cross section roughness. After completing the sensitivity analysis, the culvert approach was selected along with a combination of model settings resulting in the most reasonable flood profile relationships.

The backwater elevation of the ponded water upstream of the culvert crossing was checked using the Federal Highway Administration culvert analysis program HY 8. The calculated water surface elevation in HY 8 was within five-hundredths of a foot when compared to the HEC-RAS backwater elevation calculated at the second cross section upstream of the structure (cross section four of a hydraulic structure) with the same irregular downstream cross section and irregular roadway deck. Flood flows may experience a drawdown in the immediate vicinity of the culvert inlet and a hydraulic jump may roll in and out of the culvert barrel as indicated by the HEC-RAS computation.

As discussed below in Section 4.13 “Critical Depth and Profile Smoothing”, the drawdown in the flood profiles was smoothed to a level pool backwater condition upstream of the culvert. Smoothing of flood profiles through the 1% AC event was manually completed to eliminate the crossing profiles. Flood profiles were elevated above the top of the culvert barrel for recurrence intervals with the downstream water surface above the top of the barrel. The crossing is overtopped by the 0.2% AC and 1%+ AC flood profiles.

4.6.5 Junction Creek RS 19,776 & 21,326 Crossings (JNC 110 and JNC 120)

Both these locations are culvert crossings through the Union Pacific Railroad grade. They consist of a primary opening constructed from stone in the shape of an arch. Both of the primary masonry culverts constrict the normal creek channel width and have scoured channel bottom inverts lower than the immediately adjacent streambed upstream and downstream. The primary openings have insufficient capacity for flood flows and corrugated steel overflow culverts have been installed with inverts at approximately 80% of the height of the primary culvert opening. The primary and overflow culverts also have much different barrel lengths and entrance conditions.

To allow approximation of the dissimilarity in material, inlet loss, barrel length, and invert elevation, the multiple opening option was selected in the hydraulic model. The railroad embankment has a large impact on flood flows as the dual culvert system has much less capacity than the natural valley and large headwater elevations are required to convey flood flows through the crossings.

The deep headwater results in plunging flows through the crossings for events greater than the 4% AC flood. The plunging flow profile and elevated channel bottom downstream of the

crossing results in a hydraulic jump within the culvert or immediately downstream of the outlet. The combination of plunging flow and hydraulic jump results in crossing profiles within the structure. The structure constriction of the floodplain, the deep headwater, and the elevated downstream channel are indications that the water surface through the crossing would likely approach super critical flow within the crossing and a hydraulic jump would likely occur. Flood profiles were smoothed through structure to eliminate the crossing profiles.

4.6.6 Lateral Weirs

Lateral weirs were specified as a broad crested weir and weir coefficients ranging from 0.5 to 2.0 were assigned in accordance with the recommendations in the HEC-RAS Reference Manual (USACE 2016b). In general, lateral weir coefficients are lower than typical values used for inline weirs. Application of a lower value is based on the energy/momentum loss associated with flow lines turning from their downstream orientation to a lateral direction out of the river/reach (RAS Solution 2013). The flow coefficients selected for each weir are summarized in Table 16.

Table 16: Selected Lateral Weir Coefficients

River	River Station	Lateral Weir Coefficient	Description
Gleed Ditch	1,500	2.0	Top of irrigation ditch embankment generally elevated 3-feet or more above the adjacent ground.
	1,950		
	2,440		
	2,680		
Junction Creek	6,946	0.5	Both non-elevated overbank as well as elevated irrigation head gate berm and structure overtopping.
	19,846	0.63	Both non-elevated overbank as well as constructed berms less than 3-feet above natural ground partially extending across the discharge area.
Junction Creek Overflow	7,662	2.0	Railroad grade embankment generally elevated 3-feet or more above adjacent ground.
	8,240		
	8,530		
	9,801		

The lateral weirs act as the hydraulic control for flow splits from the Junction Creek floodplain as well as additional flow splits and flow losses from the receiving split flow reaches. Please see Section 4.10 “Split Flow Analysis” and Section 4.11 “Worst Case Scenarios” below for additional information.

4.7 Floodplain Roughness

Roughness coefficients, typically Manning’s ‘n’ values in HEC-RAS, represent the frictional resistance acting on water flowing in the floodplain or the stream channel. The roughness coefficients are used in the model calculations to determine water surface elevations. Four land classes were developed for the study area to establish roughness coefficients based on ground and cover conditions. The land classes were developed through interpretations of aerial photographs and Montana Department of Revenue Land Classification Units. Roughness coefficients assigned within the hydraulic model were determined based on field observation, aerial photography, land-use mapping and the USGS publication *Guide to Selecting Manning’s Roughness Coefficients for Natural Channels and Flood Plains* (USGS, 1982).

Channel and floodplain roughness for relatively small streams with steep gradients are frequently higher than traditionally expected. Higher roughness values are also appropriate where the ratio of conveyance area to wetted perimeter is relatively low according to published research (USGS, 1985; USDA, 2014b; Yochum & Bledsoe, 2010). For example, a small creek channel with poorly connected floodplain would have higher roughness compared to large riverine settings with well-connected floodplains. Floodplain roughness values included in the hydraulic model are within the calculated range(s) which includes both surface resistance to flow as well as more difficult to explicitly quantify energy losses due to turbulence including:

- Cross section variability
- Plunging flows
- Tortured overbank flow paths with shallow overbank flood depths

Manning's roughness work sheets for the various channel and overbank conditions based on the USGS Manning's Selection publication have been included in Appendix I as well as the Supplemental Information Folder of the digital submission.

The USGS guide was used to develop minimum, maximum, and initial Manning's 'n' values for each land class. The range of roughness coefficients used in this study are provided in Table 17. Roughness coefficients were evaluated at each cross-section and adjustments to the horizontal limits were made to fit with the terrain data represented by the cross section. Adjustments to the roughness coefficients were also made as needed during hydraulic model development. Roughness coefficients were selected primarily for modeling the 1% AC flood event. Consequently, critical depth occasionally occurs for other magnitude flood events throughout the model (see Section 4.13 "Critical Depth and Profile Smoothing" below).

The flood flow paths for Junction Creek Overflow and Alder Creek are overflow routes only. These flow paths do not convey base flow and frequently do not have a typical channel and overbank disparity in floodplain roughness. Consequently, there are locations along these flow paths where roughness coefficients were increased in the "channel" to values more typical of overbank flow conditions.

Table 17: Manning's 'n' Values

Roughness Area Land Class Type	Manning's 'n' Value	Description
Main Channel	0.031 – 0.070	Coarse gravel, cobbles, and small boulders.
Pasture	0.028 – 0.054	Grasses, alfalfa, intermixed with weeds.
Sage brush	0.037 – 0.069	Sage brush with intermixed grasses.
Urban areas	0.062 – 0.135	Herbaceous & woody vegetation with manmade structures.
Willows	0.077 – 0.115	Willows with stems of herbaceous vegetation.

4.8 Areas of Non-Conveyance

As indicated on the Hydraulic work maps in Appendix A, there are areas where backwater or no-flow conditions exist. These conditions provide limited or non-conveyance in the downstream direction. For these areas, the ineffective flow area method was implemented to model and calculate the total effective conveyance for each cross section. Review of the modeled cross sections in HEC-RAS identified depression areas that are not hydraulically

connected to the stream body. These areas were also classified as ineffective flow areas in order for the model to correctly calculate the appropriate conveyance at the cross section.

The areas of non-conveyance included the following:

- Backwater and ponded areas.
- Flow constriction or expansion.
- Areas isolated by non-accredited earthen berms, railroad embankments or elevated roads.
- High topography either upstream or downstream that eliminates flow in a lower area.

The blocked obstruction module of HEC-RAS was used to simulate the overbank flow restriction or backwater effects that would result from the Gleed Ditch bank to the east or upgradient of the diversion structure with Junction Creek. The blocked obstruction is located along the right overbank of the cross section at Junction Creek RS 6,841. The elevation of the obstruction was set at the average top of bank elevation of the Gleed Ditch bank (see Section 4.6 for additional discussion).

Areas of flow expansion and contraction at the cross sections bounding structures were also assigned areas of non-conveyance to represent the head loss due to two-dimensional flow contraction and expansion in a one-dimensional steady state model. The flow contraction and expansion areas were calculated in a stream wise to lateral direction using a 1:1 (upstream) and a 2:1 (downstream) ratio, respectively. The ratios of expansion and contraction were developed using the cross sectional velocities as recommended in the HEC-RAS Reference Manual (USACE 2016b).

Through the town of Lima, much of Junction Creek is a constructed ditch or canal with berms on one or both sides of the channel. These berms appear to have been constructed to constrain floodwater to the creek channel and have variable height up to three-feet above the surrounding terrain. A sensitivity analysis was performed where the 1% AC flood flow event was confined to the channel in multiple reaches throughout the town of Lima. In each case, confining the 1% AC flood flow to the primary channel resulted in water surface elevations that exceed the creek bank berm heights. This model response is confirmed by the flood history of Junction Creek discussed in the Section 4.9 “Model Calibration” below. The regulatory flood water surface elevations calculated for this study are based on flood flow conveyance across the entire floodplain cross section (not constrained by the berms).

As discussed in the Section 4.2 “Topographic Data Acquisition” and Section 4.6 “Hydraulic Structures” above, ineffective areas were used to eliminate conveyance in the outer fringe of portions of the floodplain upstream of structures with minor channel encroachments. The area set as ineffective is not connected wet area across the floodplain width since the downstream cross sections have a lower water surface elevation and the floodplain lacks connectivity at the outer fringes.

4.9 Model Calibration

The Montana Department of Transportation (MDT) was contacted and asked to review their library of aerial photographs taken during the high water events near the town of Lima, Montana. MDT reported that after a complete search, no aerial photographs for flood events were available for Junction Creek near the town of Lima, Montana.

Beaverhead County Floodplain Administration was also contacted for flood event data and they also indicated that the County did not have any flood information for Junction Creek. They indicated that Cornerstone Surveying in Dillon, Montana may have historical flood data and recommended contacting Travis Wilson, a surveyor with Cornerstone Surveying.

Mr. Wilson was contacted and he stated the most recent flood event he was aware of occurred around March 1995. The town of Lima flooded during that event and water flowed out of the Junction Creek main channel and into the Junction Creek Overflow. He recalled the post office and LDS church were flooded by the Junction Creek Overflow.

Peter McCarthy a hydrologist with the United States Geological Survey (USGS) in Helena, Montana was also contacted to inquire if they had historic flood information for Junction Creek. Mr. McCarthy searched for stream gages in service during the 1995 event. He indicated no gages are located on Junction Creek no active gages in the vicinity during the 1995 event were found. Mr. McCarthy indicated the 1995 flood event most likely occurred due to ice blockage at a Junction Creek crossing.

The DNRC was contacted to inquire about previous flood events in the town of Lima. The DNRC floodplain staff met with the town of Lima clerk, water maintenance personnel, and the mayor on February 27, 2017. These individuals noted a historic flood event in the 1980's, possibly in 1987. The town of Lima was said to have flooded up to a depth of approximately 3-feet in the main part of town. This flooding was due to ice blockage at the Railroad Crossing at Junction Creek RS 19,776 shown in Figure 2. After the flood event, the railroad company installed additional culverts at railroad crossings at approximately RS 8,400 and 9,800 along the Junction Creek Overflow to convey flood flows back to Junction Creek. The railroad company also dug out what is mapped as Alder Creek. Since this flooding was due to ice blockage during a cold weather warmup event, a recurrence interval based flood event could not be established for calibration purposes.

The DNRC was also able to find a newspaper clipping from the Dillon Tribune in their archive dated March 15, 1995, discussing a flood event that occurred in the town of Lima on Junction Creek on March 11, 1995. According to the article, this flood occurred due to fast-paced snow melt due to warm winds coupled with rainfall. During this event, Junction Creek overflowed its banks through the town of Lima with significant overbank flooding in the eastern portion of the town of Lima. Flood flows also escaped the Junction Creek banks south of the town of Lima and entered the Junction Creek Overflow reach. Flooding was worse on the east side of the town of Lima and emergency flood mitigation efforts were directed at diverting flow back across the Union Pacific Railroad embankment to the east side of the town of Lima. Flood mitigation efforts were quickly abandoned on the east side of the town of Lima and the residents waited for the flooding to pass. Unfortunately, no high water marks, estimates of flood recurrence interval, or other solid calibration data were available for model verification.

The results of the model are generally consistent with the description of the March 1995 event. The modeling is based on updated hydrologic, topographic, bathymetry field survey, and hydraulic structure survey data completed in 2016 and 2017. The floodplain modeling and mapping correlate well with the narrative accounts of the flooding.

4.10 Split Flow Analysis

There are three flow splits in the Junction Creek project. The Gleed Ditch conveys flood water from the confluence with Junction Creek approximately 1.3 river-miles upstream from the Junction Creek confluence with the Red Rock River. As discussed in the Section 3 “Hydrology” above, Gleed Ditch is not a flood source above its confluence/diversion with Junction Creek for this floodplain analysis. Gleed Ditch flood flows are conveyed west, and the portion of flood water that does not spill over the Gleed Ditch north bank is routed laterally across the valley away from the Junction Creek and Red Rock River water courses.

Approximately 3.7 river-miles above the Junction Creek confluence with the Red Rock River, the Junction Creek Overflow receives overflow discharge from the Junction Creek flooding source. The Junction Creek Overflow conveys floodwater through the town of Lima west of the Union Pacific Railroad and discharges into the Gleed Ditch water course. Alder Creek is a derivative split flow from the Junction Creek Overflow floodplain. Alder Creek collects flood flows discharging across the Union Pacific Railroad grade and conveys them back to the Junction Creek water course approximately 2.3 river-miles above the confluence with the Red Rock River. The Alder Creek confluence is near the southern corporate limits of the town of Lima.

The Lateral Structure optimization module in HEC-RAS 5.0.3 was used to determine flow sharing between reaches across lateral structures. Modeled split flow water courses and potential additional flow splits considered are discussed in more detail below. The maximum flooding for each split flow path is dependent on a worst case scenario. Please see discussion in Section 4.11 “Worst Case Scenarios” below for flood flows for each modeled split flow water course.

4.10.1 Junction Creek

Minor overtopping along the left bank of the Junction Creek floodplain occurs in the vicinity of RS 13,430 which is near cross section 13,427 and in the vicinity of RS 14,300 which is between cross sections 14,165 and 14,476. These locations were evaluated for potential split flow analysis using three criteria:

1. Split flow reach length and elevation divergence from the source floodplain
2. Split flow discharge over the overtopping area
3. Mapping width of the discharge along the split flow conveyance path

At the Junction Creek RS 13,430 vicinity potential split flow flood flows would be conveyed approximately 500-feet in a local depression between the Junction Creek floodplain and the Alder Creek floodplain. The local depression has similar invert elevations and grade to the Junction Creek channel. Flood water surface elevations were calculated excluding the adjacent low topography from the Junction Creek step-back backwater calculations. The resulting average water surface elevation at the overtopping location was checked in an irregular weir calculation application with the overtopping topography entered as the weir crest.

A non-elevated overbank weir coefficient of 0.39 was assigned in the discharge check. Lateral discharge in the vicinity of RS 13,430 would be approximately 20-cfs (2% of the flood flow) during the 1% AC flood and approximately 44-cfs (3% of the flood flow) during the

0.2% AC flood. For both flood events, the downstream flow split flooding top width would be less than 30-feet. Due to the short split flow pathway, the minor flow discharge, and channel top width less than required by map scale, a flow split was not included in the vicinity of Junction Creek RS 13,430.

At the Junction Creek RS 14,300 vicinity potential split flow flood flows would be conveyed approximately 630-feet in a local depression between the Junction Creek floodplain and the Alder Creek floodplain. The local depression has similar invert elevations and grade to the Junction Creek channel. Flood water surface elevations were calculated excluding the adjacent low topography from the Junction Creek step-back backwater calculations. The resulting average water surface elevation at the overtopping location was checked in an irregular weir calculation application with the overtopping topography entered as the weir crest.

A non-elevated overbank weir coefficient of 0.39 was assigned in the discharge check. Lateral discharge at RS 14,300 vicinity would be approximately 2-cfs (0.2% of the flood flow) during the 1% AC flood and approximately 32-cfs (2% of the flood flow) during the 0.2% AC flood. For both flood events, the downstream flow split flooding top width would be less than 30-feet. Due to the short split flow pathway, the minor flow discharge, and channel top width less than required by map scale, a flow split was not included in the vicinity of Junction Creek RS 14,300. See hydraulic work maps in Appendix A for reference.

4.10.2 Junction Creek Overflow

Union Pacific Railroad crossing over Junction Creek at RS 19,776, as shown on Figure 1, has insufficient capacity to convey all flood flows. The residual overflow is diverted into the Junction Creek Overflow at a location just west, and upstream, of the Junction Creek/Union Pacific Railroad crossing. The Junction Creek Overflow reach conveys flood flows along the west side of the Union Pacific Railroad through the town of Lima. The HEC-RAS lateral weir and flow optimization options were used to determine the flow rates that would be discharged to the Junction Creek Overflow.

Further downstream, a portion of the Junction Creek Overflow flood waters discharge into Alder Creek and eventually return to Junction Creek (Figure 1). These flood waters are diverted through culverts in the railroad embankment as well as overtopping of the railroad embankment. Lateral weirs at three culvert crossings along the railroad embankment were utilized to calculate flow rates leaving the Junction Creek Overflow reach.

A lateral Railroad Crossing at Junction Creek Overflow RS 9,801, as shown on Figure 1 and in the work maps in Appendix A, would return flows back to the Junction Creek Floodplain at RS 15,192. Additional lateral Railroad Crossing near Junction Creek Overflow RS 8,241 and 8,447, respectively (Figures 1 and 2 and Appendix A) as well as overtopping of the railroad embankment between Junction Creek Overflow RS 6,941 thru RS 8,537 would release flow to the Alder Creek reach.

The Alder Creek channel flows along the southern edge of the town of Lima before its confluence with Junction Creek approximately 350-feet south of the Slader Street crossing. For further discussion see the Section 4.11.2 “Junction Creek Overflow” below.

4.10.3 Alder Creek

As indicated in Section 4.10.2 above, a portion of the Junction Creek Overflow flood flows are diverted across the Union Pacific Railroad embankment to Alder Creek and Junction Creek through Culvert Crossings at approximate Junction Creek Overflow RS 8,241 and 8,447, respectively as well as overtopping of the railroad embankment between Junction Creek Overflow RS 6,941 and RS 8,537 (Figures 1 and 2 and Appendix A).

Lateral weir segments along the railroad embankment were used to calculate flows that would be conveyed through the culverts and over the railroad embankment. The HEC-RAS optimization option was used for the lateral weir to determine the flow rates that would be conveyed through the culverts. For further discussion see Section 4.11.2 “Junction Creek Overflow” below.

4.10.4 Gleed Irrigation Ditch

With the development of the hydraulic model and review of the initial results, it was determined that the Gleed Irrigation Ditch would function as a split flow segment where it crosses Junction Creek approximately 6,900 feet upstream of the Junction Creek confluence with the Red Rock River.

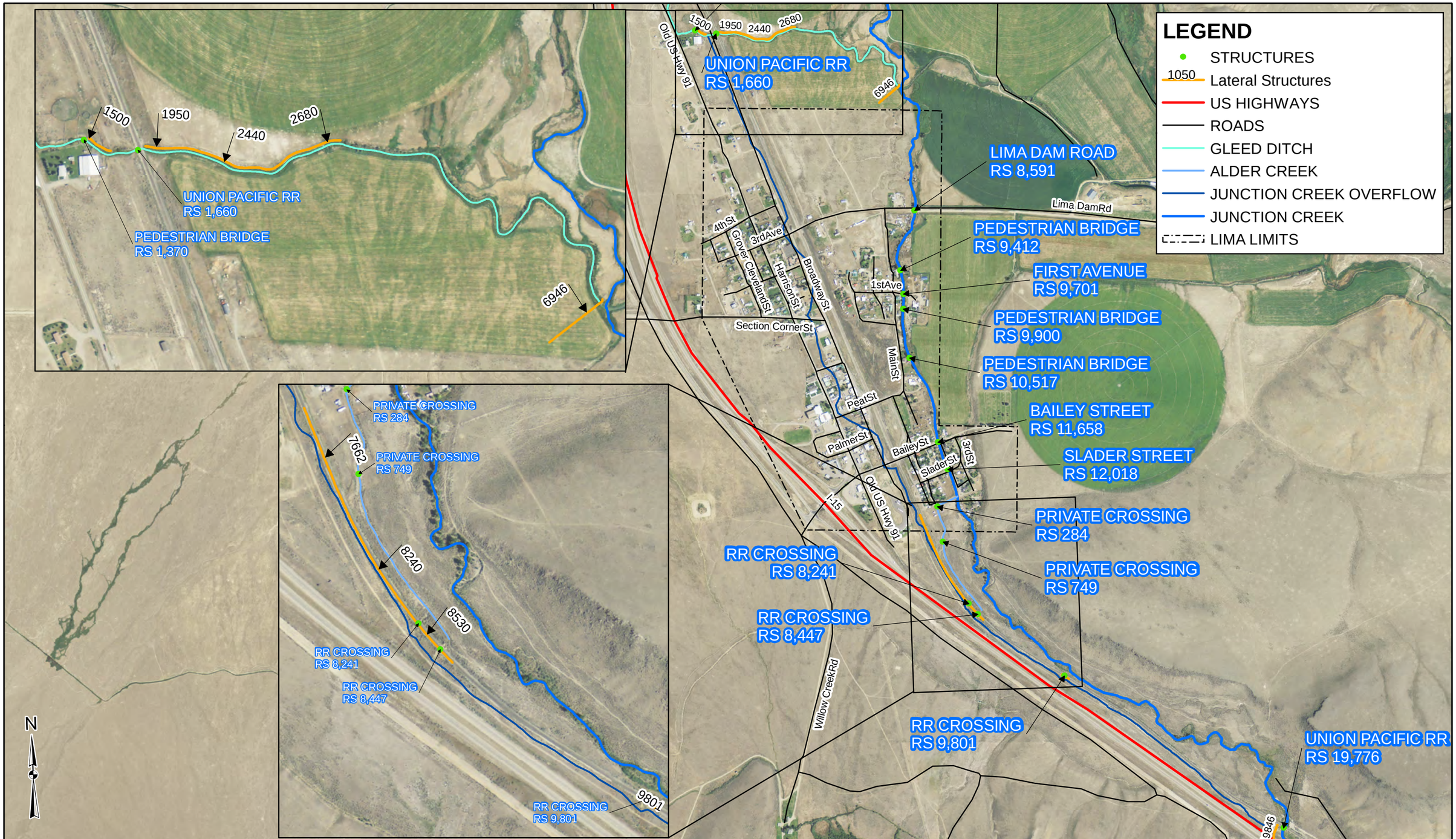
A portion of the north bank of the ditch is overtopped by flood flows that would sheet flood to undeveloped land and farm fields before rejoining Junction Creek or the Red Rock River near the confluence of the two flood sources. Lateral weir segments along the north bank of Gleed Ditch, as shown on Figure 2, were used to calculate the flow spilling out of the ditch and to determine base flood elevations for the mapping of floodplain extents south of the ditch.

The HEC-RAS optimization option was used for the lateral weirs to determine the flow rates that would be conveyed along the ditch to downstream study extents. Lateral weirs along the ditch embankment were specified as a broad crested weirs and utilized a weir coefficient of 2. For further discussion see Section 4.11.4 “Gleed Ditch” below.

4.11 Worst Case Scenarios

Worst case scenarios were considered for each of the flow splits discussed above. In each of these scenarios, conditions causing the largest flows for each stream, reach, or portion of a reach were considered. The HEC-RAS Plan, Geometry, and Flow Data names for each worst case scenario are summarized in Table 18.

Model settings were adjusted for the worst case flow for each reach. Aside from the specific alterations to structures in analyzing a worst case scenario, the geometries associated with the different plans are identical. Consequently, there are calculations points on an alternate scenario where the model does not meet hydraulic modeling standard practice for reaches not conveying worst case flows in that scenario (eg. default to critical depth at Junction Creek RS 14,841 in the Junction Creek Overflow worst case scenario).



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DRAWN BY: ZMC
CHK'D BY: MAF
APPR. BY: LDC
DATE: 05/2/18

Beaverhead County

Junction Creek Detailed Floodplain Study

MT

Split Flow Profile Baseline

PROJECT NO.
1447.046

FIG. 2

HEC-RAS River Junction nodes were used for the worst-case scenario models for confluence points (eg. Alder Creek and Junction Creek south of the town of Lima). Per HEC-RAS guidance (USACE, 2016c), cross sections above a junction node are coded with downstream reach lengths of zero. Reach lengths for each leg of the confluence junction are entered in the Junction Editor for computing the step-backwater elevations across the junction. The regulatory model requires deletion of the junction elements since the worst case scenario flows for the reaches are not in mass balance. Known water surface elevations from the appropriate worst case scenario model were entered as starting water surface elevations at the downstream cross section for each reach beginning at a junction node in the regulatory model plan.

Table 18: Worst Case Scenario Plan Summary and Applicable Stream Reaches

Worst Case Scenario	Plan Name	Geometry Name	Flow Data Name	Applicable Streams and River Stations (1% AC WSEL)
Gleed Ditch	Gleed Ditch Worst Case	Gleed Ditch Worst Case	Gleed Ditch Worst Case	Gleed Ditch – All River Stations Junction Creek – RS 6,841 thru 8,182
Junction Creek	Junction Creek Worst Case	Junction Creek Worst Case	Junction Creek Worst Case	Junction Creek – excluding RS 6,841 thru 8,182 and RS 19,800 thru 20,630
Junction Creek Overflow	Junction Creek Overflow Worst Case	Junction Creek Overflow Worst Case	Junction Creek Overflow Worst Case	Alder Creek – all River Stations Junction Creek – RS 19,800 thru 20,630 Junction Creek Overflow – all River Stations
Regulatory	Junction Creek Regulatory	Junction Creek Regulatory	Junction Creek Regulatory	All flow paths

The worst case scenario noted in Table 18 is applicable for all profiles for the reaches including the noted exceptions. The backwater river stations along Junction Creek, noted as excluded, are governed by an alternate worst case scenario and vary by profile. The river sections affected by the 1% AC profile are noted. The worst case flow for the 0.2% flood event on Gleed Ditch, below the confluence with the Junction Creek Overflow (Gleed Ditch Reach A), is from the Junction Creek Overflow worst case scenario with flows down the Junction Creek Overflow reach rather than the Gleed Ditch worst case scenario.

As discussed Section 4.10 “Split Flow Analysis” above and shown on Figure 2, Junction Creek Overflow, Alder Creek and Gleed Ditch are split flow conveyances of the Junction Creek flooding source. Utilizing the lateral weir flow optimization option within HEC-RAS, the discharge split across lateral weirs was calculated. Conservation of mass flow was balanced across the system while also balancing the energy equation.

The HEC-RAS lateral weir flow optimization was coded in accordance with the guidance provided in the HEC-RAS Reference Manual and the HEC-RAS Applications Guide (USACE 2016b, 2016d). HEC-RAS automatically calculates the mass-balances flow rates and automatically assigns the appropriate flow reduction/addition to each affected cross section adjacent to a lateral structure. After each worst case scenario plan was finalized, the cross-section flow data calculated in HEC-RAS was rounded to the whole cfs and coded for each cross section as a flow change in the regulatory model Steady Flow Data editor.

In every worst case scenario, multiple lateral weirs shared flow from a source reach to an adjacent collection reach. When simultaneously optimizing multiple lateral weir model elements, the HEC-RAS optimization routine typically cannot meet all convergence criteria and a warning of “Failed to Converge” is provided in the Computation dialogue box. Flow upstream of each lateral weir, discharge over the weir (and gates or culverts as applicable), and flow downstream of the weir was checked for every flood profile on every weir to ensure flows were balanced and no flow was added or lost in the HEC-RAS computation. The regulatory flow rate over each lateral weir was checked using an external irregular weir calculation application and the average water surface elevation along the weir to verify the final flow split data.

4.11.1 Junction Creek

Worst case scenario modeling on Junction Creek was completed to represent the flooding risk if the conveyance limitations of hydraulic crossings contributing to a flow split were to fail. Presenting failed structure flood risk provides the structure owner the opportunity to modify/replace the structure for improved capacity and potentially reduce environmental impacts on the stream without increasing the predicted flood risk at downstream properties. The worst case for flow scenario conveyed by Junction Creek occurs when assuming the irrigation check structure and Gleed Ditch berm at RS 6,823 fails and the Union Pacific Railroad crossing at Junction Creek RS 19,776 fails.

The worst case at RS 6,823 assumes the Gleed Ditch diversion structure gates are closed and the irrigation check structure and irrigation canal berm across the Junction Creek channel and floodplain fail. This worst case was analyzed by deleting the irrigation check structure and altering adjacent cross sections to approximate natural ground elevations by deleting irrigation embankment ground points collected in the LiDAR topography and survey data. Discharge to the Gleed Ditch still occurs, but at a lower flow rate. This scenario represents the worst case flooding for areas downstream of the Gleed Ditch confluence.

The worst case at RS 19,776 was analyzed by deleting the railroad grade crossing data for the Union Pacific Railroad and assuming existing bounding crossing geometry is un-altered. Discharge to the Junction Creek Overflow still occurs, but at an insignificant flow rate (2 cfs) during the regulatory flood. This scenario represents the worst case flooding for areas east of the railroad in the town of Lima.

A flow diagram of the Junction Creek worst case scenario including the flow rate upstream, lateral weir discharge, and flow rate downstream for each split flow element is provided in Figure 3 below. Additionally, the flow rate at each flow node is provided in Appendix G. Flow is rounded to the whole cfs in this documentation, while flow is tracked and output in results tables to the hundredth of a cfs in the hydraulic model.

Junction Creek Floodplain Mapping
Mapping Activity Statement: No. 2016-01
Split Flow Data Summary Map
Worst Case Scenario - Junction Creek

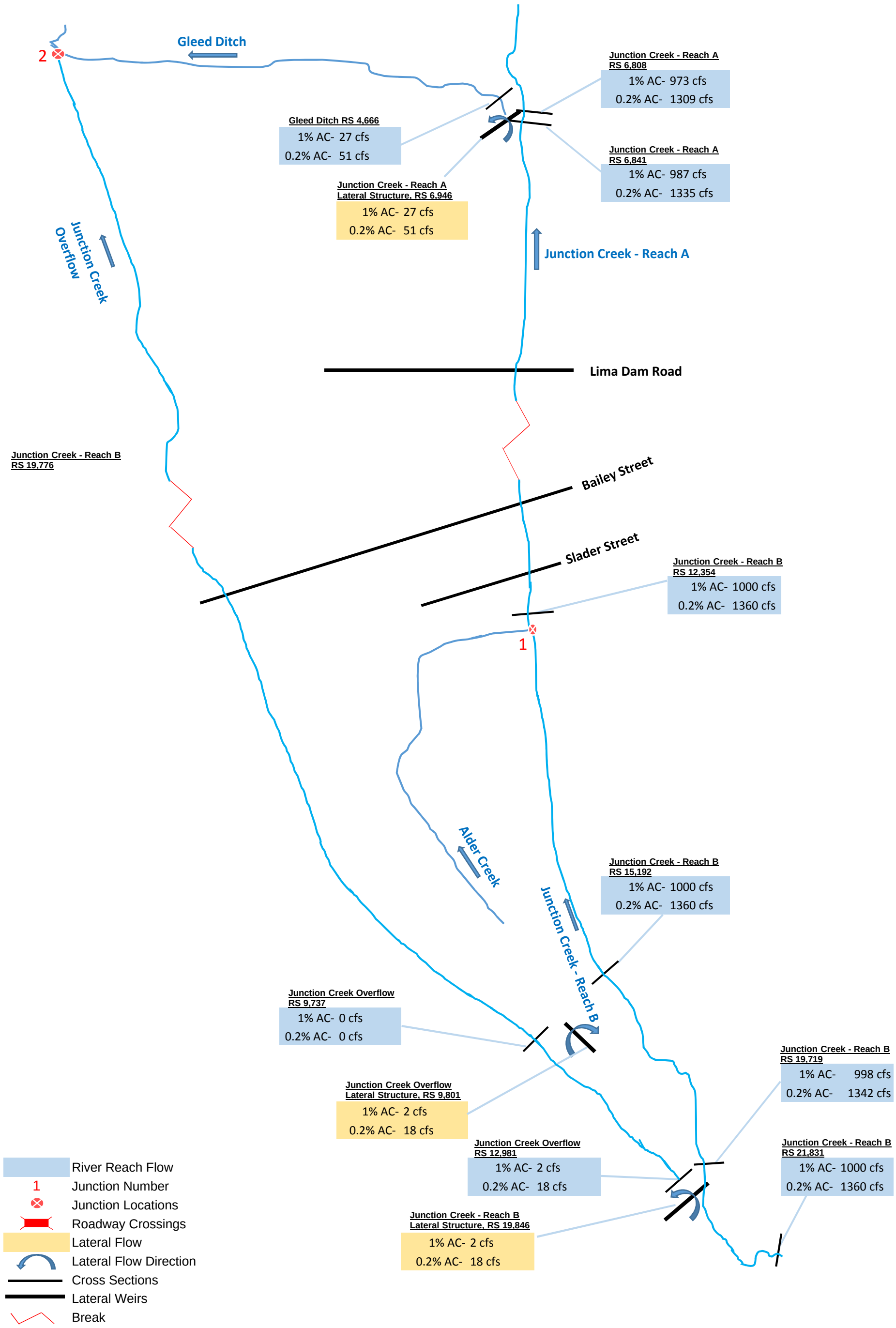

Figure 3: Junction Creek Worst Case Scenario Flow Diagram

4.11.2 Junction Creek Overflow

The worst case flow scenario on the Junction Creek Overflow occurs when assuming the Union Pacific Railroad crossing at Junction Creek RS 19,776 does not fail and the flood occurs with the existing crossing in place (ie. the crossing is not replaced or upgraded). The resultant headwater elevation upstream of this crossing yields discharge conveyed by the Junction Creek Overflow west of the railroad. A portion of those flows return to the Junction Creek floodplain prior to reaching the town of Lima through lateral culverts in the railroad grade as well as railroad grade overtopping during the 0.2% AC and 1%+ AC flood events. Remaining flow is routed through the town of Lima along the topographic low areas defining the overflow flood path.

When the HEC-RAS lateral weir optimization tool is computed in flow mass-balance to the calculated lateral weir discharge, the 1%+ AC flow rate at the downstream end of the lateral weir at Junction Creek Overflow RS 7,662 was computed as approximately 10 cfs less than the 0.2% AC flow rate due to the higher initial water surface at the upstream end of the weir. Since the 1%+ AC flow rate is approximately 140% of the 0.2% AC flow rate, it is unreasonable to assume the 1%+ AC flood flow west of the town of Lima would become less than the 0.2% AC flow rate. Therefore, a minor imbalance in flow rate over the RS 7,662 lateral weir was assigned for the 1%+ AC flood event to provide a flow rate on the Junction Creek Overflow reach downstream of this lateral weir that is approximately equal to the 0.2% AC flow rate. Flood flows assigned to each reach are in mass balance, but the computed lateral weir discharge flow rate is not balanced within the typical 1-2 cfs tolerance.

A flow diagram of the Alder Creek/Junction Creek Overflow worst case scenario including the flow rate upstream, lateral weir discharge, and flow rate downstream for each split flow element is provided in Figure 4 below. Additionally, the flow rate for each flow node is provided in Appendix G. Flow is rounded to the whole cfs in this documentation, while flow is tracked and output in results tables to the hundredth of a cfs in the hydraulic model.

4.11.3 Alder Creek

The Junction Creek Overflow worst case scenario is also the worst case for flow in Alder Creek. The source of Alder Creek flows are the above mentioned lateral culverts and railroad grade overtopping along the Junction Creek Overflow. Alder Creek discharges into Junction Creek south of Slader Street in the town of Lima and flood flows are routed down Junction Creek to the Red Rock River. Alder Creek is subject to backwater from the Junction Creek worst case scenario through river station 525 for the 1% AC event (see Profiles, Appendix B).

The Lateral Weir optimization tool in HEC-RAS automatically adds flow to the flow nodes receiving flow. The Alder Creek reach has no independent flooding source. The lateral weir data editor requires flow be added between cross sections for the receiving river reach. HEC-RAS also requires a flow to be entered at the head of each reach. Therefore, Alder Creek RS 1,847 has steady flow data entered as 0.001-cfs in the Steady Flow file. When computing water surface elevations (WSEL) for the Alder Creek reach, the 4% AC WSEL is higher than the 2% AC WSEL and 1% AC WSEL at RS 1,847 due to a numerical idiosyncrasy related to the nearly zero flow rate at the receiving reach upstream cross

section. The crossing profile issue is unique to the HEC-RAS one-dimension modeling parameters/limitations and has been ignored. Alder Creek RS 1,847 is mapped as a backwater from RS 1,739 which is the first Alder Creek flow node to actually receive flood flows.

Alder Creek is included on the Junction Creek Overflow worst case scenario flow diagram (Figure 4) which includes the flow rate upstream, lateral weir discharge, and flow rate downstream for each split flow element. Additionally, the flow rate for each flow node is provided in Appendix G. Flow is rounded to the whole cfs in this documentation, while flow is tracked and output in results tables to the hundredth of a cfs in the hydraulic model.

Junction Creek Floodplain Mapping
Mapping Activity Statement: No. 2016-01
Split Flow Data Summary Map
Worst Case Scenario - Junction Creek Overflow

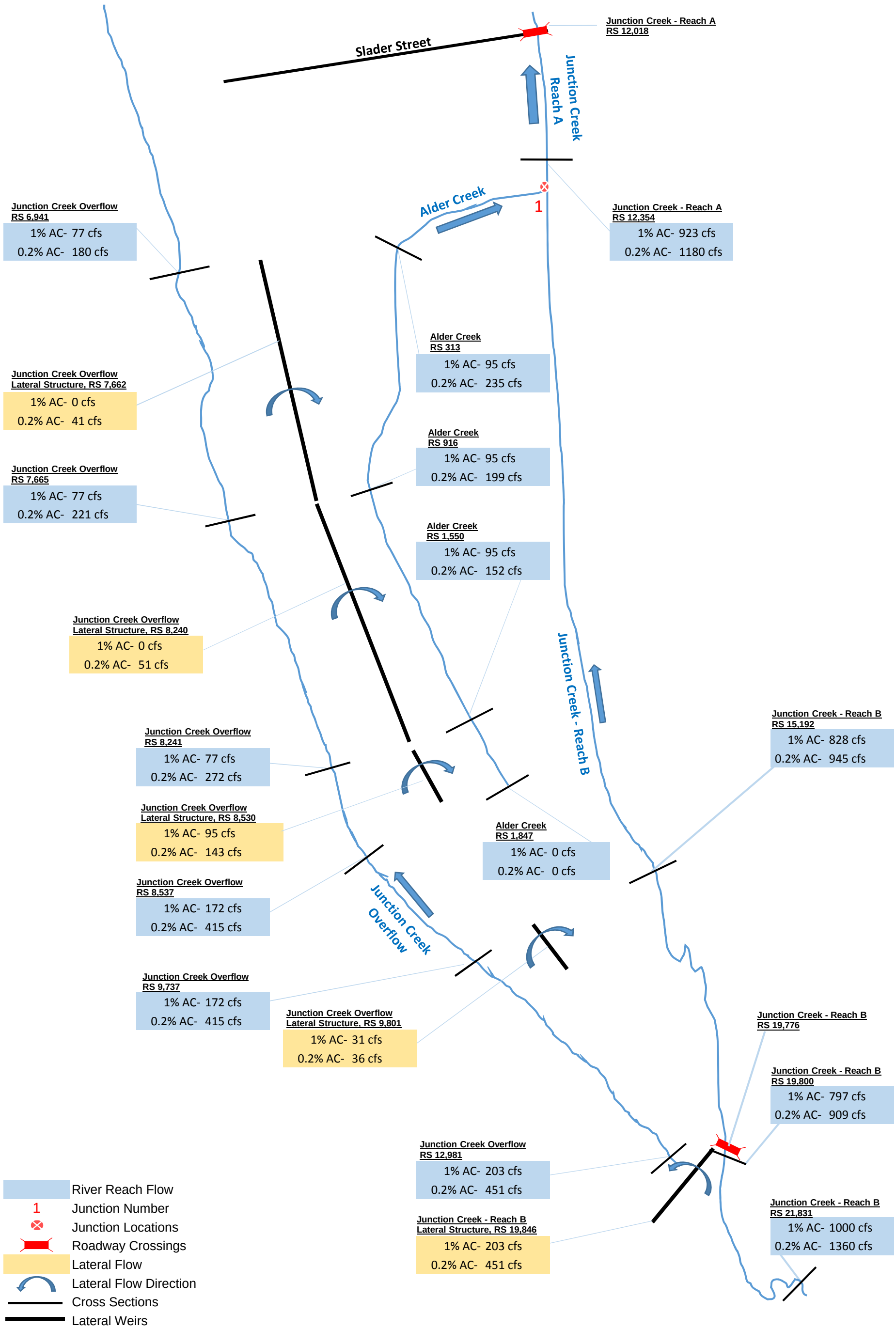

Figure 4: Junction Creek Overflow Worst Case Scenario Flow Diagram

4.11.4 Gleed Ditch

The worst case scenario for flow conveyed by the Gleed Ditch downstream of its point of confluence/diversion from Junction Creek occurs assuming flooding with the existing irrigation canal berm and check structure are in place across the Junction Creek channel and floodplain, and the Gleed Ditch diversion structure gates are open. In the Gleed Ditch worst case scenario, flood flows on Junction Creek upstream of the confluence/diversion are taken from the Junction Creek Worst Case scenario.

Flood flows are conveyed by the Gleed Ditch reach for approximately 2,000-feet, at which point overtopping occurs along right embankment allowing flood water to discharge into an adjacent field to the north. Flows discharged into this field would likely be collected in local drainage depressions and would eventually discharge to either Junction Creek or the Red Rock River near the confluence of those streams. Flood hazard identification in this overflow area is beyond the scope of this study. Additionally, topographic data was not available at the time of this study to calculate flows or provide mapping information. This land is currently under agricultural use with no development. Therefore, flood waters discharging over the embankment were discarded from the model and floodplain mapping processes.

A worst case scenario assuming failure of the Union Pacific Railroad at Gleed RS 1,660 was not completed since the railroad grade is actively maintained and much more substantial than the Gleed Ditch right embankment. During a flood event the irrigation berm would fail instead. The worst case scenario assumes the right embankment does not fail and worst case flows are conveyed past the railroad to the downstream Gleed Ditch reach.

Gleed Ditch generally continues west of study area, crossing old US Highway 91 and I-15 and continuing to the west; providing irrigation water for areas above the natural valley bottom. Modeling and mapping were truncated downstream of the last residence along Gleed Ditch near the old Highway 91 crossing in accordance with the project scope documented in MAS 2016-1.

A flow diagram of the Gleed Ditch worst case scenario including the flow rate upstream, lateral weir discharge, and flow rate downstream for each split flow element is provided in Figure 5 below. Additionally, the flow rate for each flow node is provided in Appendix G. Flow is rounded to the whole cfs in this documentation, while flow is tracked and output in results tables to the hundredth of a cfs in the hydraulic model.

Junction Creek Floodplain Mapping
Mapping Activity Statement: No. 2016-01
Split Flow Data Summary Map
Worst Case Scenario - Gleed Ditch

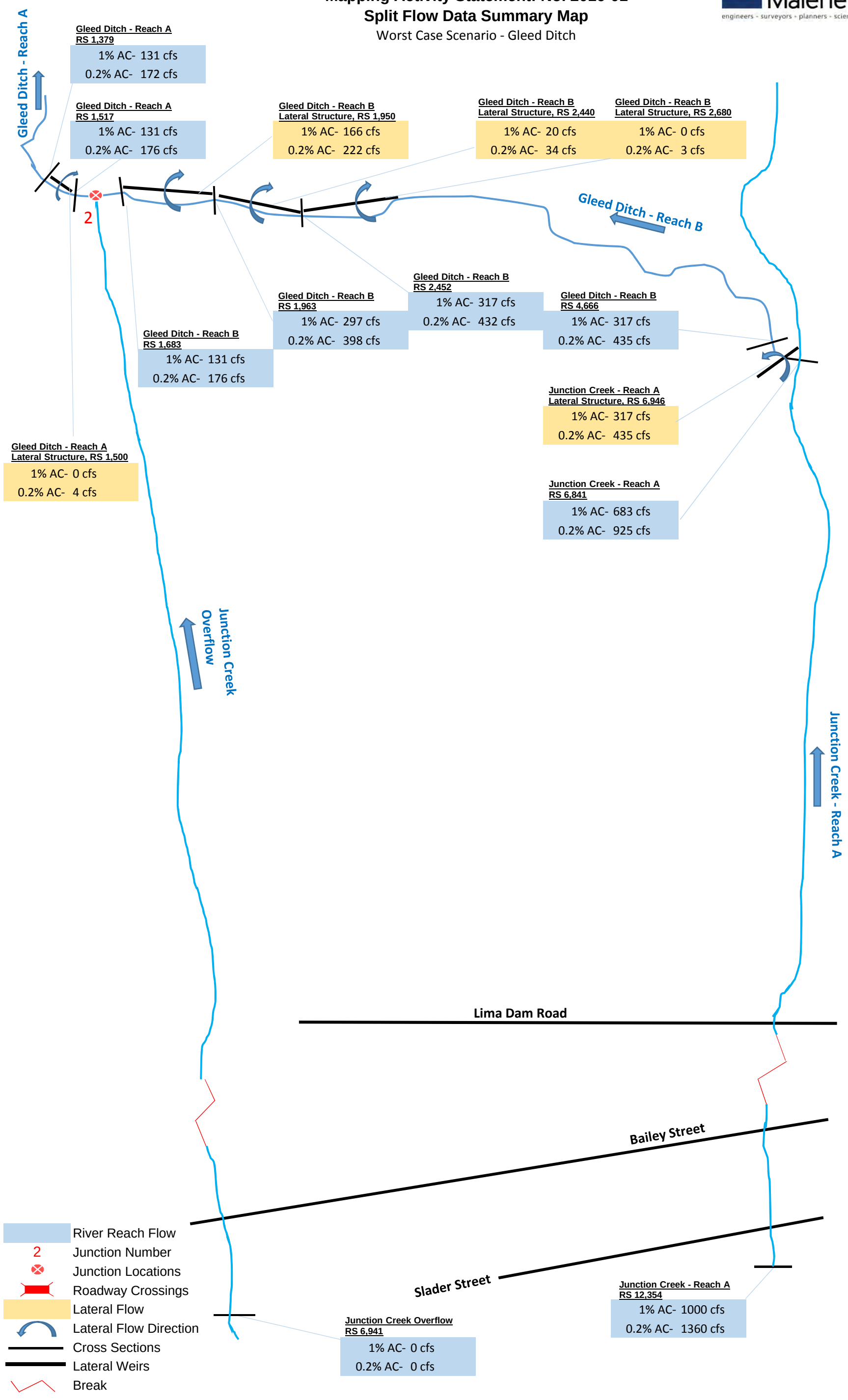

Figure 5: Gleed Ditch Worst Case Scenario Flow Diagram

4.11.5 Regulatory Hydraulic Model

A regulatory model was created based on the worst case scenario results. The HEC-RAS regulatory Plan includes a Geometry file melding all worst case scenarios and a Steady Flow file with all flow node changes from the applicable worst case scenario for each node. Flood flows in the regulatory steady flow file are not in mass-balance. Because the flows are not in balance, the plan does not include confluence junctions or active lateral weir optimization. Instead, the geometry and steady flow data have been altered to match the worst case scenario models for all locations throughout the model. Where confluence junctions were removed, the downstream flow boundary was changed to a known water surface elevation obtained from the worst case model governing each stream reach. Floodway development is based on the geometry and flow change locations in the regulatory geometry and steady flow file.

The Lateral Structure optimization module was used in HEC-RAS to compute flow splits to each modeled reach in HEC-RAS. This module automatically assigns flow data to each modeled cross section reported to one-hundredth of a cubic foot per second. The flow values were rounded to the nearest whole cubic foot per second in the regulatory model plan to provide consistency between reported flow values and modeled flow rates. The error introduced by rounding the flow data generates occasional minor inconsistency in the water surface elevations between the split flow plans with active lateral structure optimization and the Regulatory and Floodway model plans.

A flow diagram of the regulatory hydraulic model including the flow rate upstream, lateral weir discharge, and flow rate downstream for each split flow element is provided in Figure 6 below. Additionally, the flow rate for every flow node is provided in Appendix G.

4.12 Floodways

Floodway limits were computed for Junction Creek at each cross section. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations were tabulated for selected cross sections and are presented in the Floodway Data Tables (see Appendix D). The work maps show only the floodway boundary in cases where the floodway and 1% AC or 0.2% AC floodplains are either close together or coincident.

In Montana, the designated floodway is developed using a 0.5-foot surcharge instead of the Federal maximum of 1.0-foot (DNRC, 2014). These criteria take precedence over the minimum Federal criteria for purposes of regulating development in the floodplain, as set forth in the Code of Federal Regulations, 44 CFR, 60.3(d)(2).

Development of the full 0.5-feet of surcharge allowance is not always possible at all cross sections. The 0.5-foot allowance is a maximum limit that cannot be exceeded at any cross section throughout the study reach. Floodway modeling may produce a surcharge at an upstream cross section that exceeds the 0.5-foot maximum limit. Therefore, some cross sections, as shown in the Floodway Data Table, have surcharges of less than the 0.5-foot maximum allowable limit because of the effect that a greater encroachment at these locations would have on adjacent cross section surcharges.

Junction Creek Floodplain Mapping
Mapping Activity Statement: No. 2016-01
Split Flow Data Summary Map
All Streams - Regulatory Flows

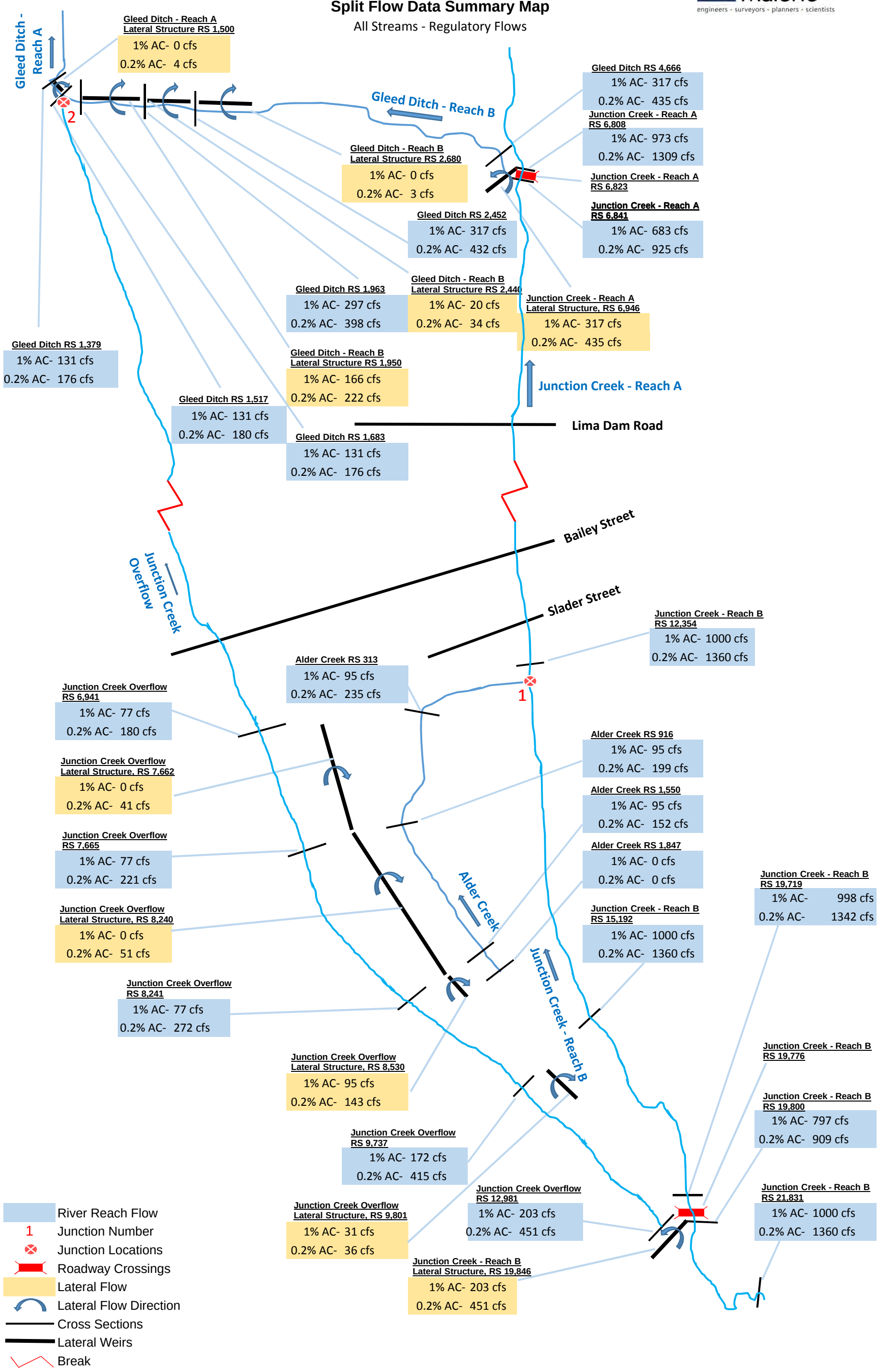

Figure 6: Regulatory Discharges Flow Diagram

Determination of whether separate regulatory floodways were to be completed for the split flow reaches was evaluated in accordance with FEMA Guidelines and Specifications, (FEMA, 2016c). This protocol includes calculating the water-surface elevations for the total flow in the main channel and comparing the water-surface elevations with the reduced flow rate due to flow divergence to the split flow reaches. If the difference in water-surface elevations is greater than the 0.5 foot maximum regulatory surcharge, then a separate regulatory floodway must be delineated for the split flow channels of the main stream as well as the flooding source stream reach.

This criteria was evaluated for the Junction Creek worst case scenario of the 1% AC flood. In the Junction Creek worst case scenario, the full 1% AC flow is conveyed by Junction Creek. Therefore, floodways for the split flow reaches of Junction Creek were not required.

4.13 Critical Depth & Profile Smoothing

The hydraulic model has been defined and calibrated for the 1% AC event. Therefore, there are critical depth defaults in the model at various locations on various non-regulatory profiles that result due to the modeling focus on the regulatory profile.

Additionally, critical depths have been allowed to remain in the model at a few locations where a critical or supercritical flow regime is hydraulically reasonable (Table 19). Generally, these locations are at, or near, structures where a flow regime change is likely to occur. At these locations, sensitivity analysis of model variables including, cross section location, structure modeling approach, expansion & contraction coefficients, inlet type, structure coefficients, and floodplain and channel roughness was performed. The final variable values were selected to yield a reasonably conservative estimate of the regulatory water surface. As this model has been completed using sub-critical calculation routines in HEC-RAS, a super-critical profile is not provided in the model. Additionally, in accordance with FEMA Guidance (FEMA, 2016c) the critical depth is reported for the cross section and presented on the Flood Profiles.

Table 19: 1% AC Critical Depth Calculations in Hydraulic Model

Stream Reach	River Station	Modeler's Notes
Alder Creek	1,847	Cross section required at start of reach, no flood source flow, flow set at 0.001-cfs per HEC-RAS required positive flow, modeling idiosyncrasy due to one-dimensional modeling parameters/limitations for split flow analysis with lateral weirs.
Junction Creek	8,560	Cross section 2 of a road overtopping crossing. Critical depth calculation as part of weir overtopping and culvert outlet conditions.
Junction Creek	11,996	Cross section 2 of a road overtopping crossing. Critical depth calculation as part of weir overtopping and downstream bridge conditions.
Junction Creek Overflow	6,047	Cross-section 1 of a road overtopping crossing. Critical depth calculation as part of weir overtopping condition.
Junction Creek Overflow	8,447	Cross section associated with lateral structure flow split discharging flow to Alder Creek.

Profile smoothing is required where minor modeling numerical idiosyncrasy or structure effects results in a water surface elevation higher than the upstream calculation node. As this type of hydraulic jump is less conservative than a water surface profile that is flat or increases upstream, the numerical model is typically checked carefully and adjusted to remove the drawdown. In some cases, especially around structures, a hydraulic jump downstream may reasonably occur; in these cases the flood profile is smoothed to present reasonable water surface elevations. Smoothing was completed in accordance with FEMA Guidance *Flood Profiles* (FEMA, 2016a). Locations where smoothing was completed are shown in Table 20 below for the 1% AC regulatory flood. The hydraulic model is tuned for the 1% AC flood profile; other profiles were smoothed both at the locations noted below and at additional locations where model inputs resulted in a drawdown for the non-regulatory flood profile.

Table 20: 1% AC Profile Smoothing River Stations

Stream Reach	River Stations	Modeler's Notes
Alder Creek	1,847	HEC-RAS requires both an upstream and downstream calculation node for a river reach receiving discharge flows from a lateral weir/culvert. Alder Creek RS 1,847 has no source flow and the profiles have been smoothed to the ponded water surface created by Alder Creek RS 1,739.
Gleed Ditch	4,421 to 4,531	Drawdown of 0.0006-feet – Smoothed to rounded DS elevation. Caused by stabilizing water surface calculations below weir discharging flow to the reach.
Junction Creek	8,630 to 8,749	Drawdown of 0.0098-feet – Smoothed to rounded DS elevation. Caused by numerical convergence parameters as stream profile transitions from valley slope to ponded conditions upstream of Lima Dam Road.
Junction Creek	9,412	Drawdown within pedestrian bridge crossing. Smoothed to downstream calculation node water surface.
Junction Creek	9,729 to 9,759	Drawdown of 0.0092-feet – Smoothed to rounded DS elevation. Caused by numerical convergence parameters as stream profile transitions from valley slope to ponded conditions upstream of First Avenue Bridge.
Junction Creek	10,517	Drawdown within pedestrian bridge crossing. Smoothed to downstream calculation node water surface.
Junction Creek	11,619 to 11,717	Drawdown and hydraulic jump through the Bailey Street culvert and upstream calculation node. Smoothed structure interior to downstream calculation node water surface and smoothed upstream to level backwater at culvert inlet.
Junction Creek	19,776	Drawdown and hydraulic jump within multiple opening culverts related to deep headwater. Crossing profiles occur due to drawdown within culverts. Profiles smoothed to eliminate drawdown and crossing profiles within multiple opening.
Junction Creek	21,326	Drawdown and hydraulic jump within multiple opening culverts related to deep headwater. Crossing profiles occur due to drawdown within culverts. Profiles smoothed to eliminate drawdown and crossing profiles within multiple opening.

4.14 cHECk-RAS

FEMA's automated review software cHECk-RAS, Version 2.0.1 (FEMA, 2011) was utilized to verify the acceptability of the hydraulic analyses described above. The currently available version of cHECk-RAS is designed to read output data from HEC-RAS 4.1.0. However, HEC-RAS version 5.0.3 was uploaded into cHECk-RAS since variations between calculated water surfaces were identified between the HEC-RAS version 5.0.3 numerical model runs required by contract and HEC-RAS 4.1.0 numerical model runs. Several messages in cHECk-RAS are incorrect and appear to be related to the loss of output reading functionality when cHECk-RAS reads HEC-RAS 5.0.3 output data. These messages were checked to verify a cHECk-RAS reading error and noted on the cHECk-RAS report. cHECk-RAS checks the following five categories of the hydraulic modeling:

- NT (Manning's roughness coefficients and transition loss coefficients)
- XS (Cross sections)
- Floodways
- Structures
- Profiles

The cHECk-RAS output messages for the Junction Creek model were reviewed and each issue was either resolved or investigated to confirm that the modeling is correct. Appendix E includes the list of cHECk-RAS messages and responses to each message.

5.0 Floodplain Mapping

Floodplain mapping was prepared using GeoHECRAS mapping tools and ESRI ArcMap 10.5 (ESRI, 2016). The GeoHECRAS application generates the raw floodplain area by intersecting the LiDAR Digital Elevation Model with a separate Digital Elevation Model (DEM) representing the water surface elevations of the 1% AC and 0.2% AC events. The results of the hydraulic modeling and topographic data are used to create products for end users that are described in the following sections.

5.1 Hydraulic Work Maps

The resulting floodplains for the 1% AC and 0.2% AC flood events are displayed on the hydraulic work maps provided in Appendix A. The base map used for the hydraulic work map is the 2015 NAIP aerial photograph. Along with the flooding extents, the work map also displays the stream profile baseline along with the cross sections utilized in the hydraulic analysis. The layout of the cross sections and structures under existing conditions are presented on the work maps. At some locations, modeled cross sections have been removed from the work maps for clarity due to dense placement required for the numerical model. Node names have been recorded in the model to assist the user when reviewing the model and the work maps; lettered cross sections are named with the appropriate letter label; mapped non-lettered cross sections are noted as NL - not labeled; non-lettered, non-mapped cross sections are noted as NL/NM - for not labeled and not-mapped.

Zone AE symbolized polygons are the delineated regulatory floodplain. The Junction Creek and split flow floodplains have been delineated in accordance with the modeling as discussed in Section 4 “Hydraulics” above.

Typically, islands that appeared to be less than one-foot higher than the adjacent 1% AC water surface profile were not delineated. Island areas one-half acre or greater in size that were bulky in shape and appeared to be one-foot or higher above the adjacent 1% AC water surface profile were evaluated on a case-by-case basis. One island was mapped out of the surrounding floodplain in the right overbank of Junction Creek in proximity to RS 9,900. This location is approximately one-half acre in size, is a bulky shape approximately 150-feet in diameter, includes a residence, and appears to be 1-2 feet above the adjacent 1% AC water surface profile.

Large backwater areas were modified to represent the elevation associated with the location where the backwater initiates from the main channel. These two adjustments provide a slight variance in the mapped widths versus the top widths described by the HEC-RAS mode at selected locations.

5.2 Map Tie-in Locations

The proposed study has larger study limits than the effective mapping. No other currently regulated flooding sources intersect streams and split flow reaches within the study area.

5.3 Floodplain Boundary Smoothing

Floodplain Boundary Smoothing was completed in compliance with the May 2016 FEMA FIRM Database Schema and FEMA Database Verification Tool parameters applicable at the time this project contract was signed in November of 2016. Floodplain smoothing was conducted using several automated processing tools and manually corrected after processing to ensure floodplain widths, fringe widths, polygon gaps, and polygon overlaps all met FEMA criteria. The QC process for floodplain boundary preparation was documented in a review checklist which has been included in Appendix F.

5.4 Changes Since Last FIRM Mapping

Changes Since Last FIRM (CLSF) mapping was completed as requested by the DNRC and included with study products. CSLF mapping products and work maps assist public entities and landowners in interpreting the changes to the floodplain mapping proposed for the new study compared to the effective study to be replaced. Work map pages and spatial files are provided in the Supplemental Data folder of the digital submission.

5.5 Letters of Map Change

At the time of this floodplain study, no record of Letters of Map Change or Letters of Map Amendment was found within the study limits.

5.6 Floodplain Boundary Standard Audit

A Floodplain Boundary Standard (FBS) Audit was completed as part of the Floodplain Mapping Task scope of work. The FBS Audit is a standardized self-review of the regulatory floodplain boundary to be carried into final mapping products. This project was within risk class C, which requires at least 85% of the test points must be within +/- 1 foot of the ground elevation. More than 96% of the test points passed the audit criteria for this project. The FBS Audit summary report has been included in Appendix F and the test points shapefile has been included in the Supplemental Data folder of the digital submission.

5.7 Depth Grids

Depth Grids were prepared for each profile included in the hydraulic model (10%, 4% 2%, 1% 1plus, & 0.2% AC). They were prepared in accordance with the FEMA Guidance *Flood Depth and Analysis Grids* and have been included in the Supplemental Data folder of the digital submission.

6.0 Flood Insurance Study Products

Digital profiles for the 10%, 4%, 2%, 1%, 1%+, and 0.2% annual-chance water surface elevations were created using FEMA's RASPLOT software (FEMA 2013). The HEC-RAS 5.0.3 data files could not be imported directly into RASPLOT. Instead, RASPLOT was used to create an empty database editable in Microsoft Access. HEC-RAS output data was manually extracted, organized in Microsoft Excel prior to importing in the database using Microsoft Access. Minor edits and corrections were then completed in RASPLOT following the typical workflow process and the profile plots were created in .dxf file format. Additional information, edits and formatting were made using AutoCAD. Profiles were developed following Flood Profiles FEMA Guidance for Flood Risk Analysis and Mapping (FEMA 2016a). The profiles illustrating the results of the study are provided in Appendix B.

7.0 References

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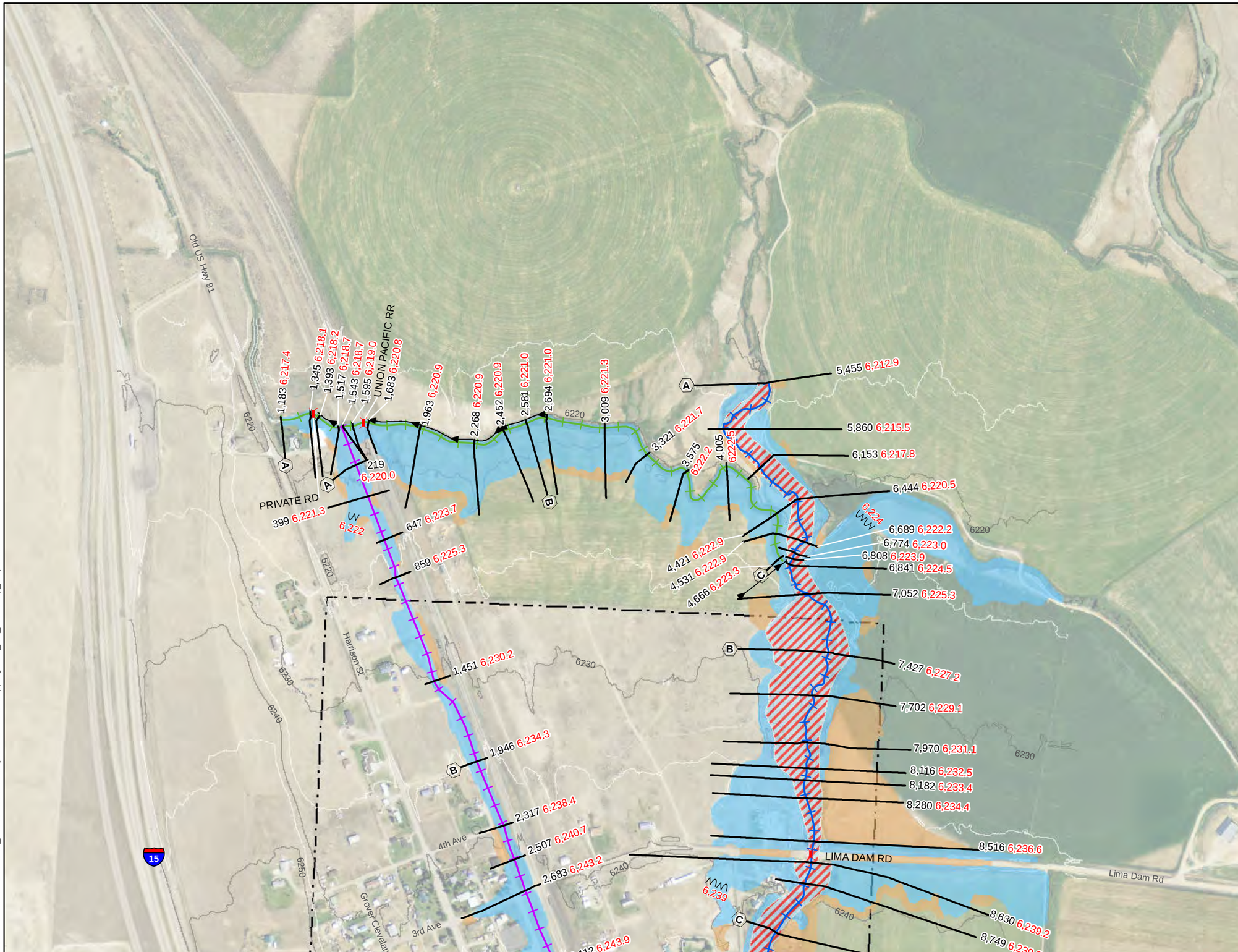
APPENDICES

Appendix A – Hydraulic Work Maps

JUNCTION CREEK TOPOGRAPHIC WORK MAP



LEGEND

- Alder Creek
- Gleed Ditch
- Junc Crk Overflow
- Junction Creek
- Roadway Crossings
- Lima Town Limits
- Cross Sections
- Lateral Weir

Proposed Flood Hazard Area

- 0.2% AC (500 Yr)
- 1% AC (100 Yr)
- Floodway
- Backwater
- 5' Contour
- 10' Contour

Labels

- (A) Cross Section Letter
- 5,455 River Station
- 6,212.9 Water Surface Elevation
- 100 Feet Along Profile Baseline

0 250 500 750 Feet

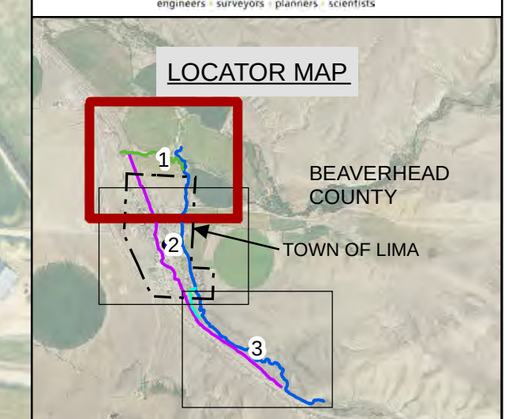
Hydraulic Work Map - Junction Creek Watershed Project
Beaverhead County, MT Risk MAP - MAS No. 2016-01
Imagery: NAIP 2015
Topographic Data, LiDAR 2017
Horizontal Datum: NAD83, Vertical Datum: NAVD88, Feet
Date: 07/10/2018
Note: To improve mapping clarity, not all modeled cross sections are displayed in this work map.

MONTANA DNRC

BEAVERHEAD COUNTY · wide·open·adventure

Morrison Maierle
engineers · surveyors · planners · scientists

LOCATOR MAP



Junction Creek Map 1 of 3

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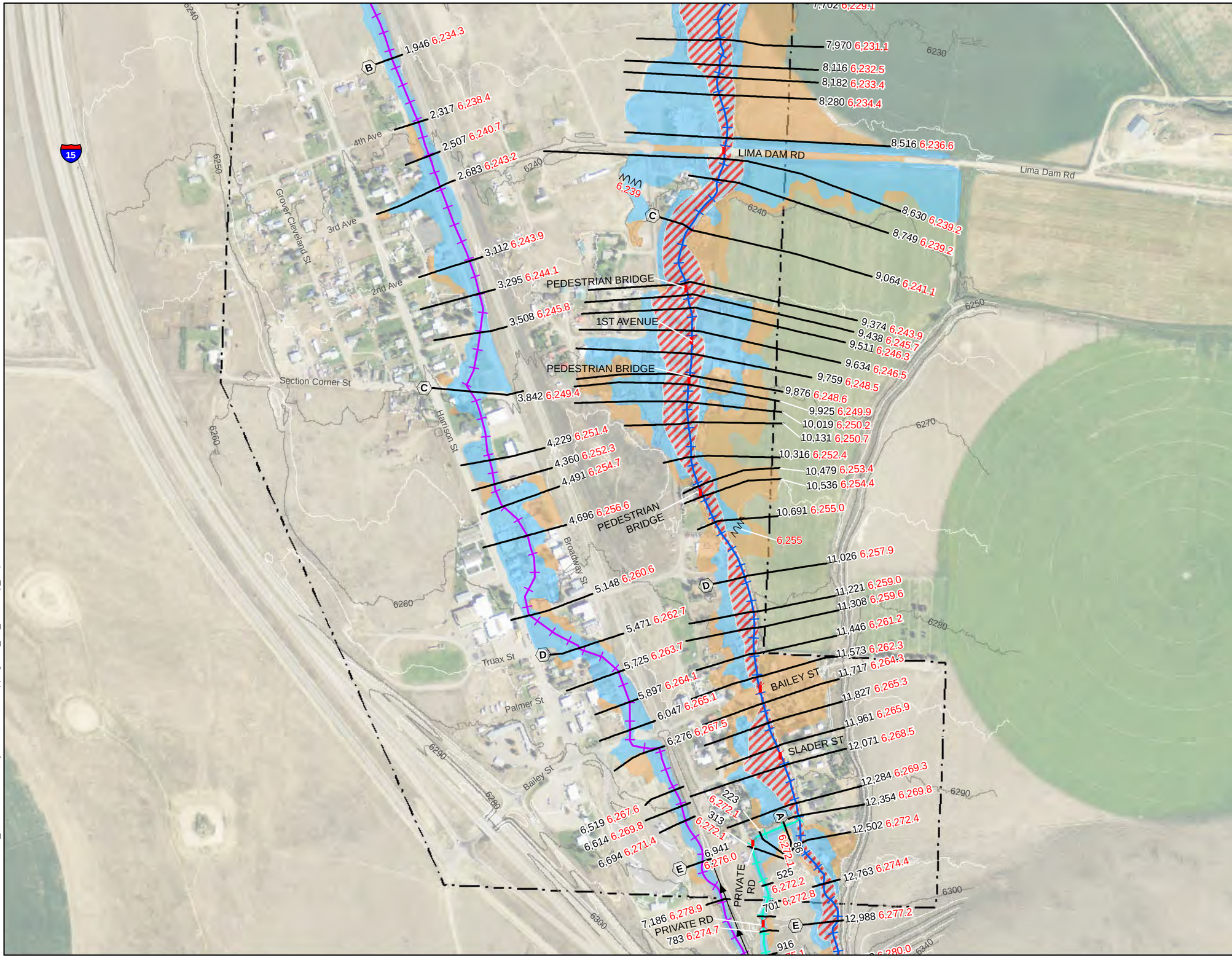
JUNCTION CREEK TOPOGRAPHIC WORK MAP



LEGEND

- Alder Creek
- Gleed Ditch
- Junc Crk Overflow
- Junction Creek
- Roadway Crossings
- Lima Town Limits
- Cross Sections
- Lateral Weir

Proposed Flood Hazard Area

- 0.2% AC (500 Yr)
- 1% AC (100 Yr)
- Floodway
- Backwater
- 5' Contour
- 10' Contour

Labels

- (A) Cross Section Letter
- 5,455 River Station
- 6,212.9 Water Surface Elevation
- 100 Feet Along Profile Baseline

0 250 500 750 Feet

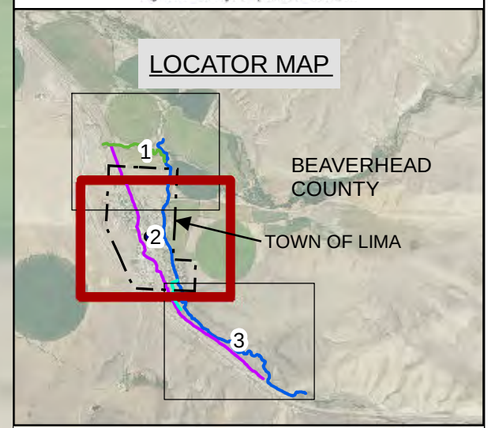
Hydraulic Work Map - Junction Creek Watershed Project
Beaverhead County, MT Risk MAP - MAS No. 2016-01
Imagery: NAIP 2015
Topographic Data, LiDAR 2017
Horizontal Datum: NAD83, Vertical Datum: NAVD88, Feet
Date: 07/10/2018
Note: To improve mapping clarity, not all modeled cross sections are displayed in this work map.

MONTANA DNRC

BEAVERHEAD COUNTY

Morrison Maierle
engineers • surveyors • planners • scientists

LOCATOR MAP



Junction Creek Map 2 of 3

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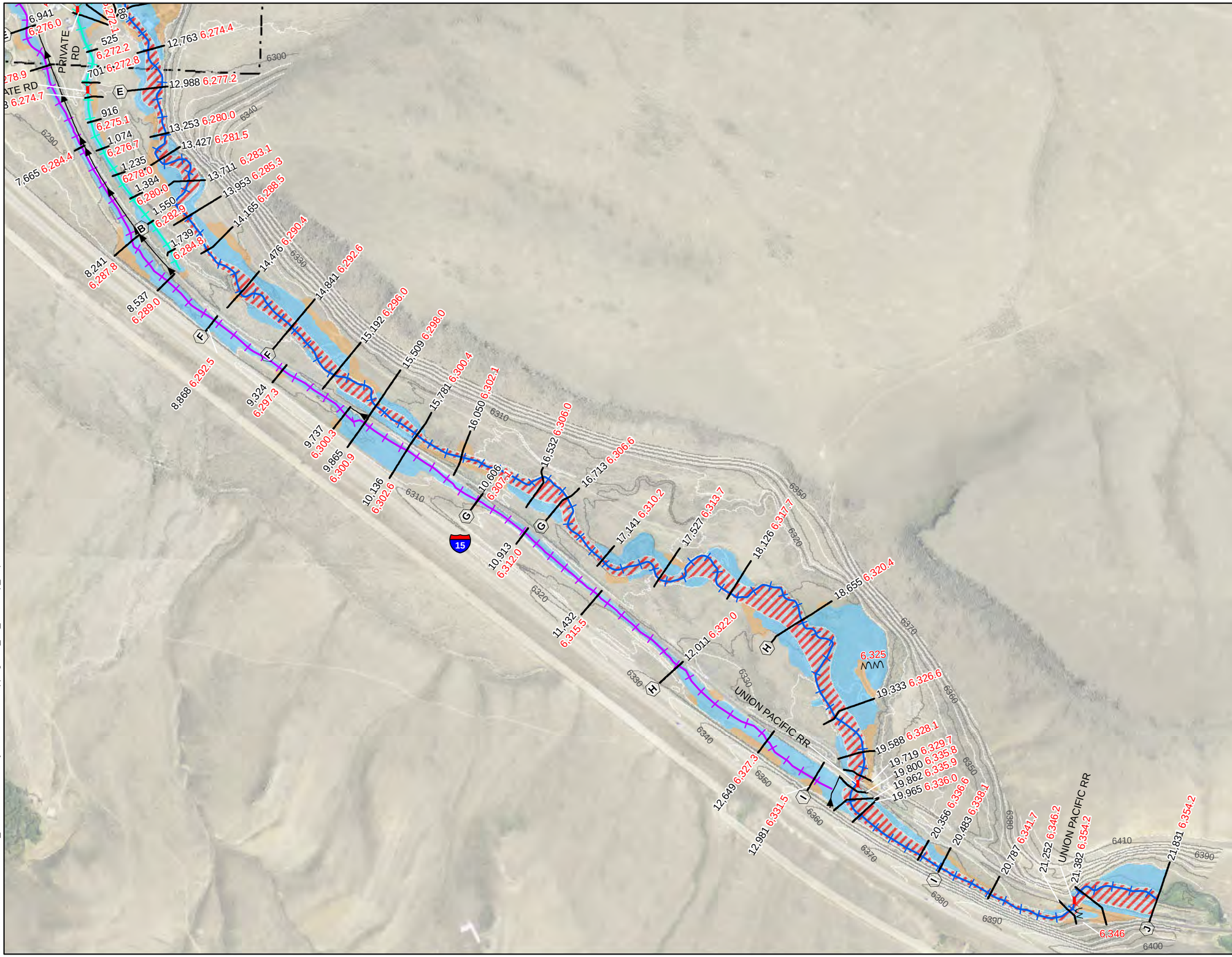

JUNCTION CREEK TOPOGRAPHIC WORK MAP

LEGEND

- Alder Creek
- Gleed Ditch
- Junc Crk Overflow
- Junction Creek
- Roadway Crossings
- Lima Town Limits
- Cross Sections
- Lateral Weir

Proposed Flood Hazard Area

- 0.2% AC (500 Yr)
- 1% AC (100 Yr)
- Floodway
- Backwater
- 5' Contour
- 10' Contour

Labels

- (A) Cross Section Letter — 5,455 River Station
- 6,212.9 Water Surface Elevation
- 100 Feet Along Profile Baseline

0 250 500 750 Feet

Hydraulic Work Map - Junction Creek Watershed Project
Beaverhead County, MT Risk MAP - MAS No. 2016-01
Imagery: NAIP 2015
Topographic Data, LiDAR 2017
Horizontal Datum: NAD83, Vertical Datum: NAVD88, Feet
Date: 07/10/2018
Note: To improve mapping clarity, not all modeled cross sections are displayed in this work map.

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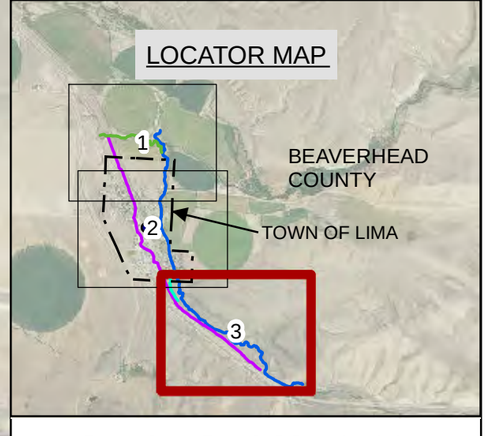

Junction Creek Map 3 of 3

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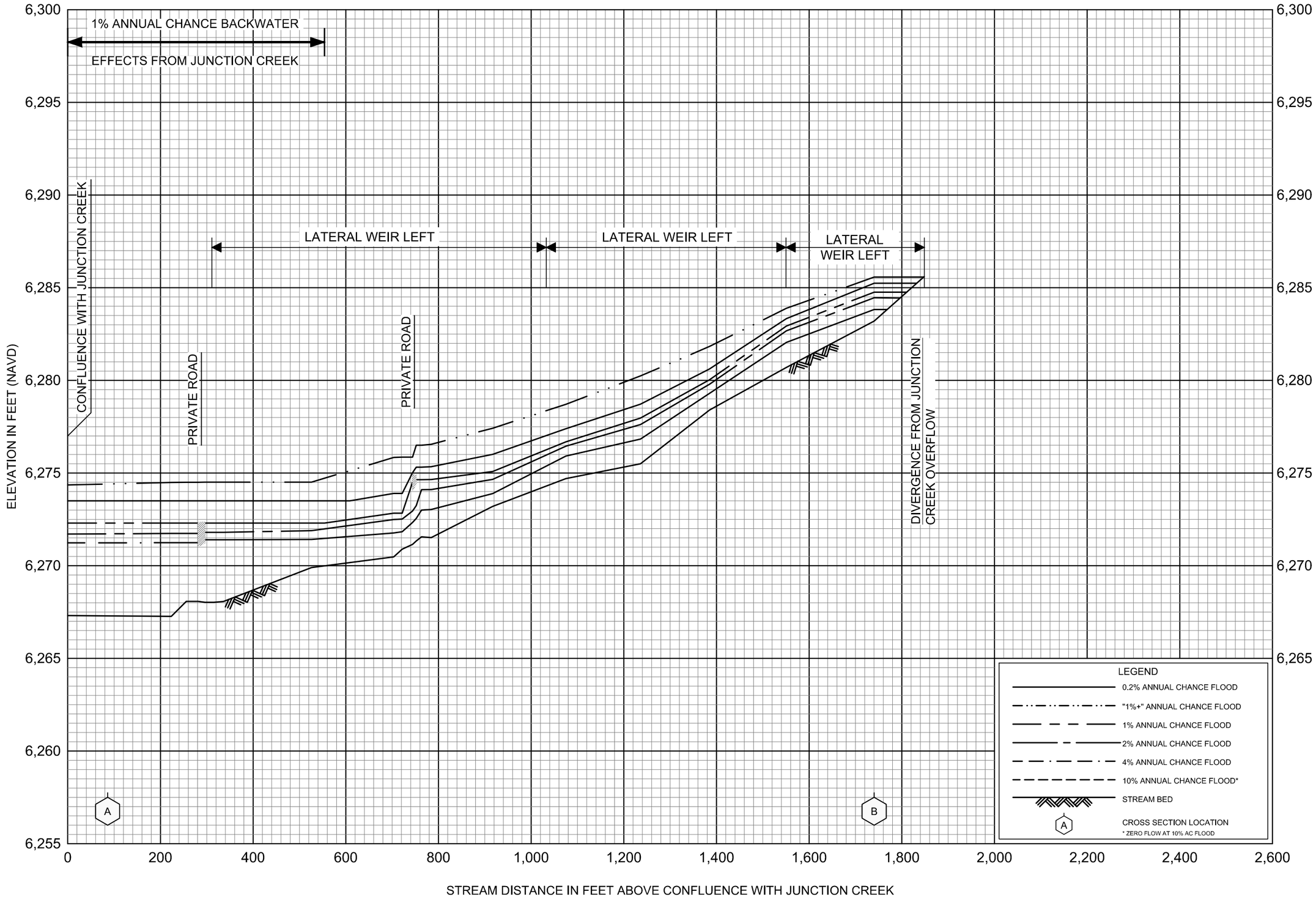
Appendix B – Profiles

- Alder Creek
- Gleed Ditch
- Junction Creek
- Junction Creek Overflow



FLOOD PROFILES

ALDER CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

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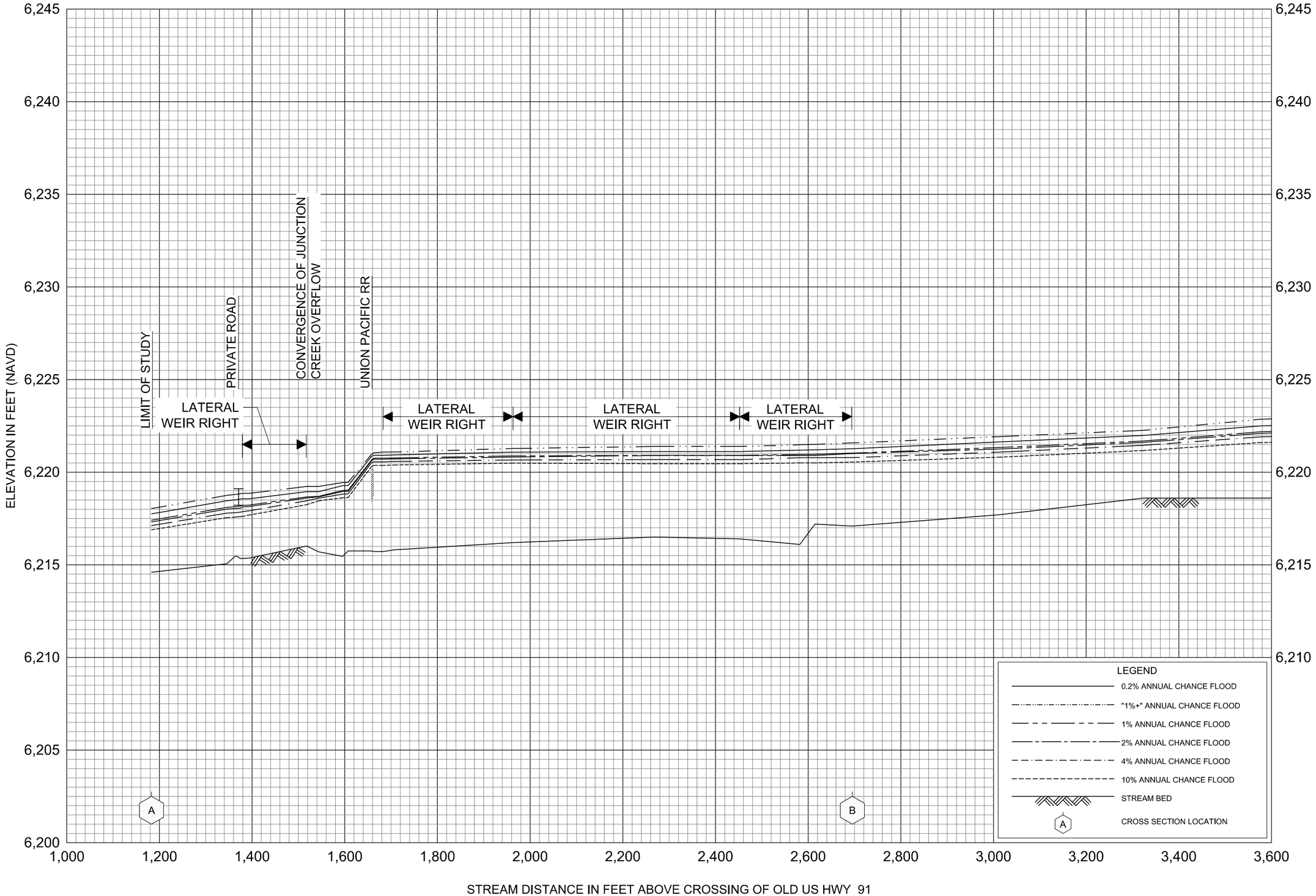

FLOOD PROFILES

GLEED DITCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

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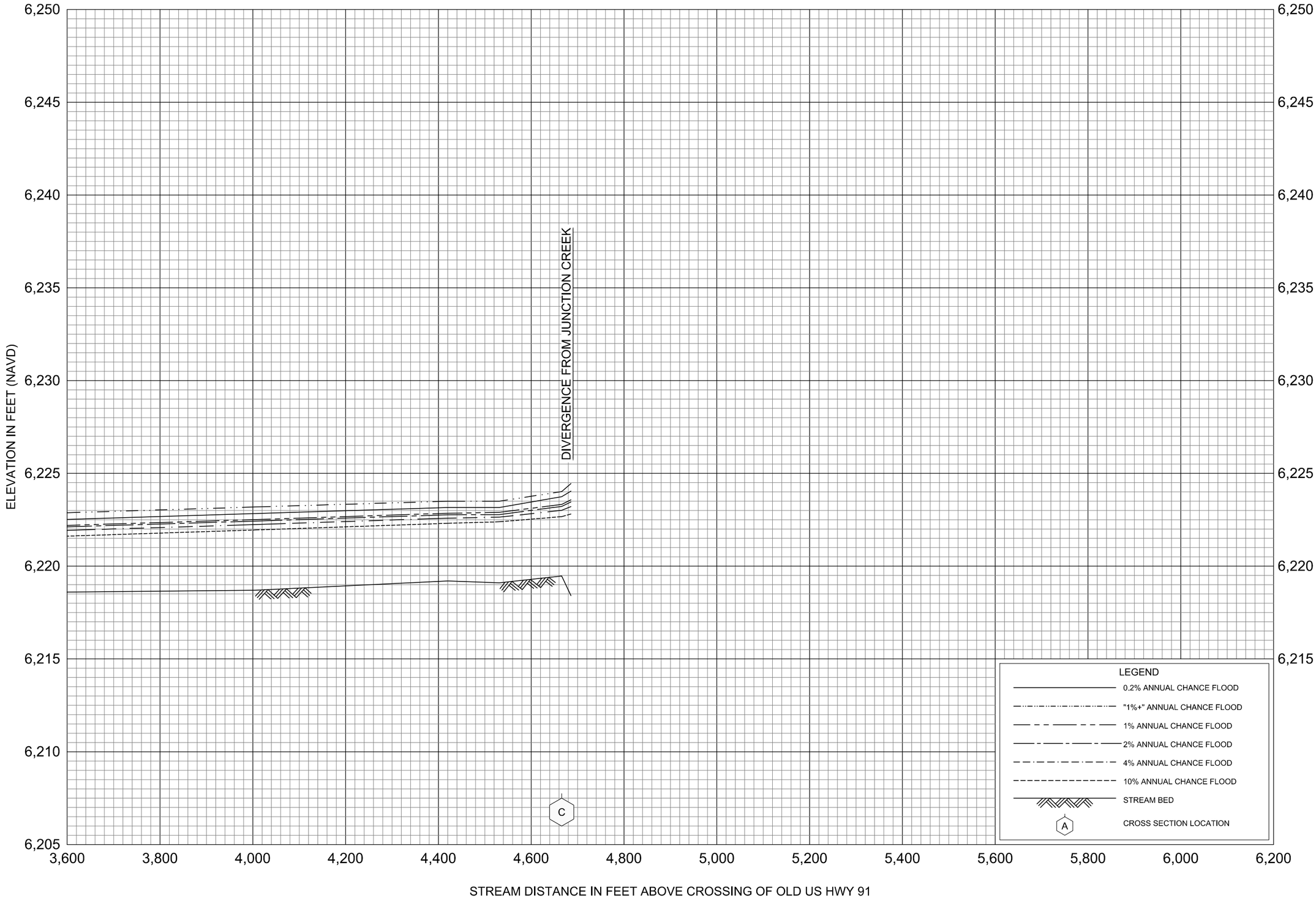


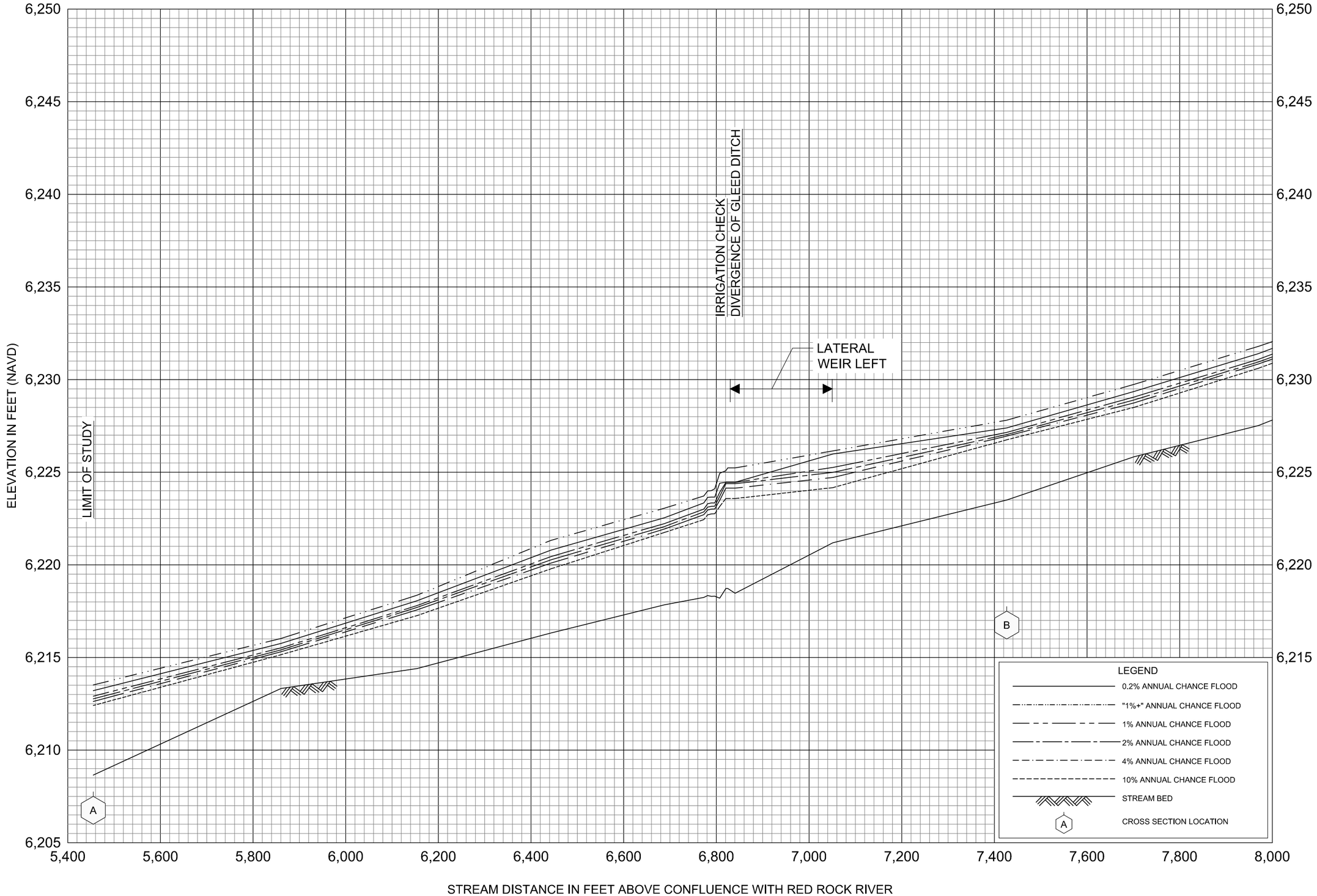
FLOOD PROFILES

GLEED DITCH

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



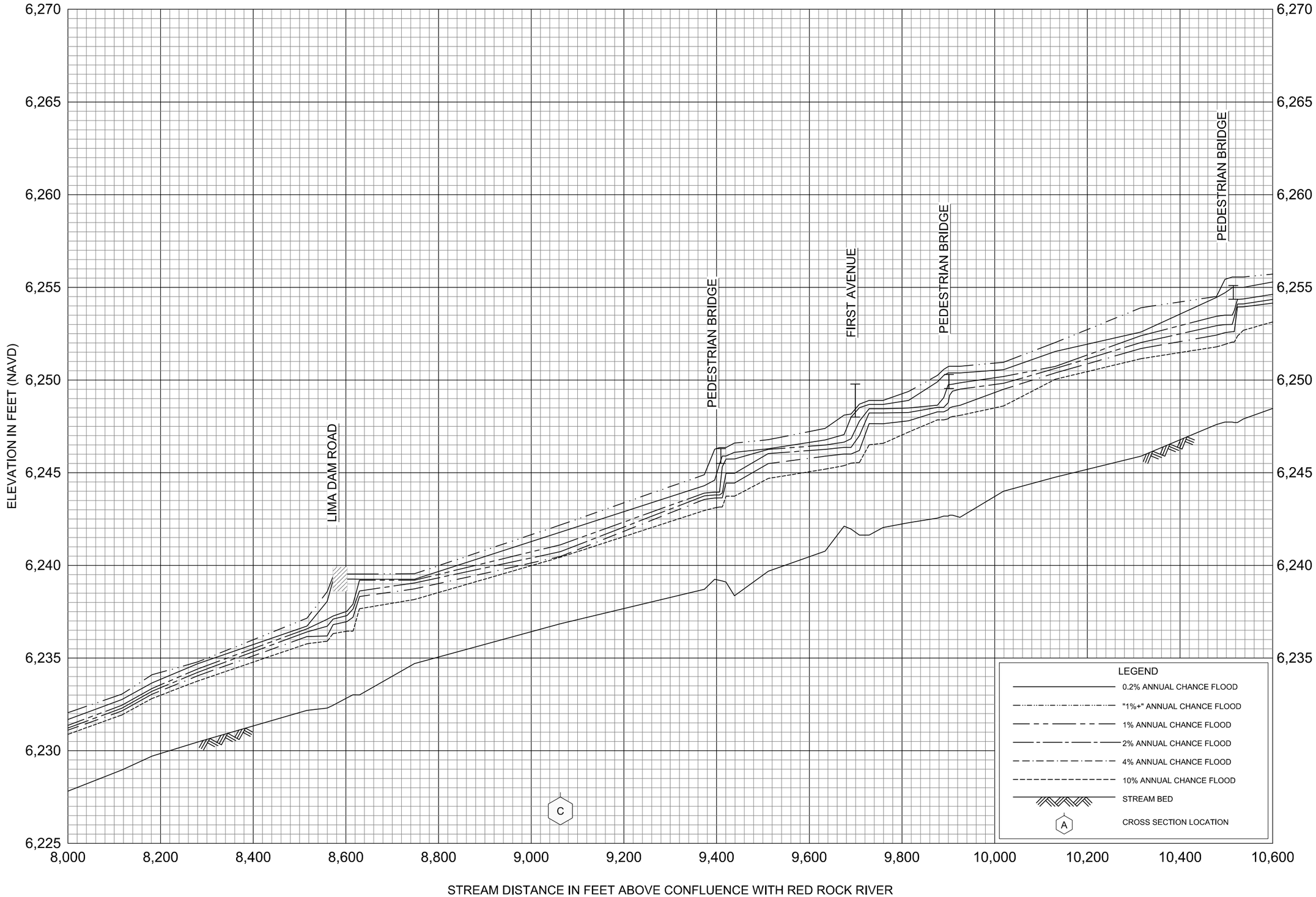
FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

JUNCTION CREEK

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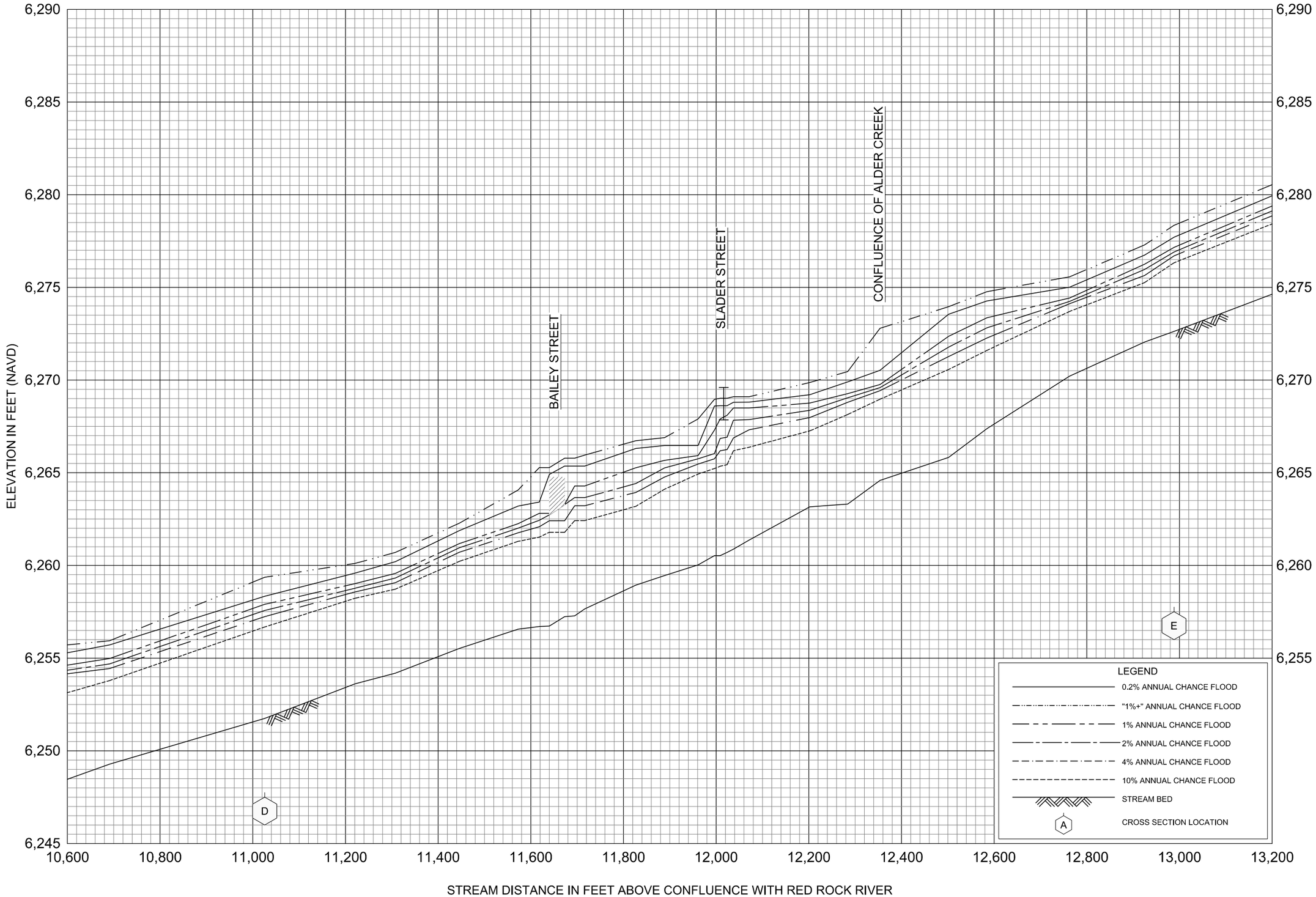
BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

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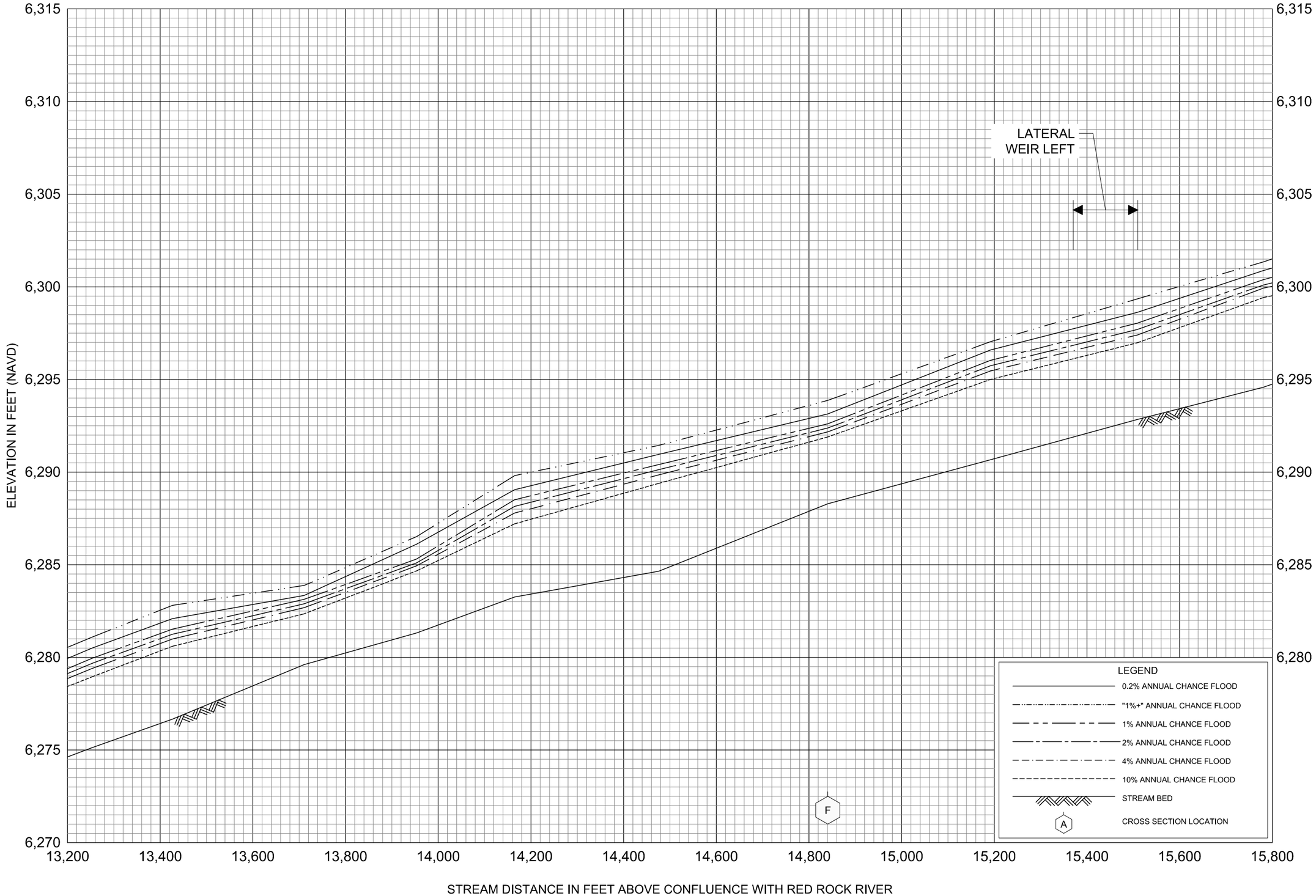


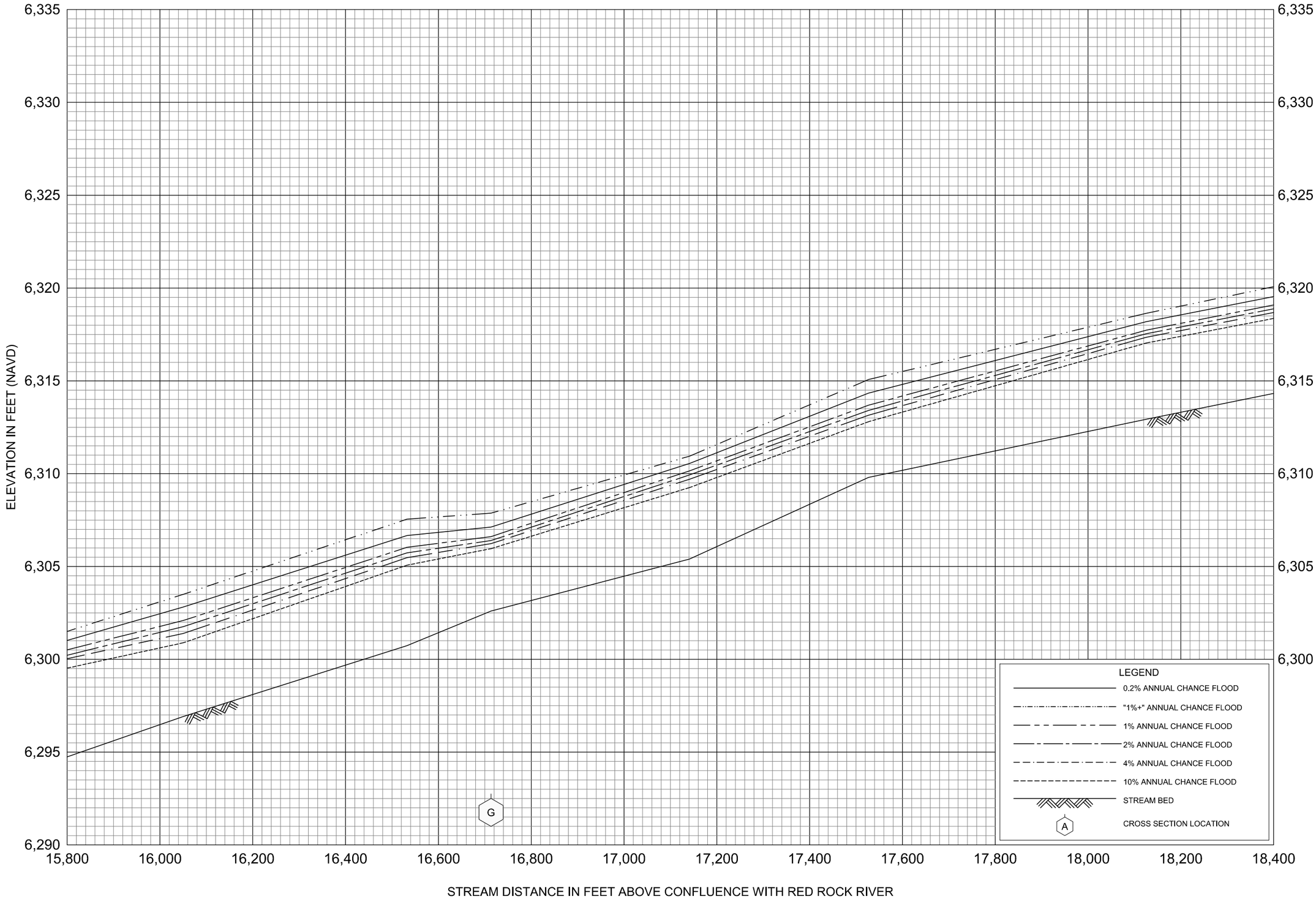
FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



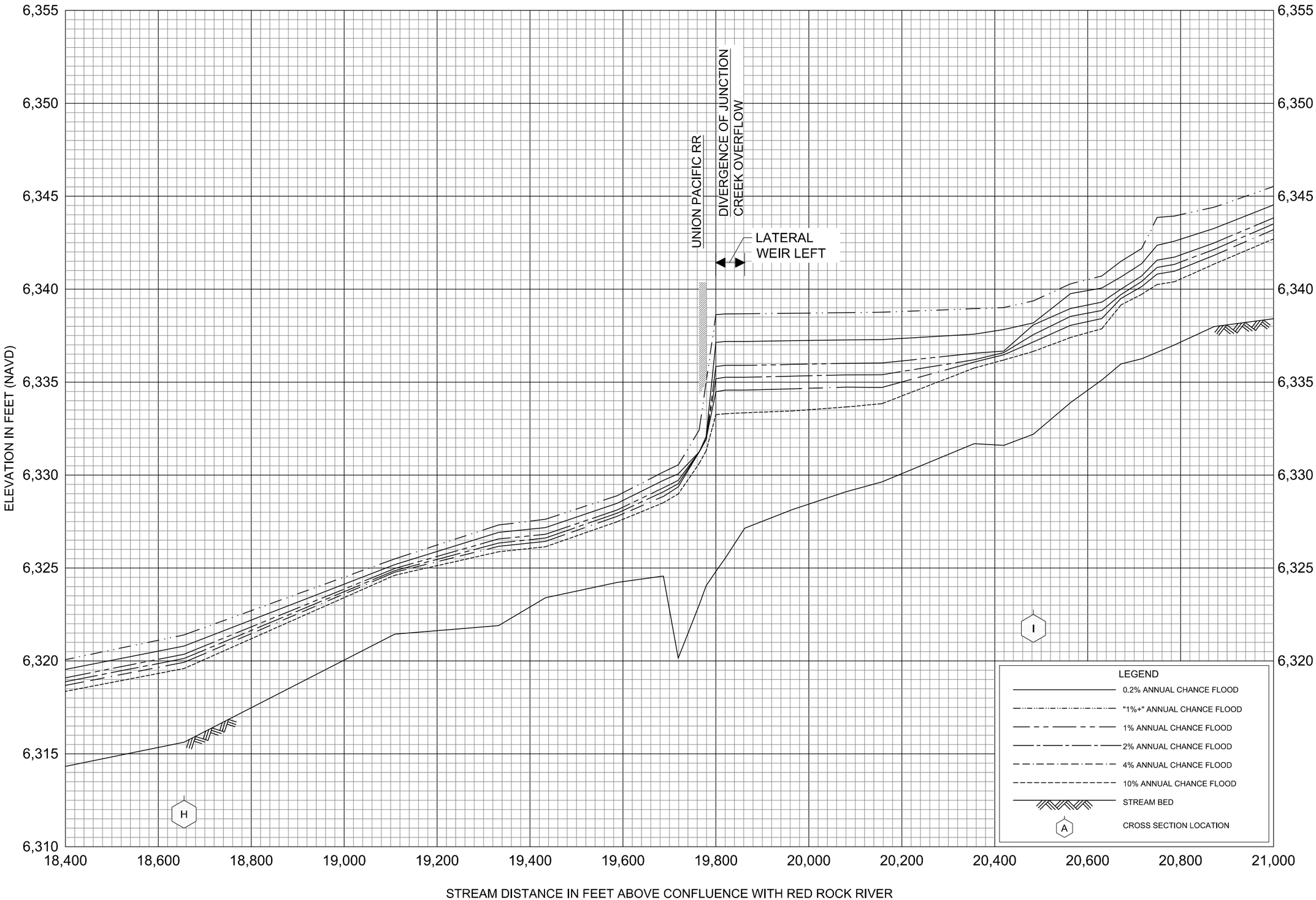
FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

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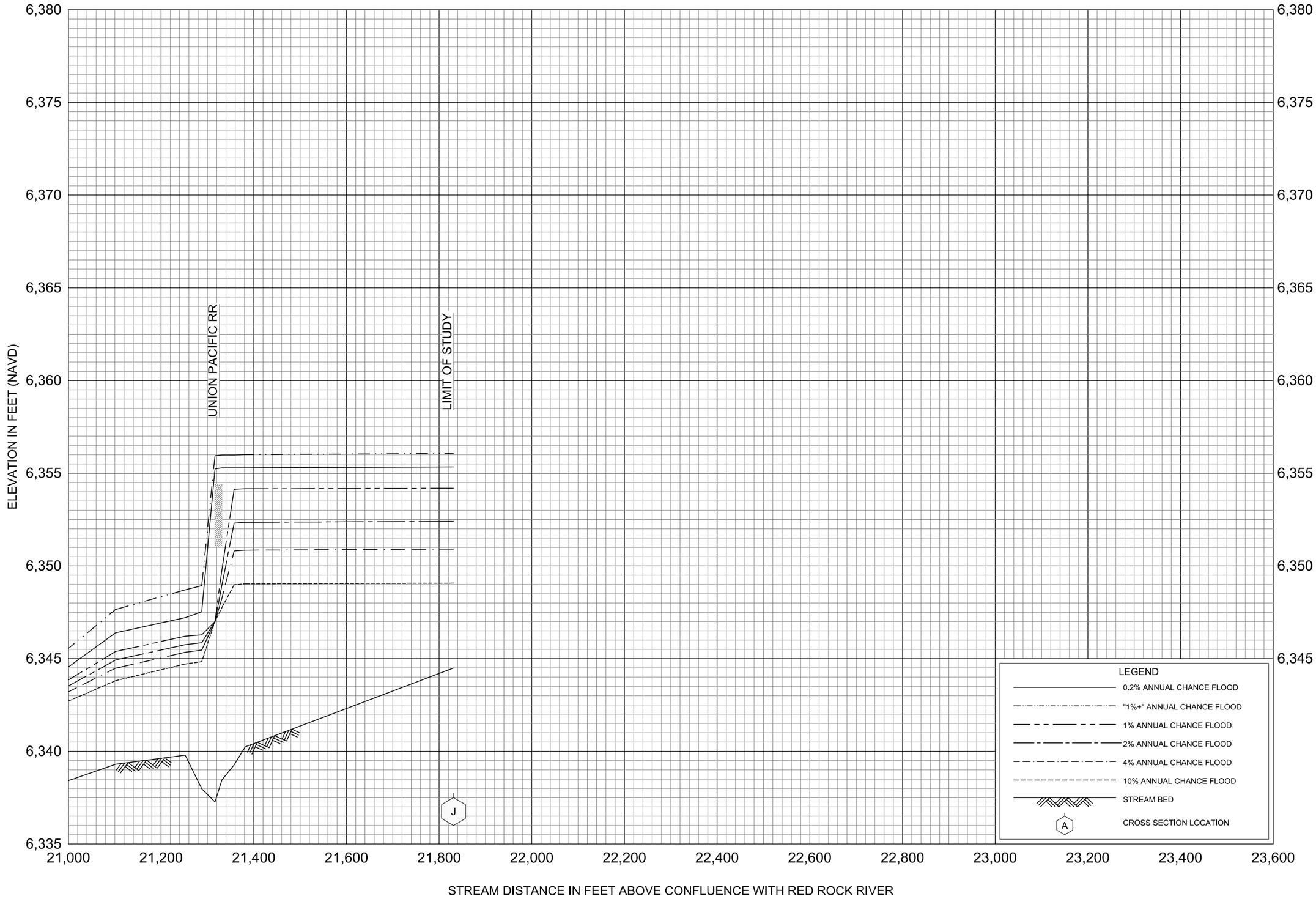


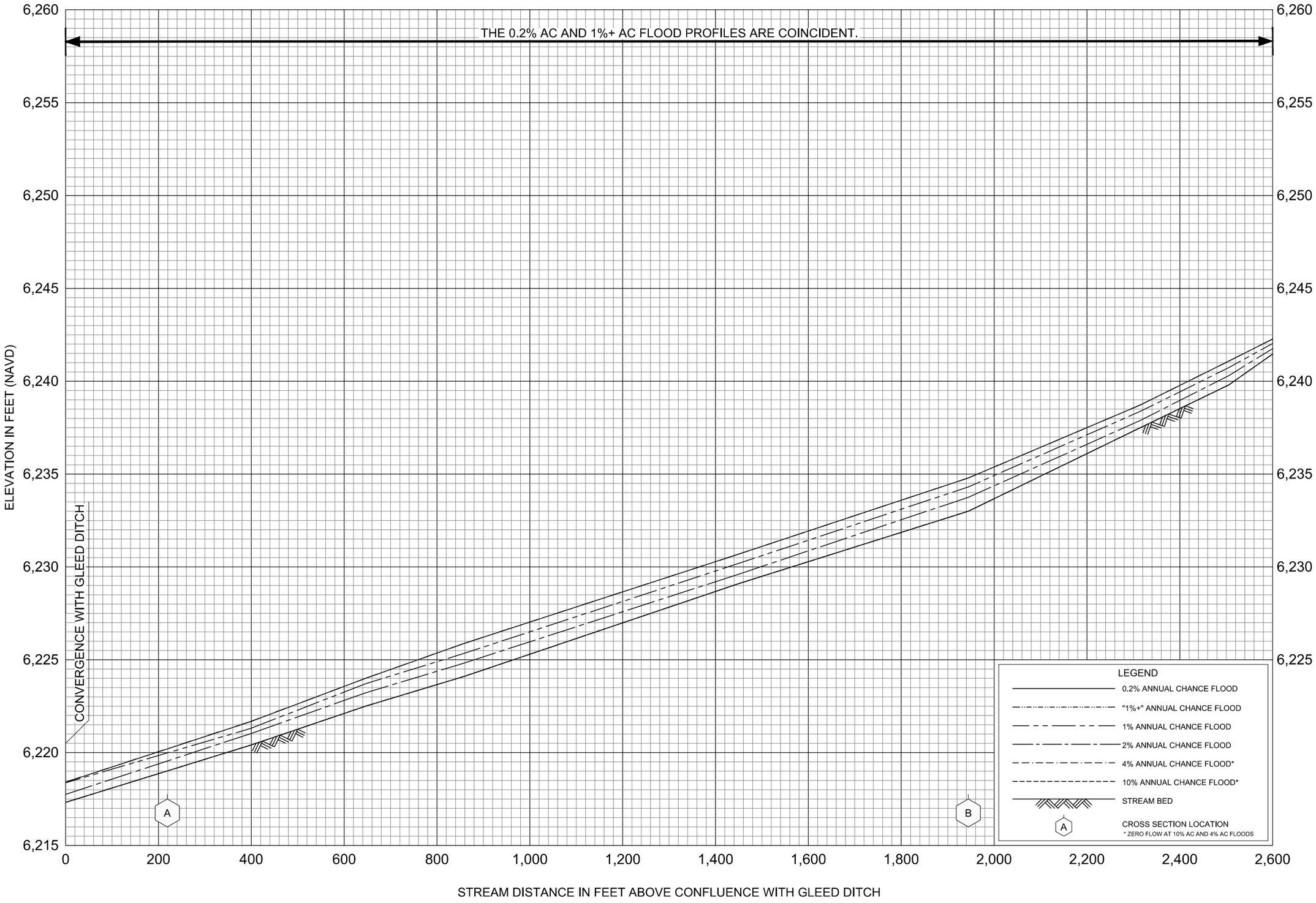
FLOOD PROFILES

JUNCTION CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



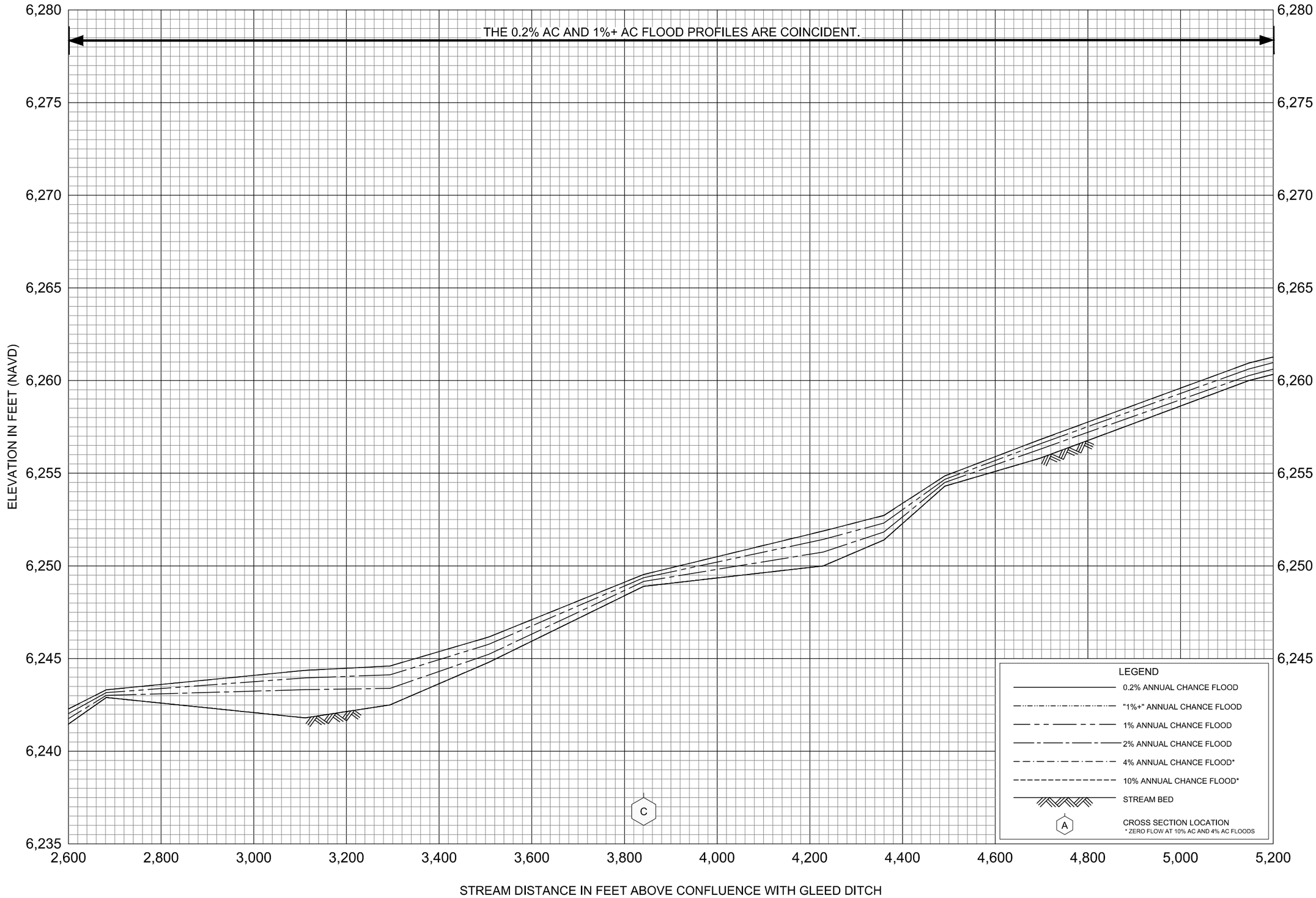
FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



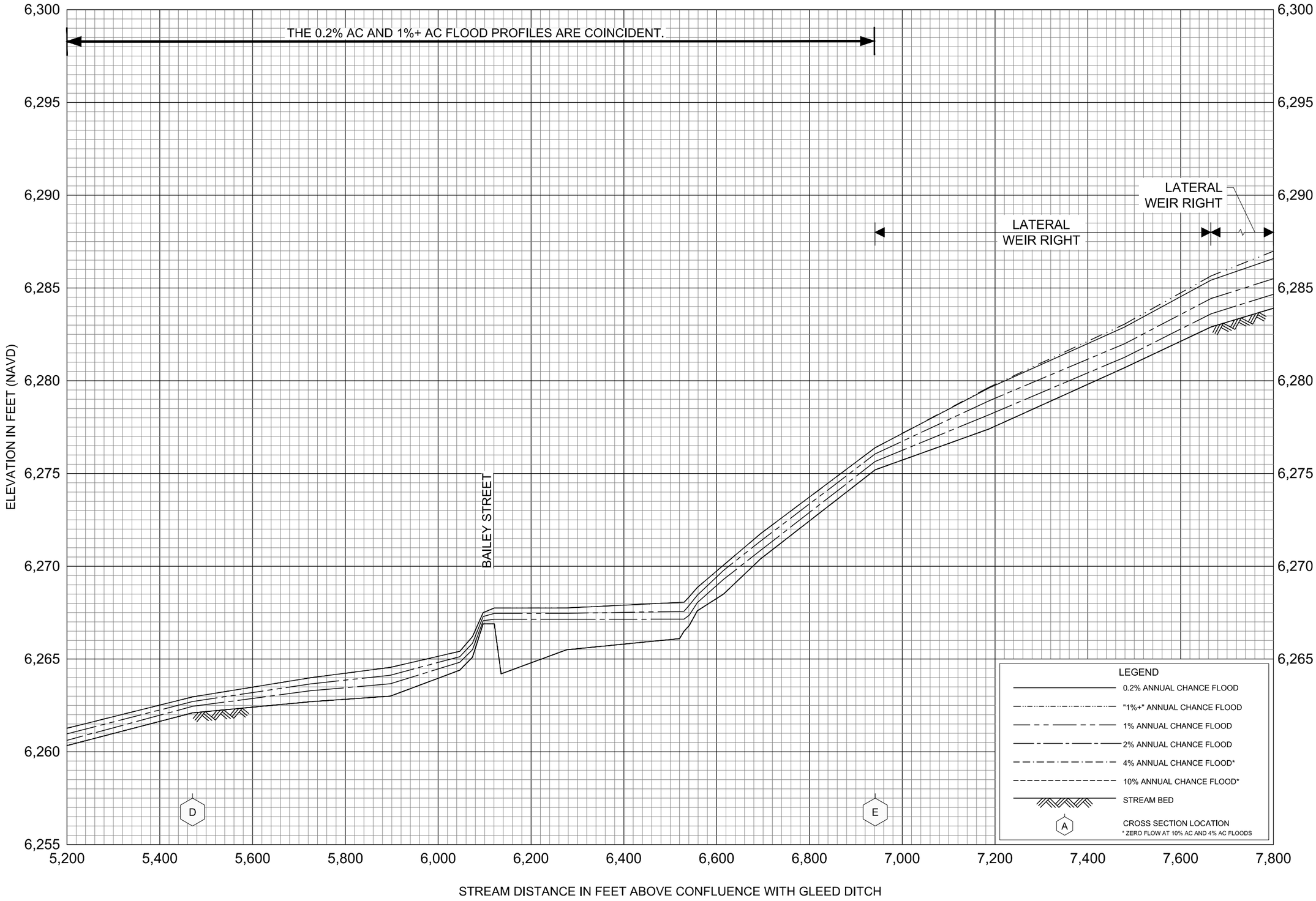
FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



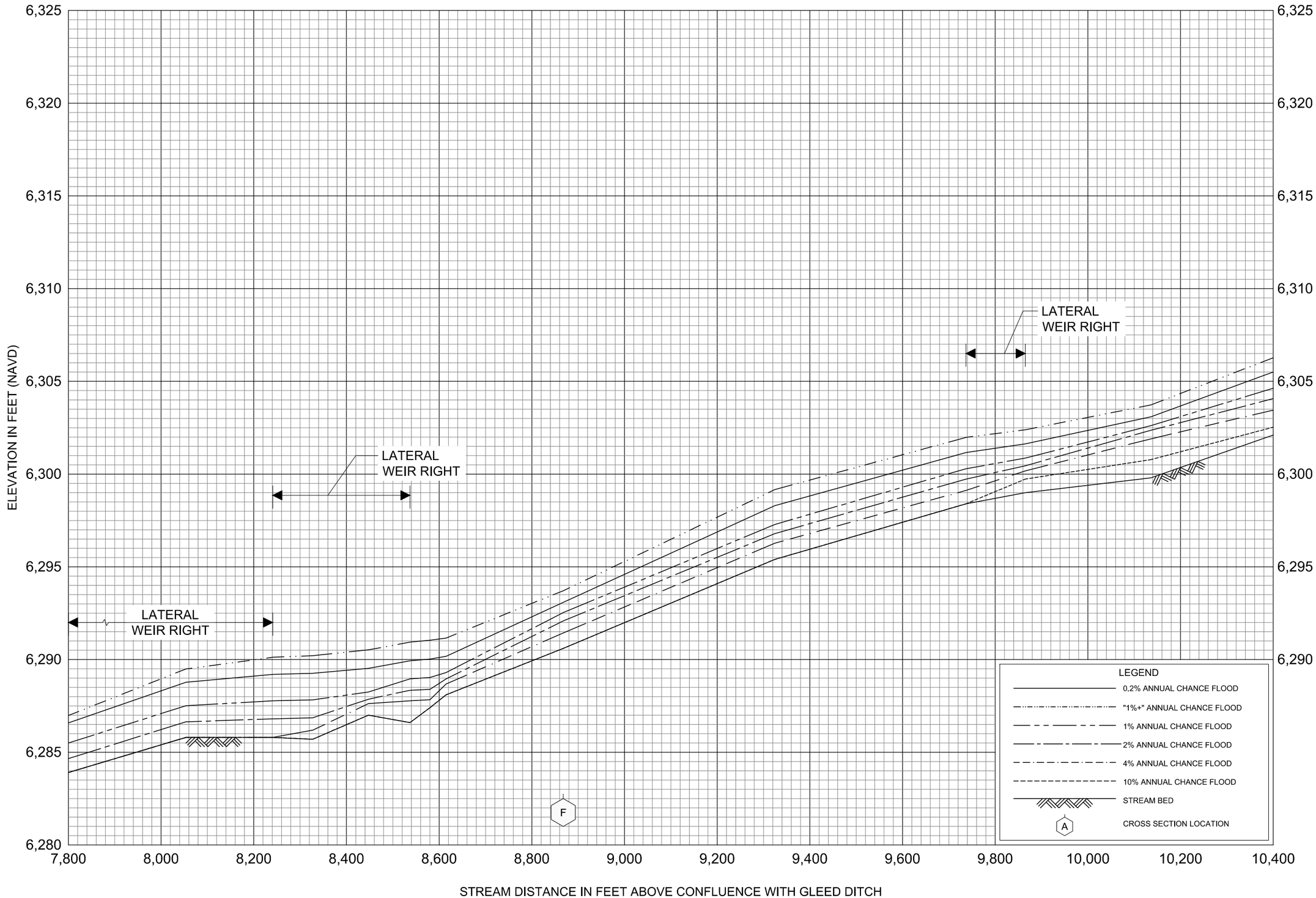
FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



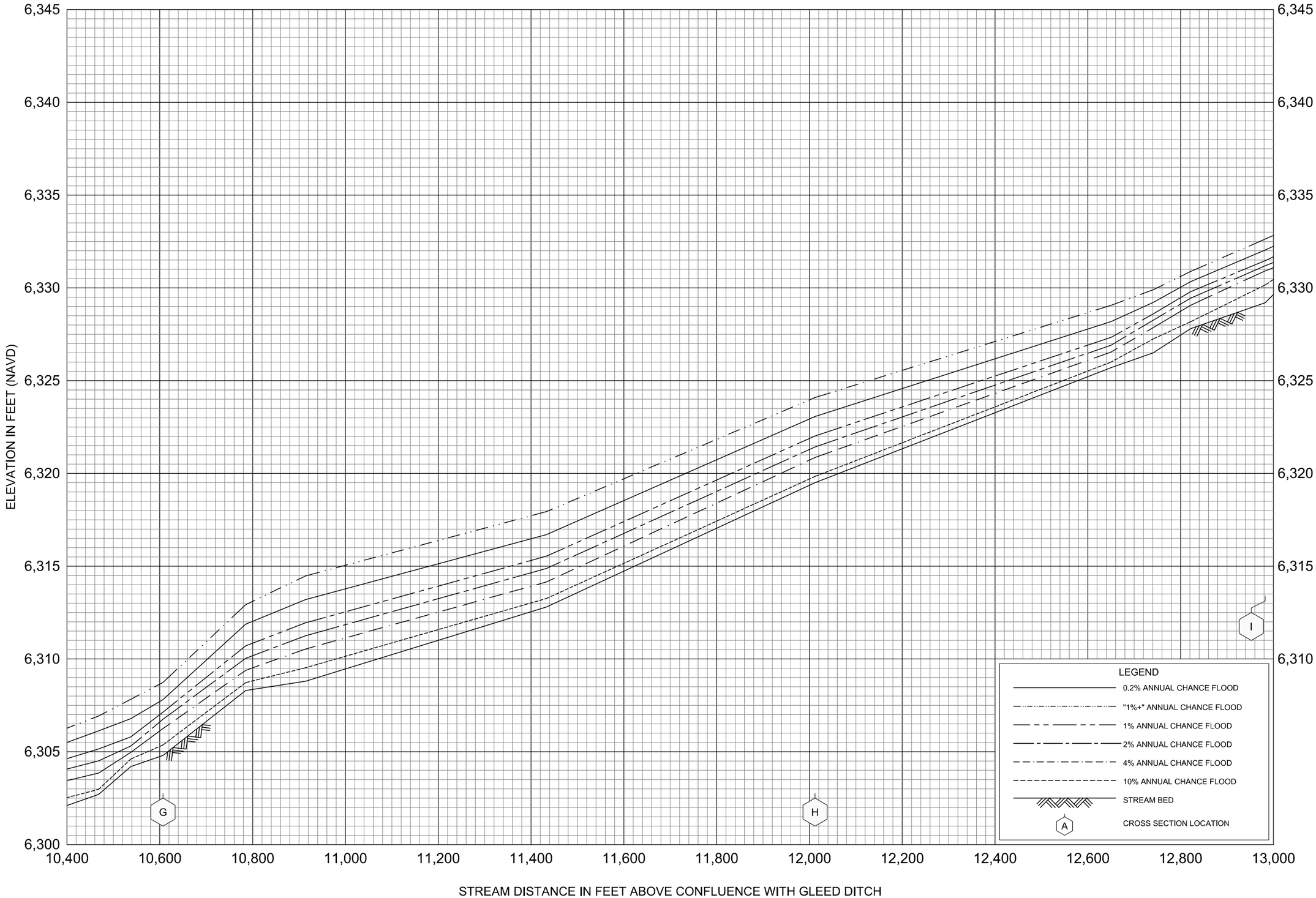
FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



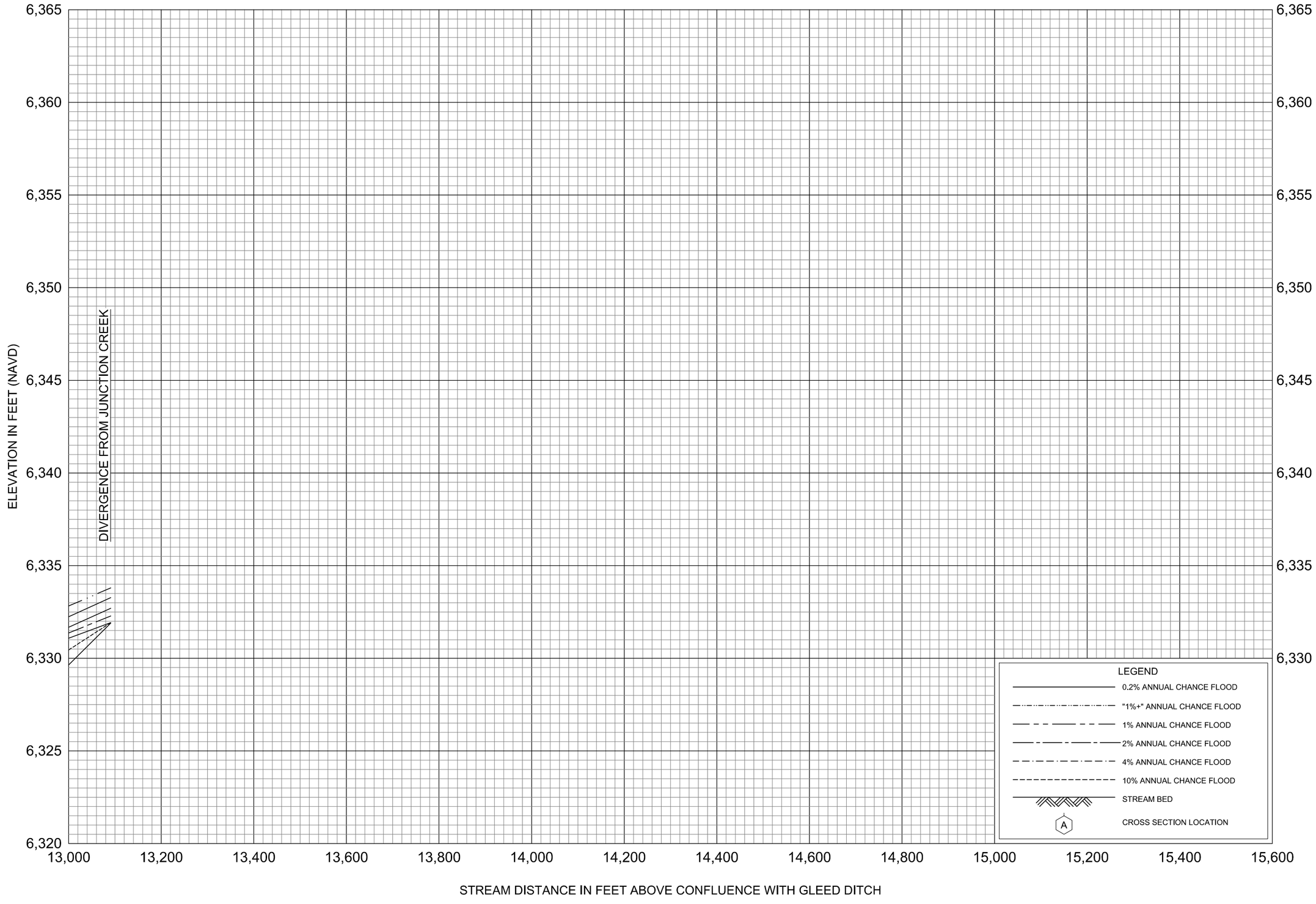
FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS



FLOOD PROFILES

JUNCTION CREEK OVERFLOW

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

Appendix C – Structure Photographs

Beaverhead County
Junction Creek Bridge Structure Photographs
Mapping Activity Statement (MAS): No 2016-01

ID No.	Location	River	Reach	River Station	Spans	Total Span (feet)	Page
JNC_010	Pedestrian Bridge	Gleed Ditch A		1370	1	20.0	3
JNC_040	Lima Dam Road	Junction Crk A		8591	1	25.5	5
JNC_060	Pedestrian Bridge	Junction Crk A		9412	2	48.0	6
JNC_070	First Avenue Bridge	Junction Crk A		9701	1	23.8	7
JNC_072	Pedestrian Bridge	Junction Crk A		9900	1	31.0	8
JNC_075	Pedestrian Bridge	Junction Crk A		10517	2	28.0	9
JNC_080	Bailey Street Bridge	Junction Crk A		11658	1	20.0	10
JNC_090	Slader Street Bridge	Junction Crk A		12018	1	16.5	11

ID No.	Location	River Reach	River Station	Total Length (feet)	Culvert Type	Culvert Size (feet)	Page
JNC_020	Union Pacific Railroad Crossing	Gleed Ditch B	1660	61.0	CSPA	3.58 x 2.25	4
ALD_095	Private Crossing	Alder Creek	284	40.0	CSP	3	12
ALD_096	Private Crossing	Alder Creek	749	12.0	CSP	3	13
ALD_100	Railroad Crossing	Junction Crk Overflow	8530	43.0	RCP	4	14
ALD_102	Railroad Crossing	Junction Crk Overflow	8530	37.0	DI	2	15
ALD_104	Railroad Crossing	Junction Crk Overflow	9801	38.0	DI	2	16
JNC_110	Union Pacific Railroad Crossing	Junction Crk - B	19776	40.0	CSP	6	17
				30.5	MCPA	6 x 8	
JNC_120	Union Pacific Railroad Crossing	Junction Crk - B	21326	48.0	CSP	7	18
				28.0	MCPA	4.6 x 7.5	

Culvert Types:
CSPA – Corrugated Steel Pipe Arch
CSP – Corrugated Steel Pipe
RCP – Reinforced Concrete Pipe
DI – Ductile Iron Pipe
MCPA – Masonry Constructed Pipe Arch

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_010_01_DSFACE
	Date: 11/22/2016
	Description: View of the pedestrian bridge downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_010_01_USFACE
	Date: 11/22/2016
	Description: View of the pedestrian bridge upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_020_01_DSFACE
	Date: 11/17/2016
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_020_01_USFACE
	Date: 11/17/2016
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Lima Dam Road
	Photo Name: JNC_040_01_DSFACE
	Date: 11/18/2016
	Description: View of the downstream face of Lima Dam Rd
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Lima Dam Road
	Photo Name: JNC_040_01_USFACE
	Date: 11/18/2016
	Description: View of the upstream face of Lima Dam Rd
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_060_01_DSFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_060_01_USFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: First Avenue Bridge
	Photo Name: JNC_070_01_DSFACE
	Date: 11/18/2016
	Description: View of the downstream face of First Avenue
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: First Avenue Bridge
	Photo Name: JNC_070_01_USFACE
	Date: 11/18/2016
	Description: View of the upstream face of First Avenue
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_072_01_DSFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_072_01_USFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_075_01_DSFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Pedestrian Bridge
	Photo Name: JNC_075_02_USFACE
	Date: 11/18/2016
	Description: View of the pedestrian bridge upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Bailey Street Bridge
	Photo Name: JNC_080_01_DSFACE
	Date: 11/18/2016
	Description: View of the downstream face of Bailey Street
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Bailey Street Bridge
	Photo Name: JNC_080_01_USFACE
	Date: 11/18/2016
	Description: View of the upstream face of Bailey Street
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Slader Street Bridge
	Photo Name: JNC_090_01_DSFACE
	Date: 11/18/2016
	Description: View of the downstream face of Slader Street
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Slader Street Bridge
	Photo Name: JNC_090_01_USFACE
	Date: 11/18/2016
	Description: View of the upstream face of Slader Street
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Private Crossing
	Photo Name: ALD_095_01_DSFACE
	Date: 11/22/2016
	Description: View of the private crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Private Crossing
	Photo Name: ALD_095_01_USFACE
	Date: 11/22/2016
	Description: View of the private crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Private Crossing
	Photo Name: ALD_096_01_DSFACE
	Date: 11/22/2016
	Description: View of the private crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Private Crossing
	Photo Name: ALD_096_01_USFACE
	Date: 11/22/2016
	Description: View of the private crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_100_01_DSFACE
	Date: 11/22/2016
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_100_01_USFACE
	Date: 11/22/2016
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_102_01_DSFACE
	Date:
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_102_01_USFACE
	Date:
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_104_01_DSFACE
	Date:
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers • surveyors • planners • scientists	Structure Name: Railroad Crossing
	Photo Name: ALD_104_01_USFACE
	Date: 11/22/2016
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_110_01_DSFACE
	Date: 11/17/2016
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_110_01_USFACE
	Date: 11/17/2016
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_120_01_DSFACE
	Date: 11/17/2016
	Description: View of the railroad crossing downstream face
	Project: Junction Creek Floodplain Study

Morrison Maierle engineers · surveyors · planners · scientists	Structure Name: Union Pacific Railroad Crossing
	Photo Name: JNC_120_01_USFACE
	Date: 11/17/2016
	Description: View of the railroad crossing upstream face
	Project: Junction Creek Floodplain Study

Appendix D – Floodway Data Table

- Junction Creek

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (**FEET**)	SECTION AREA (**SQ. FEET**)	MEAN VELOCITY (**FEET/ SEC**)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
JUNCTION CREEK								
A	5,455	70	187	5.2	6212.9	6212.9	6213.4	0.5
B	7,427	405[2]	233	4.3	6227.2	6227.2	6227.3	0.1
C	9,064	152[2]	226	4.4	6241.1	6241.1	6241.2	0.1
D	11,026	107	263	3.8	6257.9	6257.9	6258.2	0.3
E	12,988	113[2]	179	5.6	6277.2	6277.2	6277.3	0.1
F	14,841	62	147	6.8	6292.6	6292.6	6292.8	0.2
G	16,713	70	186	5.4	6306.6	6306.6	6307.1	0.5
H	18,655	110	231	4.3	6320.4	6320.4	6320.7	0.3
I	20,483	29	138	7.3	6338.1	6338.1	6338.2	0.1
J	21,831	114	749	1.3	6354.2	6354.2	6354.4	0.2

[1] Feet above confluence with Red Rock River.
[2]Floodway topwidth includes width of high ground area.

TABLE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

BEAVERHEAD COUNTY, MT

AND INCORPORATED AREAS

FLOODWAY DATA

JUNCTION CREEK

Appendix E – cHECk-RAS Checklists

cHECk-RAS Report

HEC-RAS Project:	*junctioncreek.prj*
Plan File:	*junctioncreek.p01*
Geometry File:	*junctioncreek.g01*
Flow File:	*junctioncreek.f02*
Report Date:	*1/26/2018*

Message ID	Message	Cross sections affected	Comments
BR LF 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is low flow because, 1. EGEL 3 of $egel3$ is less than or equal to MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is less than MxLoCdU of $mxlocdu$.	1660(Culvert-UP); 8591(Culvert-UP); 9412(Bridge-UP); 9701(Bridge-UP); 9900(Bridge-UP); 10517(Bridge-UP); 11658(Culvert-UP); 12018(MultiOpen-UP)	This a comment, not an error.
BR LF 03	This is the upstream internal Bridge Section ($secno3$). The selected profile is $profilename$. Type of flow is low flow. Critical depth occurs at the BRU section. However, input BrSelMthd is not Momentum. Select Momentum as the Low Flow Method and rerun the plan.	1660(Culvert-UP); 8591(Culvert-UP); 9412(Bridge-UP); 9701(Bridge-UP); 9900(Bridge-UP); 10517(Bridge-UP); 11658(Culvert-UP); 12018(MultiOpen-UP)	This comment is not applicable for culverts. The comment is also not applicable to perched bridges with no roadway embankments.
BR PW 01	This is a Bridge Section. The selected profile is $profilename$. Type of flow is sluice gate pressure and weir flow because, 1. EGEL 3 of $egel3$ is greater than MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is equal to or greater than MxLoCdU of $mxlocdu$. 3. WSEL 2 of $wsel2$ is less than MxLoCdD of $mxlocdd$.	749(Culvert-UP)	This is a comment, not an error.
BR PW 02	This is a Bridge Section. The selected profile is $profilename$. Type of flow is submerged pressure and weir flow because, 1. EGEL 3 of $egel3$ is greater than MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is equal to or greater than MxLoCdU of $mxlocdu$. 3. WSEL 2 of $wsel2$ is equal to or greater than MxLoCdD of $mxlocdd$.	284(Culvert-UP); 1370(Bridge-UP)	This is a comment, not an error.
BR PW 03	This is a Bridge Section. The High Flow Method is Energy Only. The selected profile is $profilename$. Type of flow is sluice gate pressure and weir flow. However, the EGEL difference between Sections 3 and 2 is more than 1.0 foot. Press/Weir should be selected as the High Flow Method.	749(Culvert-UP)	This is a comment, not an error.
CV CF 01	This is ($strucname$). Culvert Chart # is $chart$ and Scale # is $scale$. Culvert entrance shape is $shape$. Culvert entrance loss coefficient is $inputentlosscoef$. It should be equal to $entlosscoef$. Please refer to Table 6-3 and Table 6-4 on Page 6-26 of HEC-RAS Hydraulic Reference Manual	11658	This culvert is very sensitive to a variety of input data. The inlet coefficient selection is intentional. Please see the Hydraulic Summary Report for additional information.
CV LF 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is low flow because, 1. EGEL 3 of $egel3$ is less than or equal to MinTopRd of $minelweirflow$. 2. EGEL 3 of $egel3$ is less than MxLoCdU of $mxlocdu$.	1660; 8591; 11658; 19776; 21326	This is a comment, not an error.

CV LW 03	This is ($strucname$). The tolerance ratio of {(QWeir + Qculv) - QTotal}/Qtotal is more than 0.01. Please investigate the problem.	1660; 8591; 11658; 19776; 21326	Checked flows manually and WSELs using FHWA HY8 v. 7.5. Flows match input and WSELs calculated in HEC-RAS. This may be an output error in HEC-RAS or a problem with cHECk-RAS reading HEC-RAS 5.0.3 data output.
CV PW 01	This is ($strucname$). The selected profile is $profilename$. Type of flow is pressure and weir flow because, 1. EGEL 3 of $egel3$ is greater than MinTopRd of $Min_El_Weir_Flow$. 2. EGEL 3 of $egel3$ is greater than MxLoCdU of $MxLoCdU$.	284	This is a comment, not an error.
CV PW 03	This is ($strucname$). The tolerance ratio of {(QWeir + Qculv) - QTotal}/Qtotal is more than 0.01. Please investigate the problem.	1660; 8591; 11658; 19776; 21326	Checked flows manually and WSELs using HY8 7.5. Flows matched input and WSELs calculated in HEC-RAS. This may be an output error in HEC-RAS or problem with cHECk-RAS reading HEC-RAS 5.0.3 data output.
IW TF 01e	This is an InlineWeir section. The selected profile is $profilename$. There is no flow at the structure.	6108(InlineWeir)	Checked flows manually. This may be an output error in HEC-RAS or problem with cHECk-RAS reading HEC-RAS 5.0.3 data output.
IW TF 04	This is an Inline Weir. The selected profile is $profilename$. Type of flow is UNKNOWN. cHECk-RAS cannot find MxLoCd or MnTpRd elevation or the given conditions do not satisfy the type of flow specified in the cHECk-RAS program. Please review the ground and road data and the encroachment stations, or please review the message IW TF 01 for inline weir to determine the type of flow.	6108(InlineWeir); 6823(InlineWeir)	Appears to be a problem with cHECk-RAS reading HEC-RAS 5.0.3 data output. Inline weir geometry is coded correctly.
MP SW 01DD	The name of the stream is ($streamname$). The flow regime is subcritical or mixed flow. The downstream starting water-surface elevation, SWSEL, is computed from different methods.		All Confluence reaches start from known WSELs based on Worst Case Scenario Modeling.
MP SW 01UD	The name of the stream is ($streamname$). The flow regime is mixed flow or supercritical. The upstream starting water-surface elevation, SWSEL, is computed from different methods.		Gleed Ditch Reach A and Junction Creek Reach A start from normal depth boundary conditions.
MS IF 01S2L	This is Section 2 of Multiple Structures. Left Ineffective Flow Station was not considered at Section 2. The Multiple Block Ineffective Flow option should be used. The left ineffective flow elevation should be higher than the highest discharge that has low flow or pressure flow or less than the WSEL of the lowest discharge that has weir flow. The placement of the ineffective flow stations is explained on page 5-10 of the Applications Guide (HEC, 2010).	12018(MultiOpen); 19776(MultiOpen); 21326(MultiOpen)	Ineffective flow stations set at LT and RT of Multiple Openings. Culverts are close enough there is no ineffective area between the openings at the bounding cross sections.

MS IF 01S2R	This is Section 2 of Multiple Structures. Right Ineffective Flow Station was not considered at Section 2. Multiple Block Ineffective Flow option should be used. The right ineffective flow elevation should be higher than the highest discharge that has low flow or pressure flow or less than the WSEL of the lowest discharge that has weir flow. The placement of the ineffective flow stations is explained on page 5-10 the Applications Guide (HEC, 2010).	12018(MultiOpen); 19776(MultiOpen); 21326(MultiOpen)	Ineffective flow stations set at LT and RT of Multiple Openings. Culverts are close enough there is no ineffective area between the openings at the bounding cross sections.
MS IF 01S3L	This is Section 3 of Multiple Structures. Left Ineffective Flow Station was not considered at Section 3. Multiple Block Ineffective Flow option should be used. The left ineffective flow elevation should be equal to $LMnTpRdU$. The placement of the ineffective flow stations is explained on page 5-10 of the Applications Guide (HEC, 2010).	12018(MultiOpen); 19776(MultiOpen); 21326(MultiOpen)	Ineffective flow stations set at LT and RT of Multiple Openings. Culverts are close enough there is no ineffective area between the openings at the bounding cross sections.
MS IF 01S3R	This is Section 3 of Multiple Structures. Right Ineffective Flow Station was not considered at Section 3. Multiple Block Ineffective Flow option should be used. The right ineffective flow elevation should be equal to $RMnTpRdU$. The placement of the ineffective flow stations is explained on page 5-10 of the Applications Guide (HEC, 2010).	12018(MultiOpen); 19776(MultiOpen); 21326(MultiOpen)	Ineffective flow stations set at LT and RT of Multiple Openings. Culverts are close enough there is no ineffective area between the openings at the bounding cross sections.
NT RC 01L	All of the left overbank Manning’s "n" values are less than 0.030. The "n" values for the overbank areas are usually larger than 0.030 (Chow, 1959, page 113). The "n" value(s) should be re-evaluated. Follow the procedure outlined to compute the overbank "n" value(s) for a natural floodplain (FHWA, 1984). Or follow the procedure outlined to compute the "n" values for urban development (USGS, 1977). Please submit supporting information on the evaluation of the "n" values.	11658(Culvert-DN); 11658(Culvert-UP)	Appears to be a problem with cHECk-RAS reading HEC-RAS 5.0.3 data output. Roughness data are reasonable.
NT RC 01R	All of the right overbank "n" values are less than 0.030. Manning’s "n" values for the overbank areas are usually larger than 0.030 (Chow, 1959, page 113). The "n" value(s) should be re-evaluated. Follow the procedure on pages 17 and 54 of (FHWA, 1984) to compute the overbank "n" value for the natural floodplain. Or follow the procedure in (USGS, 1977) to compute the "n" value for urban development. Please submit supporting information on the evaluation of "n" value.	11658(Culvert-DN); 11658(Culvert-UP)	Appears to be a problem with cHECk-RAS reading HEC-RAS 5.0.3 data output. Roughness data are reasonable.

NT RC 05	The left overbank n-value of $nlob$ and the right overbank n-value of $nrob$ are less than or equal to the channel n-value of nch. Follow the procedure in (FHWA, 1984) to compute the n-value for the natural floodplain and the channel. Or follow the procedure in (USGS, 1977) to compute the n-value for urban development. Please submit supporting information on the evaluation of n-values.	223; 255; 284(Culvert-DN); 284(Culvert-UP); 313; 334; 1550; 1739; 86; 399; 647; 859; 1451; 1946; 2317; 2507; 6047; 6074; 6108(InlineWeir-UP); 6135; 6276; 6519; 6529; 6540; 6558; 7186; 7478; 7662(-DN); 7662(-UP); 7665; 8053; 9737; 9801(-DN); 9801(-UP); 9865; 11432; 12011	Overbank and channel n-values verified. Much of the split flow paths are seldomly active overflow channels with similar substrate and vegetation across the cross section.
NT RS 01S2C	This is Section 2 of a hydraulic structure. Channel n value of $chl2$ is less than the channel n value of $chl1$ at Section 1. Normally the channel "n" value at Section 2 represents the reach between Section 2 and Section 1, and is higher than the "n" value within the hydraulic structure. Please change the "n" value or provide supporting information for the use of the lower "n" value.	8560; 11619	N-values set to maintain sub-critical flow and parallel profiles.
NT RS 01S3C	This is Section 3 of a hydraulic structure. Channel n value of $chl3$ is less than the channel n value of $chl4$ at Section 4. Normally the channel "n" value at Section 3 represents the reach between Section 3 and Section 4, and is higher than the "n" value within the hydraulic structure. Please change the "n" value or provide supporting information for the use of the lower "n" value.	762; 9420	N-values set to maintain sub-critical flow and parallel profiles.
NT TL 01S2	This is Section2 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively, for typical structure sections according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	9396; 9675; 9890	These structures are perched and do not encroach into the channel. No flow narrowing occurs. Therefore the constraction/expansion losses are not "typical" for a structure.
NT TL 01S3	This is Section3 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively, for typical structure sections according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	9420; 9729; 9909	These structures are perched and do not encroach into the channel. No flow narrowing occurs. Therefore the constraction/expansion losses are not "typical" for a structure.
NT TL 01S4	This is Section 4 of a hydraulic structure. The contraction and expansion loss coefficients are cc and ce. They should be equal to 0.3 and 0.5, respectively according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010)..	9438; 9759; 9925	These structures are perched and do not encroach into the channel. No flow narrowing occurs. Therefore the constraction/expansion losses are not "typical" for a structure.
NT TL 02	Contraction and expansion loss coefficients are cc and ce, respectively. However, this cross section is not at a hydraulic structure. They should be equal to 0.1 and 0.3 according to page 5-8 of the HEC-RAS Hydraulic Reference Manual (HEC, 2010).	2694; 6782; 6790; 7052	These cross-sections are closely spaced near a structure and flow is expanding.

ST DT 03	This is ($Structure$) section. The Contraction Length is longer than the Expansion Length. Section 4 channel distance of $Length_Chnl4$ is longer than Section 2 channel distance of $Length_Chnl2$. Section 4 and Section 1 should be relocated. The HEC-RAS geometry file may need to be recreated using a GIS program.	749(Culvert-UP); 1660(Culvert-UP); 6108(InlineWeir-UP); 9900(Bridge-UP)	Cross-sections and structure represented appropriately. Appears to be an issue with cHECk-RAS reading HEC-RAS 5.0.3 correctly.
ST GD 02BD	This is the Downstream Bridge Section. There is only one bridge. However, the low cord line crosses the ground line at more than two locations. The ground and deck/roadway data should be checked.	1370(Bridge); 9412(Bridge); 9701(Bridge); 9900(Bridge); 10517(Bridge)	These cases occur when there is a bridge perched over the channel and no associated roadway embankment. High chord and low chord elevations and stations are correct.
ST GD 02BU	This is the Upstream Bridge Section. There is only one bridge. However, the low cord line crosses the ground line at more than two locations. The ground and deck/roadway data should be checked.	1370(Bridge); 9412(Bridge); 9701(Bridge); 9900(Bridge); 10517(Bridge)	These cases occur when there is a bridge perched over the channel and no associated roadway embankment. High chord and low chord elevations and stations are correct.
ST IF 01S2L	This is Section 2 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Left Ineffective Flow station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be equal to wsel2 of $wsel$. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	6108(InlineWeir); 6823(InlineWeir)	Ineffective Flow stations and elevations set to align with topograhy and meet Hydraulic Reference Manual guidance.
ST IF 01S2R	This is Section 2 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Right Ineffective Flow Station was not considered at Section 2. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be equal to wsel2 of $wsel$. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	6823(InlineWeir)	Ineffective Flow stations and elevations set to align with topograhy and meet Hydraulic Reference Manual guidance.
ST IF 01S3L	This is Section 3. The highest flood frequency that has low or pressure flow is $profilename$. However, the Left Ineffective Flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The left ineffective flow elevation should be equal to lmntprdu of $lmntprdu$. The placement of the left ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	6108(InlineWeir)	Ineffective Flow stations and elevations set to align with topograhy and meet Hydraulic Reference Manual guidance.

ST IF 01S3R	This is Section 3 of a hydraulic structure. The highest flood frequency that has low or pressure flow is $profilename$. However, the Right Ineffective Flow station was not considered at Section 3. The ineffective flow station and elevation should be inserted. The right ineffective flow elevation should be equal to rmntprdu of $rmntprdu$. The placement of the right ineffective flow station is explained on page 5-7 of Hydraulic Reference Manual (HEC, 2010).	6108(InlineWeir)	Ineffective Flow stations and elevations set to align with topograhy and meet Hydraulic Reference Manual guidance.
ST IF 05S2R	This is Section 2 of a hydraulic structure. The right ineffective flow station is within the opening area of the structure. The right ineffective flow station of $ineffstar$ is less than the upstream right abutment station of $abutstar$ at ($strucname$). The Right ineffective flow station should be adjusted.	9396(Bridge); 9675(Bridge); 9890(Bridge); 10497(Bridge); 11996(MultiOpen)	Appears to be a cHECk-RAS error reading HEC-RAS 5.0.3. Ineffective area stations are not within open areas of structures or within bank stations.
ST IF 05S3R	This is Section 3 of a hydraulic structure. The right ineffective flow station is within the opening area of the structure. The right ineffective flow station of $ineffstar$ is less than the upstream right abutment station of $abutstar$ at ($strucname$). The Right ineffective flow station should be adjusted.	6841(InlineWeir); 9420(Bridge); 9729(Bridge); 9909(Bridge); 10524(Bridge); 12037(MultiOpen)	Appears to be a cHECk-RAS error reading HEC-RAS 5.0.3. Ineffective area stations are not within open areas of structures or within bank stations.
ST IF 07S1R	This is Section 1. Right Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 3 of the downstream structure.	9374(Bridge); 9634(Bridge); 9876(Bridge)	Ineffective flow areas typically set for other overbank depressions and are not related to modeling the nearby hydraulic structure.
ST IF 07S4R	This is Section 4. Right Ineffective flow option was considered at this section. However, it should be a fully expanded cross section. Ineffective flow stations and elevations should be cleared from this section, unless the areas beyond the ineffective flow stations are not within the flow path of the stream. This message should be ignored if this section is Section 2 of the upstream structure.	9438(Bridge); 9759(Bridge); 9925(Bridge)	Ineffective flow areas typically set for other overbank depressions and are not related to modeling the nearby hydraulic structure.

ST IF 08S2	This is Section 2 of a hydraulic structure. Permanent Ineffective Flow Areas option is used. Please disable this option for steady flow. This option may be used for unsteady flow. This option may be used to solve crossing of profiles due to sudden increase in cross sectional area in steady flow.	10497(Bridge)	Permanent ineffecitive areas selected due to crossing profiles related to the sudden increase in cross sectional area in steady flow.
ST IF 08S3	This is Section 3 of a hydraulic structure. Permanent Ineffective Flow Areas option is used. Please disable this option for steady flow. This option may be used for unsteady flow. This option may be used to solve crossing of profiles due to sudden increase in cross sectional area in steady flow.	9729(Bridge); 10524(Bridge)	Permanent ineffecitive areas selected due to crossing profiles related to the sudden increase in cross sectional area in steady flow.
ST IF 10S2L	This is Section 2 of a ($Structure$). More than one set of Left Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	9396(Bridge); 9675(Bridge); 9890(Bridge); 10497(Bridge)	Ineffective flow areas typically set for other overbank depressions as well as hydraulic structure modeling criteria.
ST IF 10S3L	This is Section 3 of a ($Structure$). More than one set of Left Ineffective Flow Stations were considered. There is only one structure at this location. Multiple Block Ineffective Flow option should not be used unless the area blocked by the ineffective flow stations can be considered non conveyance. The cHECk-RAS will only check the ineffective flow elevations adjacent to the structure opening.	9420(Bridge); 9729(Bridge); 9909(Bridge); 10524(Bridge)	Ineffective flow areas typically set for other overbank depressions as well as hydraulic structure modeling criteria.
XS BO 01R	Block Obstruction. Flow Code will be "BR". The block obstruction elevation is higher than the right bank elevation. Lower the block obstruction elevation to the bank elevation or provide an explanation. This option is suitable to fill isolated depression areas.	1345; 1363; 1379; 1393	Blocked obstruction represents buildings obstructing flow in the floodplain.
XS CD 01	Critical Depth occurs at $assignedname$ flood. Flow Code will be "C". The Ineffective flow option is used. The Ineffective Flow elevation is equal to or higher than the Critical WSEL. Please investigate whether this selection is appropriate.	1607; 1683; 4696; 5148; 5471; 6047; 6074; 6519; 6558; 6694; 9865; 10136; 6841; 7702; 7970; 8116; 8182; 8280; 8516; 8560; 8616; 8630; 8749; 9064; 9374; 9396; 9420; 9438; 9511; 9634; 9675; 9729; 9759; 9814; 9876; 9890; 9909; 9925; 10019; 10131; 10316; 10479; 10497; 10524; 10536; 10691; 11026; 11446; 11573; 11619; 11695; 11717; 11996; 12037; 12071; 12202; 12284; 13427; 13711; 13953; 14165; 14476; 14841; 15192; 15509; 15781; 16050; 18655; 19687; 19719; 19800; 19820; 21288; 21358; 21382; 21831	Model input data has been tailored to the regulatory flood profile. Critical depth for other included profiles is anticipated.

XS CT 03	Maximum number of iterations is $maxnoiter$. It should be the default value of 20.		Iterations set correctly. Appears to be an issue with cHECk-RAS reading HEC-RAS 5.0.3
XS DC 04L	There is no flow on the right overbank at the downstream cross section $presecno$ for the 1%-annual-chance flood. There is no flow on the left overbank at this Section $secno$. Consider placing a cross section in between these sections. The HEC-RAS geometry file may need to be recreated using a GIS program.	2268; 2581; 2614; 399; 647; 859; 1451; 1543; 1946; 2317; 2507; 2683; 3112; 3295; 3508; 3842; 4229; 4360; 4491; 4696; 5148; 5471; 5725; 5897; 6529; 6540; 6558; 6614; 6694; 6941; 7186; 7478; 8053; 8327; 8447; 8580; 8615; 8868; 9324; 9737; 10136; 10468; 10537; 10606; 10784; 10913; 11432; 12011; 12649; 12740; 12820; 12981; 13090; 5860; 6153; 6444; 6689; 6774; 6782; 6790; 7427; 7702; 7970; 8116; 8182; 8280; 9064; 10131; 10316; 11026; 11221; 11308; 11446; 11889; 12284; 12354; 12502; 219; 12585; 12763; 12925; 12988; 13253; 13427; 13711; 13953; 14165; 14476; 14841; 15192; 15509; 15781; 16050; 16532; 16713; 17141; 17527; 18126; 18655; 19108; 19333; 19434; 19588; 19965; 20080; 20157; 20356; 20419; 20483; 20563; 20630; 20672; 20716; 20750; 20787; 20872; 20998; 21102	Appears to be an issue with cHECk-RAS reading HEC-RAS 5.0.3. Cross-sections developed correctly and with sufficient density.
XS DC 04R	There is no flow on the left overbank at the downstream cross section $presecno$. There is no flow on the right overbank at this Section $secno$ for the 1%-annual-chance flood. Consider placing a cross section in between these sections. The HEC-RAS geometry file may need to be recreated using a GIS program.	2268; 2581; 2614; 399; 647; 859; 1451; 1543; 1946; 2317; 2507; 2683; 3112; 3295; 3508; 3842; 4229; 4360; 4491; 4696; 5148; 5471; 5725; 5897; 6529; 6540; 6558; 6614; 6694; 6941; 7186; 7478; 8053; 8327; 8447; 8580; 8615; 8868; 9324; 9737; 10136; 10468; 10537; 10606; 10784; 10913; 11432; 12011; 12649; 12740; 12820; 12981; 13090; 5860; 6153; 6444; 6689; 6774; 6782; 6790; 7427; 7702; 7970; 8116; 8182; 8280; 9064; 10131; 10316; 11026; 11221; 11308; 11446; 11889; 12284; 12354; 12502; 219; 12585; 12763; 12925; 12988; 13253; 13427; 13711; 13953; 14165; 14476; 14841; 15192; 15509; 15781; 16050; 16532; 16713; 17141; 17527; 18126; 18655; 19108; 19333; 19434; 19588; 19965; 20080; 20157; 20356; 20419; 20483; 20563; 20630; 20672; 20716; 20750; 20787; 20872; 20998; 21102	Appears to be an issue with cHECk-RAS reading HEC-RAS 5.0.3. Cross-sections developed correctly and with sufficient density.
XS DF 01L	Divided flow. Flow code will be DL. The $assignedname$ flood discharge has a divided flow. The starting and ending stations of the cross section should not extend beyond the watershed boundary of the studied stream. Please review the extent of the cross section. If the cross section extends beyond the watershed boundary then the cross sections need to be trimmed and the HEC-RAS geometry file may need to be recreated using a GIS program. Or use the ineffective flow option, if it has not been considered, to limit the extent of the cross section or to block the divided flow area if it is a local depression.	1363; 1379	Cross sections and Ineffective areas set appropriately.
XS FS 01	The name of the stream is $streamname$. $frictionslopename$ method was used. The Average Conveyance method should be selected.		Average Conveyance selected for all simulations. Appears to be an issue for cHECk-RAS reading HEC-RAS 5.0.3.

XS IF 02R	Flow code will be MIR. Multiple (block) Ineffective Stations are selected for the right overbank at this River Station. This is not Section 2 or Section 3 of Multiple Openings or Multiple Culverts. Please justify why the Multiple Blocks Ineffective Flow option was used. Consider using the normal Ineffective Flow option.	1607; 1683; 4696; 6694; 6841; 8116; 8182; 8280; 8516; 8560; 8616; 8630; 8749; 9374; 9396; 9420; 9438; 9511; 9634; 9675; 9729; 9759; 9814; 9876; 9890; 9909; 9925; 10019; 10131; 10316; 10497; 10524; 10536; 11573; 11619; 11695; 11996; 12037; 12071; 13953; 15509; 16050; 19687; 19719; 19800; 19820; 21288; 21358	Multiple block ineffective ares required for multiple overbank depressions.
XS IF 03R	The Right Ineffective Flow Station is within the channel. The Right Ineffective Flow Station of $ineffstar$ is less than the RightBankSta of $bankstar$. The Right Ineffective Flow Station or the RightBankSta should be adjusted.	4696; 6694; 8116; 8182; 8280; 8749; 9511; 9814; 10019; 10131; 10316; 13953; 15509; 16050	Appears to be an issue with cHECk-RAS reading HEC-RAS 5.0.3 output. Ineffective area stations are not within the channel.

Appendix F – QA/QC Checklists

HEC-RAS
QA Review Checklist

Project Name:	Beaverhead County Flood Study	Model:	Junction Creek
Project Number:	1447.046	MAS:	2016-01
Completed By:	Kristyn Mayernik	Date:	01/29/18
Changes Made:	Luke Carlson	Date:	01/29/18

HEC-RAS Model Items:
Check appropriate box: *(If "NA" is checked, an explanation should be entered below item.)*

Yes	No	N/A	
☒	☐	☐	Does the model go through Critical Depth for any of the flows? If no, then go to next item. If yes, is this reasonable? If so, go to errors and check whether critical depth was calculated or assumed. If critical depth was calculated, run under mixed flow. If critical depth was assumed, model should be revised. *Critical depth was calculated or assumed for several locations, primarily for the flow events larger than the 100-year flow. As the primary purpose of the model is the 100-year event, the critical depth locations were allowed to remain rather than artificially change the calculated WSEL for the 100-year event.*
☐	☐	☒	Model has been calibrated (if possible). *Calibration data was searched for from multiple sources. No such data appears to be available for this study area. See report for more information.*
☒	☐	☐	2-year (50% Annual-Chance) event water surface is within channel. (10% was within)
☒	☐	☐	Multiple Critical Depth Search has been set.
☒	☐	☐	Energy Grade Line decreases is in downstream direction. WSE on Gleed Ditch & JNC increase but is discussed in Report.
☒	☐	☐	Ineffective flows overtopping at correct elevation (roadway and other sections). See spreadsheet. OK
☒	☐	☐	Continuity between X-SECs, especially when overtopping occurs.
☒	☐	☐	Flow widths are appropriate and/or calibrated.
☒	☐	☐	Right overbank flow at an acceptable event.
☒	☐	☐	Flow in channel.
☒	☐	☐	Left overbank flow at an acceptable event?
☒	☐	☐	Ineffective flow locations & elevations entered and checked. JCO 8447 ROB may need an IE, *OK, no IE needed due both to actual 1% modeled WSEL as well as continuity of terrain and mapping completed.*
☒	☐	☐	Contraction/Expansion coefficients checked.
☒	☐	☐	Entrance loss coefficients checked.

HEC-RAS Model Items:
Check appropriate box: (If "NA" is checked, an explanation should be entered below item.)

Yes	No	N/A	
☒	☐	☐	Structure X-SECs located at 1:1 upstream and 2:1 downstream and are fully expanded.
☒	☐	☐	Reach distances between X-SECs checked. (Use an aerial photograph with surveyed X-SEC locations for reference. The X-SECs should be labeled with stations used in HEC-RAS and/or the U/S and D/S distances).
☒	☐	☐	Manning's "n" values checked and at each cross-section.
☒	☐	☐	Bank stations checked and are appropriate for each cross-section.
☒	☐	☐	Energy Method set for bridges in pressure flow or if ratio of EGL to Existing ground/Low chord to Existing Ground is less than or equal to 1.2. If ratio is greater than 1.2, use Pressure/Weir Method. If overtopping of the roadway is occurring, Pressure/Weir may need to be selected to calculate the weir flow over the road even if the bridge is not in pressure flow.
☒	☐	☐	Culvert calculation method set at highest "Upstream EG" or explain otherwise.
☐	☐	☒	Scour calculations have been checked. *(No scour calculations with a floodplain study.)*
☐	☐	☒	Contraction Scour bank points are set outside of Bridge Opening. (This make HEC-RAS determine flows, depths, widths, etc). *(No scour calculations with a floodplain study.)*
☐	☐	☒	Pier Scour K2 Coefficient set at 1, if angle of attack of the flow is 0 degrees and bridge is not skewed or flow is parallel with the pier. Otherwise check HEC-18 for K2 based on L/a ratio. *(No scour calculations with a floodplain study.)*
☐	☐	☒	HEC-RAS error for Abutment Scour been accounted for by entering all of the data for the Abutment Scour calculation. *(No scour calculations with a floodplain study.)*
☐	☐	☒	Independent check of HEC-RAS scour calculations using Excel spreadsheets. *(No scour calculations with a floodplain study.)*
☐	☐	☒	Plot toes and tops of slope for proposed bridge on the topographic mapping for project to check for skew, channel centerline, and overall layout. Show skew of bridge and the roadway stationing (if available). *(No proposed bridge with a floodplain study.)*

Hydraulics Report Items:
Check appropriate box: *(If "NA" is checked, an explanation should be entered below item.)*

Yes	No	N/A	
☐	☐	☒	Multiple opening crossings set with conveyances only at the left and right extents of cross section. *(No multiple opening in this model reach)*
☒	☐	☐	Check HEC-RAS output Errors, Warnings and Notes. Some culverts are supercritical during 1%AC. *OK supercritical flow in structure with high headwater is expected and reasonable.*
☒	☐	☐	Version of HEC-RAS listed in report.
☒	☐	☐	High water events and floodplain risks within project limits discussed in the report.
☐	☐	☒	Existing and proposed overtopping events discussed in the report. *(No proposed bridge in a floodplain study.)*
☐	☐	☒	Water surface elevation(s) on the date of survey listed in report and the Bridge Rec Memo. *(No proposed bridge in this floodplain study.)*
☐	☐	☒	Hydraulic Data Summary Sheet completed. *(No proposed bridge in this floodplain study.)*
☐	☐	☒	Channel width modeled in HEC-RAS matches Report & Bridge Recommendation Memo. *(No proposed bridge in a floodplain study.)*

Hydraulic Data

Quality Assurance (QA) Tracking

Project Name: Beaverhead County Flood Study

Mapping Activity Statement No.: 2016-01

Model: Junction Creek

Task Completed: Jan. 24, 2018

Submission Date: Jan. 31, 2018

QC Review Activity		
1. Ready for QC	LTP: LDC	Date: August 30, 2017
2. QC Review	QCR: KKM	Date: August 30, 2017
3. Concurrence	LTP: LDC	Date: August 31, 2017
4. Changes Made	LTP: LDC	Date: Sept. 4, 2017
5. Changes Verified	QCR: KKM	Date: Sept. 12, 2017
FEMA PTS Review 1 Response		
6. Changes Made	LTP: LDC	Date: Jan. 24, 2018
7. Changes Verified	QCR: KKM	Date: Jan. 29, 2018

LTP – Lead Technical Professional: Luke Carlson_____

QCR – Quality Control Reviewers: Kristyn Mayernik_____

QA Review Checklist for Hydraulics

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
01	Is the computer program used for hydraulic modeling approved by FEMA, and is it a current model version?	The list of models approved by FEMA can be found at www.fema.gov/fhm/en_modl.shtm	Pass ☒ Fail ☐ N/A ☐	
02	Does the model cover the reach of detailed study shown on the workmap?		Pass ☒ Fail ☐ N/A ☐	
03	Were both Multiple and Floodway models run?		Pass ☒ Fail ☐ N/A ☐	
04	Does the flow used in the hydraulic model match with the Summary of Discharges table?		Pass ☒ Fail ☐ N/A ☐	
05	Do split flow reaches check with master flow diagram and table and check for continuity with hydrology?		Pass ☒ Fail ☐ N/A ☐	
06	Are the 1% AC flows identical for both multiple & floodway models?		Pass ☒ Fail ☐ N/A ☐	
07	Is the starting water surface boundary condition of the model appropriate?		Pass ☒ Fail ☐ N/A ☐	
08	Is the Starting Water Surface Elevation for floodway run within 0.5 foot surcharge limit?		Pass ☒ Fail ☐ N/A ☐	
09	Are all floodway surcharges less than or equal to 0.5 foot?		Pass ☒ Fail ☐ N/A ☐	
10	There are no negative surcharges.		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
11	Are all bridges visible on the workmap modeled or is a reason for not modeling provided?		Pass ☒ Fail ☐ N/A ☐	
12	Are bridges/culverts correctly modeled with high and low flow methods selection?		Pass ☒ Fail ☐ N/A ☐	
13	Are bridges/culverts coded with correct low chord, high chord, pier widths, coefficients and centerline stations?		Pass ☒ Fail ☐ N/A ☐	
14	Have ineffective flow areas, if any, been identified and blocked?		Pass ☒ Fail ☐ N/A ☐	JCO 8447 ROB may need an IE *OK, no IE needed due both to actual 1% modeled WSEL as well as continuity of terrain and mapping completed.*
15	Does the River Stationing match the downstream channel reach lengths in the model?		Pass ☒ Fail ☐ N/A ☐	
16	Does the model's stationing as represented on the profile, match the stream distances shown on the map?		Pass ☒ Fail ☐ N/A ☐	
17	Are the left and right overbank distances adjusted for flow around curves?		Pass ☒ Fail ☐ N/A ☐	JNC 11717, 16532, 17141-19108, (OK caused by meandering)
18	Are cross-sections placed perpendicular to channel?		Pass ☒ Fail ☐ N/A ☐	
19	Are cross-section bank stations set at top of main channel bank?		Pass ☒ Fail ☐ N/A ☐	
20	Do cross-sections extend beyond the 0.2% AC floodplain?		Pass ☒ Fail ☐ N/A ☐	
21	Are cross-sections spaced correctly for general criteria of 900-1100 feet maximum between cross-sections?		Pass ☒ Fail ☐ N/A ☐	

QA Review Checklist for Hydraulics

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
22	Are split flow paths unencroached and identified?		Pass ☒ Fail ☐ N/A ☐	
23	Are all Check-RAS error messages resolved?		Pass ☒ Fail ☐ N/A ☐	cHECk-RAS completed. Minor issues with cHECk-RAS reading HEC-RAS 5.0.3 output as noted in the comments.
24	Are the Manning's n values used in the model within reasonable ranges?		Pass ☒ Fail ☐ N/A ☐	Manning's n values are reasonable but update ranges on Page 4 of the report. *OK, Page 4 documents roughness in* Effective *study, not the proposed study. See Table 16 page 26 for roughness ranges for this study.*
25	Are Levees, if present, modeled appropriately based on whether they are certified according to NFIP (65.10)?		Pass ☐ Fail ☐ N/A ☒	
26	Are expansion/contraction coefficients set at 0.3 and 0.5 at correct river stations for bridge/culvert crossings?		Pass ☒ Fail ☐ N/A ☐	Unless otherwise noted.
27	For areas where non-certified levees are shown on the workmap has analysis been provided for With & Without Levee conditions?		Pass ☐ Fail ☐ N/A ☒	
28	Have sufficient backup hydraulic analysis been provided for any shallow flooding, or coastal areas, if any?		Pass ☐ Fail ☐ N/A ☒	
29	Metadata file is submitted?		Pass ☒ Fail ☐ N/A ☐	
30	Hydraulic model is calibrated to available high water?		Pass ☐ Fail ☐ N/A ☒	Calibration data was not available. Newspaper clippings and oral records of past flooding appear to be consistent with the model and are discussed in the Hydraulic Summary Report.

Profiles:

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
31	Do the profiles meet FEMA format & font criteria?		Pass ☒ Fail ☐ N/A ☐	
32	Have appropriate vertical and horizontal scales been chosen?		Pass ☒ Fail ☐ N/A ☐	
33	Are elevations referenced to NAVD88 and shown?		Pass ☒ Fail ☐ N/A ☐	
34	Does the title block show the correct community or county and State names?		Pass ☒ Fail ☐ N/A ☐	
35	Does the beginning station reference match the labeling of the left side of the first profile for each flooding source?		Pass ☒ Fail ☐ N/A ☐	
36	Is the backwater or influence from the receiving stream shown on the profile?		Pass ☒ Fail ☐ N/A ☐	
37	Do the profiles have appropriately spaced lettered cross-sections?		Pass ☒ Fail ☐ N/A ☐	
38	Are all the corporate limits and confluences shown on the profile?		Pass ☒ Fail ☐ N/A ☐	Should you show Lima Limits on the profile? *Corporate limits are not included on profiles based on current (Nov. 2016) guidance. Update Hydraulics QA checklist.*
39	Do the bridge and culvert labels match with the labels shown on the base map?		Pass ☒ Fail ☐ N/A ☐	
40	Do bridge low chord, high chord, and river station match HEC-RAS model?		Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
41	Do the locations of the lettered cross sections with respect to bridges and confluences match with the mapped locations?		Pass ☒ Fail ☐ N/A ☐	
Floodway Data Tables:				
42	Do the overall font & formatting meet FEMA criteria?		Pass ☒ Fail ☐ N/A ☐	
43	Is the proper community name and stream name shown?		Pass ☒ Fail ☐ N/A ☐	
44	Do the beginning station and measurement units match the profile?		Pass ☒ Fail ☐ N/A ☐	
45	Do the Cross Section Letter distances match the stations shown on the Profile?	(rounded to nearest foot)	Pass ☒ Fail ☐ N/A ☐	
46	Are the WIDTH and SECTION AREA in FDT exactly the same as the model output?	(rounded to nearest foot)	Pass ☒ Fail ☐ N/A ☐	
47	Do the Velocity numbers match the Mean Velocity output?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	
48	Are backwater elevations or influence elevations from the profile, if any, shown in the Regulatory Column?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	
49	Are the With and Without Floodway WSELs shown “without consideration of backwater”, and do they match the model output?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	
50	Is the correct Datum shown?	Must match Profile and FIRM	Pass ☒ Fail ☐ N/A ☐	

No.	Hydraulic Review	Definition	Pass Fail N/A	Reviewer Comments
51	Does the INCREASE column, equal the difference between WITH & WITHOUT columns?	(rounded to one decimal point)	Pass ☒ Fail ☐ N/A ☐	

Floodplain Boundary Standard Audit Report

1. Review type	GIS - FBS	4. Description of Materials Reviewed	Beaverhead County, MT – Junction Creek Floodplain Mapping FBS deliverable. Beaverhead County is Risk Class C. Morrison-Maierle completed the hydraulics and floodplain mapping TSDN. QST under contract with MT DNRC completed the DEM.
2. Mapping partner	Morrison-Maierle		
3. Final approver & date	Breanne Carr / 6/28/2018	5. Reference ID	Hydraulics and Floodplain Mapping
4. Reviewer & date	Luke Carlson / 6/28/2018		

Number	Description	Results	Comments
7.	Name of stream reaches and/or coastline audited	Junction Creek and separate flood profiles for split flow alignments consisting of Junction Creek Overflow, Alder Creek, and Gleed Ditch.	
8.	Total stream and/or coastal shoreline length audited	6.5 miles	Junction Creek-3.1 miles, Junction Creek Overflow-2.5 miles, Alder Creek-0.3 miles, Gleed Ditch-0.6 miles
9.	Number of floodplain boundary points audited	1,055 Risk Class C Points	
10.	Number of floodplain boundary points passed (see attached shapefile)	1,017 Risk Class C Points	
11.	Number of floodplain boundary points failed (see attached shapefile)	38 Risk Class C Points	
12.	Overall pass/fail percentages for study audit risk classes	Risk Class C Passed - 96.4% Failed - 3.6%	
13.	Stream and/or coastal shoreline name and length that passed audit	6.5 miles of stream passed the audit. Junction Creek-3.1 miles, Junction Creek Overflow-2.5 miles, Alder Creek-0.3 miles, Gleed Ditch-0.6 miles	

Floodplain Mapping Data

Quality Control Tracking

Project Name: Beaverhead County Flood Study

Mapping Activity Statement No.: 2016-01

Task Completed: 7/09/2018

Submission Date: 7/10/2018

QC Review Activity		
1. Ready for QC	LTP: LDC	Date: 7/10/2018
2. QC Review	QCR: KKM	Date: 7/10/2018

LTP – Lead Technical Professional: Luke Carlson

QCR – Quality Control Reviewers: Kristyn Mayernik

No.	Floodplain Mapping Review	Definition	Pass Fail N/A	Reviewer Comments
01	Has a clear index of workmaps been provided, and are all workmaps available? Are all studied flood sources clearly identified?	The list of models approved by FEMA can be found at www.fema.gov/fhm/en_modl.shtm	Pass ☒ Fail ☐ N/A ☐	
02	Is the datum of the workmap topography shown?		Pass ☒ Fail ☐ N/A ☐	
03	Does the range of the identified cross sections for each flood source match the range in the model?		Pass ☒ Fail ☐ N/A ☐	
04	Are the mapped floodway widths within 5% of the floodway model top-widths?		Pass ☒ Fail ☐ N/A ☐	
05	Is the new floodway designed to match and tie in to the effective floodway if any?		Pass ☐ Fail ☐ N/A ☒	New study entirely replaces effective mapping and extends beyond it both upstream and downstream
06	Do the floodplain boundaries of the individual flood sources tie in to other flood sources or to effective floodplain data, and are they smooth with sufficient vertices?		Pass ☒ Fail ☐ N/A ☐	
07	Does the range of BFEs on the workmap agree with the range of BFEs on the Profile?		Pass ☒ Fail ☐ N/A ☐	
08	Do the BFEs, XS BFE labels, and floodplain boundaries agree with the contours?		Pass ☒ Fail ☐ N/A ☐	FBS audit completed with greater than 96% passing rate.
09	Check the relationship of vector or DOQQ images to flooding.		Pass ☐ Fail ☐ N/A ☒	Explicit calibration data is not available for comparison to flood mapping boundaries
10	Floodplain boundary smoothing, gap removal, and flood fringe removal are within study tolerance.		Pass ☒ Fail ☐ N/A ☐	
11	Ensure 1% annual chance, floodway, 0.2% annual chance polygons do not overlapping on another.		Pass ☒ Fail ☐ N/A ☐	

No.	Floodplain Mapping Review	Definition	Pass Fail N/A	Reviewer Comments
12	S_XS, Floodway data tables, and L_XS_Elev regulatory water surface elevations are consistent.		Pass ☒ Fail ☐ N/A ☐	One inconsistency in the L_XS_Elev table corrected
13	S_FLD_HAZ_AR meets topology rules.		Pass ☒ Fail ☐ N/A ☐	
	DEPTH GRIDS			
14	The grids cover the entire project area.		Pass ☒ Fail ☐ N/A ☐	
15	If the flood risk data extends outside the project area, then the grid data is not clipped at the project area boundary.		Pass ☒ Fail ☐ N/A ☐	
16	Flood Risk Database contains grid data to the full extent of the underlying modeling.		Pass ☒ Fail ☐ N/A ☐	
17	Depth and Analysis Grids share the same terrain and bathymetry source datasets as the engineering models.		Pass ☒ Fail ☐ N/A ☐	
18	Riverine depth grids for new studies include the 10%, 4% 2%, 1%, and 0.2% annual chance flood events.		Pass ☒ Fail ☐ N/A ☐	
19	The pixels of all the grids are aligned (raster snapping).		Pass ☒ Fail ☐ N/A ☐	
20	New coastal studies include depth grid for at least the 1% annual chance flood event.		Pass ☐ Fail ☐ N/A ☒	
21	Depth grids for open water reflect the depth of flooding above normal pool.		Pass ☐ Fail ☐ N/A ☒	

No.	Floodplain Mapping Review	Definition	Pass Fail N/A	Reviewer Comments
22	Coastal depth grids for open water areas use the modeling bathymetry source data (when available) to the full extent of the flood hazard zone shown on the FIRM.		Pass ☐ Fail ☐ N/A ☒	
23	Depth grid cell size is based on the density of the ground elevation data used and the appropriate precision that can be supported by the data (e.g., 2-ft contour => 2-m cell).		Pass ☒ Fail ☐ N/A ☐	
24	The horizontal datum of the depth grid(s) is NAD83[NSRS-2007].		Pass ☒ Fail ☐ N/A ☐	
25	The depth grid is floating point with data rounded to the nearest tenth of a unit (i.e., 0.1 feet, 0.1 feet/second, or 0.1%).		Pass ☒ Fail ☐ N/A ☐	
26	The depth grid(s) have the same spatial reference, origin, resolution, and rotation.		Pass ☒ Fail ☐ N/A ☐	
27	All grids have the same spatial extent and data type.		Pass ☒ Fail ☐ N/A ☐	
28	For the 1% annual chance depth grid, the depth grid covers the horizontal extent of the respective 1% annual chance floodplain.		Pass ☒ Fail ☐ N/A ☐	Appears that the depth grid is shifted slightly. *Shift is very minor and much less than mapping tolerance of ~25 feet.*
29	For the 0.2% annual chance depth grid, the depth grid covers the horizontal extent of the respective 0.2% annual chance floodplain		Pass ☒ Fail ☐ N/A ☐	
30	Depth grids of the 10%, 4% 2% (or other lower frequencies) are contained within the 1% annual chance floodplain.		Pass ☒ Fail ☐ N/A ☐	.
31	The data value ranges for all depth grids are reasonable.		Pass ☒ Fail ☐ N/A ☐	
32	All resulting grid values are positive values (i.e. subtract the higher frequency grid from the lower frequency grid).		Pass ☒ Fail ☐ N/A ☐	

No.	Floodplain Mapping Review	Definition	Pass Fail N/A	Reviewer Comments
33	Calculated depth at intersection of cross sections and floodplain matches depth grid (or valid value is found within the range of cell values within 1 cell).		Pass ☒ Fail ☐ N/A ☐	One location on JCO where the depth of the XS doesn't match the grid *Reviewed – OK within adjacent grid cells*
34	Supporting documentation is included for locations where the flood depth grid has large gaps due to issues with the underlying terrain data.		Pass ☐ Fail ☐ N/A ☒	
35	All gaps and voids within the applicable grid boundary appear correct.		Pass ☒ Fail ☐ N/A ☐	
36	All slivers where two intermediate depth grids have been merged are removed.		Pass ☒ Fail ☐ N/A ☐	
37	Dataset is present in Database and naming convention is correct.		Pass ☒ Fail ☐ N/A ☐	
38	All Rasters are Floating Point, resolution of 0.1 units (except Hillshade Raster, an integer raster).		Pass ☒ Fail ☐ N/A ☐	
39	Depth Grids for all reaches have been combined into a study-wide grid.		Pass ☒ Fail ☐ N/A ☐	
40	Values for 10% Depth Grid are less than values for 4% Depth Grid (which is < 2%, which is < 1%, which is < than 0.2%)in corresponding cells.		Pass ☒ Fail ☐ N/A ☐	
41	The cst_dpthxxxpct raster dataset represents water depth in feet for a coastal type of analysis.		Pass ☐ Fail ☐ N/A ☒	
42	The depth_xxxpct raster dataset represents water depth in feet for a non-coastal type of analysis.		Pass ☒ Fail ☐ N/A ☐	
43	Water Surface Change Grid has the same spatial reference, origin, resolution, and rotation as depth grids (and/or other rasters).		Pass ☐ Fail ☐ N/A ☒	

Appendix G – Worst Case Scenario Flow Split Tabular Flow Data

Morrison Maierle

Beaverhead County Modernization Project, Phase II
Mapping Activity Statement: No. 2016-01
Split Flow Data - Regulatory Flow Summary

Morrison Maierle
engineers • surveyors • planners • scientists

Junction Creek Flow Data Summary Table

		JNC - Reach B					JNC - Reach A		
Recurrence Interval		21831	19820	19800	19719	15192	12354	6841	6808
Flow Rate (cfs)	10% AC	540	537.0	533	540	540	540	368	537
	4% AC	720	695.0	670	720	720	720	481	710
	2% AC	850	794.0	738	850	850	850	560	833
	1% AC	1,000	898.0	797	998	1,000	1,000	683	973
	0.2% AC	1,360	1,135.0	909	1,342	1,360	1,360	925	1,309
	1%+ AC	1,930	1,515.0	1,100	1,820	1,847	1,915	1,316	1,767

Junction Creek Overflow Flow Data Summary Table

		Junction Creek Overflow										
Recurrence Interval		13090*	12981	9737	8447	8327	8241	8053	7665	7478	7186	6941
Flow Rate (cfs)	10% AC	0	7	0	0	0	0	0	0	0	0	0
	4% AC	0	50	25	19	6	0	0	0	0	0	0
	2% AC	0	112	83	66	33	16	16	16	16	16	16
	1% AC	0	203	172	149	101	77	77	77	77	77	77
	0.2% AC	0	451	415	379	307	272	255	221	212	189	180
	1%+ AC	0	830	790	749	666	625	506	268	249	200	180

Alder Creek Flow Data Summary Table

		Alder Creek												
Recurrence Interval		1847*	1739	1550	1384	1235	1074	916	783	762	701	525	334	313
Flow Rate (cfs)	10% AC	0	0	0	0	0	0	0	0	0	0	0	0	0
	4% AC	0	13	25	25	25	25	25	25	25	25	25	25	25
	2% AC	0	34	67	67	67	67	67	67	67	67	67	67	67
	1% AC	0	48	95	95	95	95	95	95	95	95	95	95	95
	0.2% AC	0	72	152	169	177	186	199	208	212	217	221	230	235
	1%+ AC	0	83	225	344	403	463	532	551	561	571	580	600	610

Gleed Ditch Flow Data Summary Table

		Gleed Ditch - Reach B									Gleed Ditch - Reach A		
Recurrence Interval		4686*	4666	2614	2581	2452	2268	1963	1706	1683	1517	1393	1379
Flow Rate (cfs)	10% AC	0	172	172	172	172	168	165	123	81	81	81	81
	4% AC	0	239	239	239	239	233	226	164	101	101	101	101
	2% AC	0	290	290	290	290	281	273	197	122	122	122	122
	1% AC	0	317	317	317	317	307	297	214	131	131	131	131
	0.2% AC	0	435	434	433	432	415	398	287	176	180	178	176
	1%+ AC	0	599	594	589	585	550	516	373	230	245	237	230

Lateral Weir Flow Data Summary Table

		JNC		JNC OVF				Gleed Ditch			
Recurrence Interval		19846	6946	9801	8530	8240	7662	2680	2440	1950	1500
Flow Rate (cfs)	10% AC	7	172	7	0	0	0	0	7	84	0
	4% AC	50	239	25	25	0	0	0	13	125	0
	2% AC	112	290	29	67	0	0	0	18	151	0
	1% AC	203	317	31	95	0	0	0	20	166	0
	0.2% AC	451	435	36	143	51	41	3	34	222	4
	1%+ AC	830	598	40	165	357	88	14	69	286	15

* HEC-RAS requires a flow at the head of every reach. These reaches have no base flow and the Lateral Weir input requires both and upstream and a dowstream cross section for the receiving reach. Therefore the upstream reach must be coded as zero (approximately) flow to meet HEC-RAS input data requirements.

= Total lateral weir discharge

= calculated flow split tracking

Beaverhead County Modernization Project, Phase II
Mapping Activity Statement: No. 2016-01
Junction Creek Split Flow - Worst Case Data Summary

Morrison Maierle
engineers • surveyors • planners • scientists

Junction Creek Flow Data Summary Table

Recurrence Interval		JNC - Reach B							Junct - Reach A				
		21831	19820	19800	19719	check	15192	check	12354	check	6841	6808	check
Flow Rate (cfs)	10% AC	540	540	540	540	540	540	540	540	540	539	537	537
	4% AC	720	720	720	720	720	720	720	720	720	715	710	710
	2% AC	850	850	850	850	850	850	850	850	850	841	833	833
	1% AC	1,000	999	999	998	998	1,000	1,000	1,000	1,000	987	973	973
	0.2% AC	1,360	1,354	1,348	1,342	1,342	1,360	1,360	1,360	1,360	1,335	1,309	1,309
	1%+ AC	1,930	1,893	1,857	1,820	1,820	1,847	1,847	1,915	1,915	1,841	1,767	1,767

Junction Creek Overflow Flow Data Summary Table

Recurrence Interval		JNC_OVF						
		13090	12981	9737	8447	8327	8241	check
Flow Rate (cfs)	10% AC	0	0	0	0	0	0	0
	4% AC	0	0	0	0	0	0	0
	2% AC	0	0	0	0	0	0	0
	1% AC	0	2	0	0	0	0	0
	0.2% AC	0	18	0	0	0	0	0
	1%+ AC	0	110	83	66	32	15	15

Alder Creek Flow Data Summary Table

Recurrence Interval		Alder Crk			
		1847	1739	1550	check
Flow Rate (cfs)	10% AC	0	0	0	0
	4% AC	0	0	0	0
	2% AC	0	0	0	0
	1% AC	0	0	0	0
	0.2% AC	0	0	0	0
	1%+ AC	0	34	68	68

Lateral Weir Flow Data Summary Table

Recurrence Interval		JNC		JNC_OVF)	
		19846	6946	9801	8530
Flow Rate (cfs)	10% AC	0	3	0	0
	4% AC	0	10	0	0
	2% AC	0	17	0	0
	1% AC	2	27	2	0
	0.2% AC	18	51	18	0
	1%+ AC	110	148	27	68

* HEC-RAS requires a flow at the head of every reach. These reaches have no base flow and the Lateral Weir input requires both and upstream and a dowstream cross section for the receiving reach. Therefore the upstream reach must be coded as zero (approximately) flow to meet HEC-RAS input data requirements.

= Total lateral weir discharge

= calculated flow split track 435

Beaverhead County Modernization Project, Phase II
Mapping Activity Statement: No. 2016-01
Junction Creek Overflow Split Flow - Worst Case Data Summary

Junction Creek Flow Data Summary Table

Recurrence Interval		Junction Creek - Reach B						JNC - Reach A	
		21831	19820	19800	check	15192	check	12354	check
Flow Rate (cfs)	10% AC	540	537	533	533	540	540	540	540
	4% AC	720	695	670	670	695	695	720	720
	2% AC	850	794	738	738	767	767	834	834
	1% AC	1,000	898	797	797	828	828	923	923
	0.2% AC	1,360	1,135	909	909	945	945	1,180	1,180
	1%+ AC	1,930	1,515	1,100	1,100	1,140	1,140	1,750	1,750

Junction Creek Overflow Flow Data Summary Table

Recurrence Interval		Junction Creek Overflow											
		13090	12981	9737	8447	8327	8241	8053	7665	7478	7186	6941	check
Flow Rate (cfs)	10% AC	0	7	0	0	0	0	0	0	0	0	0	0
	4% AC	0	50	25	19	6	0	0	0	0	0	0	0
	2% AC	0	112	83	66	33	16	16	16	16	16	16	16
	1% AC	0	203	172	149	101	77	77	77	77	77	77	77
	0.2% AC	0	451	415	379	307	272	255	221	212	189	180	180
	1%+ AC	0	830	790	749	666	625	506	268	249	200	180	180

Alder Creek Flow Data Summary Table

Recurrence Interval		Alder Creek													
		1847	1739	1550	1384	1235	1074	916	783	762	701	525	334	313	check
Flow Rate (cfs)	10% AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	4% AC	0	13	25	25	25	25	25	25	25	25	25	25	25	25.0
	2% AC	0	34	67	67	67	67	67	67	67	67	67	67	67	67.0
	1% AC	0	48	95	95	95	95	95	95	95	95	95	95	95	95.0
	0.2% AC	0	72	152	169	177	186	199	208	212	217	221	230	235	235.0
	1%+ AC	0	83	225	344	403	463	532	551	561	571	580	600	610	610.0

Lateral Weir Flow Data Summary Table

Recurrence Interval		Junction Creek		Junction Creek Overflow			
		19846	6946	9801	8530	8240	7662
Flow Rate (cfs)	10% AC	7	133	7	0	0	0
	4% AC	50	186	25	25	0	0
	2% AC	112	224	29	67	0	0
	1% AC	203	254	31	95	0	0
	0.2% AC	451	286	36	143	51	41
	1%+ AC	830	402	40	165	357	88

* HEC-RAS requires a flow at the head of every reach. These reaches have no base flow and the Lateral Weir input requires both and upstream and a dowstream cross section for the receiving reach. Therefore the upstream reach must be coded as zero (approximately) flow to meet HEC-RAS input data requirements.

= Total lateral weir discharge

= calculated flow split tracki 435

Beaverhead County Modernization Project, Phase II
Mapping Activity Statement: No. 2016-01
Gleed Ditch Split Flow - Worst Case Data Summary

Junction Creek Flow Data Summary Table

		JNC - Reach B							JNC - Reach A			
Recurrence Interval		21831	19820	19800	19719	check	15192	check	12354	check	6841	check
Flow Rate (cfs)	10% AC	540	540	540	540	540	540	540	540	540	368	368
	4% AC	720	720	720	720	720	720	720	720	720	481	481
	2% AC	850	850	850	850	850	850	850	850	850	560	560
	1% AC	1,000	999	999	998	998	1,000	1,000	1,000	1,000	683	683
	0.2% AC	1,360	1,354	1,348	1,342	1,342	1,360	1,360	1,360	1,360	925	925
	1%+ AC	1,930	1,893	1,857	1,820	1,820	1,847	1,847	1,915	1,915	1,316	1,316

Junction Creek Overflow Flow Data Summary Table

		JNC_OVF						
Recurrence Interval		13090	12981	9737	8447	8327	8241	check
Flow Rate (cfs)	10% AC	0	0	0	0	0	0	0
	4% AC	0	0	0	0	0	0	0
	2% AC	0	0	0	0	0	0	0
	1% AC	0	2	0	0	0	0	0
	0.2% AC	0	18	0	0	0	0	0
	1%+ AC	0	110	83	66	32	15	15

Alder Creek Flow Data Summary Table

		Alder Crk			
Recurrence Interval		1847	1739	1550	check
Flow Rate (cfs)	10% AC	0	0	0	0
	4% AC	0	0	0	0
	2% AC	0	0	0	0
	1% AC	0	0	0	0
	0.2% AC	0	0	0	0
	1%+ AC	0	34	68	68

Gleed Ditch Flow Data Summary Table

		Gleed Ditch - Reach B										Gleed Ditch - Reach A			
Recurrence Interval		4686	4666	2614	2581	2452	2268	1963	1706	1683	check	1517	1393	1379	check
Flow Rate (cfs)	10% AC	0	172	172	172	172	168	165	123	81	81	81	81	81	81
	4% AC	0	239	239	239	239	233	226	164	101	101	101	101	101	101
	2% AC	0	290	290	290	290	281	273	197	122	121	122	122	122	122
	1% AC	0	317	317	317	317	307	297	214	131	131	131	131	131	131
	0.2% AC	0	435	434	433	432	415	398	287	176	176	176	174	172	172
	1%+ AC	0	599	594	589	585	550	516	373	230	230	245	237	230	230

Lateral Weir Flow Data Summary Table

		JNC		JNC_OVF)		Gleed Ditch			
Recurrence Interval		19846	6946	9801	8530	2680	2440	1950	1500
Flow Rate (cfs)	10% AC	0	172	0	0	0	7	84	0
	4% AC	0	239	0	0	0	13	125	0
	2% AC	0	290	0	0	0	18	151	0
	1% AC	2	317	2	0	0	20	166	0
	0.2% AC	18	435	18	0	3	34	222	4
	1%+ AC	110	598	27	68	14	69	286	15

* HEC-RAS requires a flow at the head of every reach. These reaches have no base flow and the Lateral Weir input requires both and upstream and a dowstream cross section for the receiving reach. Therefore the upstream reach must be coded as zero (approximately) flow to meet HEC-RAS input data requirements.

= Total lateral weir discharge

= calculated flow split tracking

Appendix H – Gleed Ditch Flow Node Decision Record

Luke D. Carlson

From: Decker, Nicole <NDecker@mt.gov>
Sent: Friday, January 12, 2018 10:54 AM
To: Luke D. Carlson
Cc: Story, Steve
Subject: Gleed Ditch

Luke,

We have completed our investigation into the potential impacts of including Gleed Ditch flood or baseflows into the Junction Creek discharge at the downstream end of the study. Considering several factors, we have determined that the impact would be insignificant, rendering it unnecessary to include base/flood flows from Gleed Ditch. Please let me know if you have any questions or concerns.

Nicole Decker
Civil Engineering Specialist
MT DNRC Floodplain Program
(406) 444-6656
ndecker@mt.gov

Appendix I – Manning's Roughness Work Sheets

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 2 for channel roughness adjustments.

Junction Creek - Channel

	Min	Max	Manning's Value
Base Mannings roughness (n_b)	0.028	0.035	0.03
Irregularity adjustment (n_1)	0.001	0.005	0.002
XC variation (n_2)	0.000	0.005	0.002
Obstruction effects (n_3)	0.000	0.004	0.002
Vegetation quantity (n_4)	0.002	0.01	0.003
Meandering Coefficient (m)	1	1.3	1.05
Total n value	0.031	0.0702	**0.041**

Base Mannings' number

The Junction Creek Channel is characterized by a sand/gravel bed.

Irregularity

Junction Creek has minor irregularity with slight erosion on the bank slopes.

Cross section

Junction Creek channel varies gradually between cross-sectional shapes.

Obstruction effects

There are minimal obstructions within the channel, therefore the obstructions are negligible.

Vegetation

Junction Creek channel has a small density of vegetation along the banks of the channel, with minimal vegetation growth on channel bottom.

Meander

Valley length (ft)	14855
River length (ft)	17364
Meander Ratio	1.1689

Notes:

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 3 for floodplain roughness adjustments.

Junction Creek - Willow Riparian Floodplain

	Min	Max	Manning's Value
Base Mannings roughness	0.026	0.035	0.03
Irregularity adjustment	0.001	0.005	0.002
XC variation	0.000	0.000	0.000
Obstruction effects	0.040	0.05	0.04
Vegetation quantity	0.01	0.025	0.02
Total n value	0.077	0.115	**0.092**

Base Mannings' number

The Junction Creek Pasture floodplain soils are characterized by silty sandy soils with gravel and cobble.

Irregularity

The Junction Creek Riparian floodplain has minor to moderate irregularity with rises, and dips occuring at various frequency/density throughout the floodplain.

Obstruction effects

There are minor obstructions in the Riparian floodplain, occupying less than 15 percent of the xs area.

Vegetation

The Riparian floodplain is composed of willows, minimal timber, minimal down trees, and other small, stemy herbaceous vegetation typically fairly spread out. Although the willow vegetation is dense in some areas.

Notes:

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 3 for floodplain roughness adjustments.

Junction Creek - Sage Brush Floodplain Roughness

	Min	Max	Manning's Value
Base Mannings roughness	0.026	0.035	0.03
Irregularity adjustment	0.001	0.005	0.004
XC variation	0.000	0.000	0
Obstruction effects	0.000	0.004	0.001
Vegetation quantity	0.010	0.025	0.02
Total n value	0.037	0.069	**0.055**

Base Mannings' number

The Junction Creek Pasture floodplain soils are characterized by silty sandy soils with gravel and cobble.

Irregularity
The Junction Creek sage brush floodplain has minor irregularity with gentle rises and dips.
Obstruction effects
There are negligible obstructions in the Cultivated floodplain.
Vegetation
The sage brush floodplain is composed of sage brush with intermixed grasses.

Notes:

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 3 for floodplain roughness adjustments.

Junction Creek - Pasture Floodplain

	Min	Max	Manning's Value
Base Mannings roughness	0.026	0.035	0.03
Irregularity adjustment	0.001	0.005	0.004
XC variation	0.000	0.000	0.000
Obstruction effects	0.000	0.004	0.002
Vegetation quantity	0.001	0.01	0.01
Total n value	0.028	0.054	**0.046**

Base Mannings' number

The Junction Creek Pasture floodplain soils are characterized by silty sandy soils with gravel and cobble.

Irregularity
The Junction Creek floodplain has minor irregularity with gentle rises and dips.
Obstruction effects
There are negligible obstructions in the Pasture floodplain.
Vegetation
The Junction Creek Pasture floodplain is composed of grasses, alfalfa, & weeds up to several feet tall interspersed with occasional willow stands and sage brush.

Notes:

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 3 for floodplain roughness adjustments.

Junction Creek - Urban Floodplain

	Min	Max	Manning's Value
Base Mannings roughness	0.026	0.035	0.03
Irregularity adjustment	0.006	0.01	0.001
XC variation	0	0	0.000
Obstruction effects	0.04	0.05	0.04
Vegetation quantity	0.01	0.05	0.01
Total n value	0.082	0.135	**0.081**

Base Mannings' number

The Junction Creek Pasture floodplain soils are characterized by silty sandy soils with gravel and cobble.

Irregularity

The Junction Creek Urban floodplain has minor to moderate irregularity with rises and dips occuring at various frequency/density throughout the floodplain.

Obstruction effects

There are minor obstructions in the Urban floodplain. They typically make up less than 15% of the XS area.

Vegetation

The Urban floodplain is composed of grasses, willows, sage brush, under growth of shrubs and bushes, other stemy herbaceous vegetation, and potentially man made structures.

Notes:

Mannings roughness based on the FHWA publication "G*uide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* ". Table 3 for floodplain roughness adjustments.

Junction Creek - Urban Floodplain with Conveyance Obstructions modeling structures blocking flow

	Min	Max	Manning's Value
Base Mannings roughness	0.026	0.035	0.03
Irregularity adjustment	0.006	0.01	0.001
XC variation	0	0	0.000
Obstruction effects	0.02	0.035	0.03
Vegetation quantity	0.01	0.05	0.01
Total n value	0.062	0.12	**0.071**

Base Mannings' number

The Junction Creek Pasture floodplain soils are characterized by silty sandy soils with gravel and cobble.

Irregularity

The Junction Creek Urban floodplain has minor to moderate irregularity with rises and dips occuring at various frequency/density throughout the floodplain.

Obstruction effects

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Vegetation

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Notes: