Hydraulic Analysis and Floodplain Mapping Report

Clark Fork River Tributaries Floodplain Study
Mineral County, MT

September 2019

Contract Number: WO-MM-162
Mapping Activity Statement No. 2017-04

Clark Fork River Tributaries Floodplain Study

Hydraulic Analysis and Floodplain Mapping Report

Mineral County, Montana

PREPARED FOR:

Montana Department of Natural Resources and Conservation

Federal Emergency Management Agency

September 20, 2019

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.

_____
Mark A. Franchi, PE, CFM

PE
Stamp

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1.0 Introduction and Background

Morrison-Maierle completed the hydraulic analysis for the Clark Fork River Tributaries within Mineral County, Montana, as part of the Mapping Activity Statement (MAS) 2017-04, Mineral County Modernization, Phase II (FEMA 2017). 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), Mineral County and other stakeholders. The purpose of this report is to document the hydraulic analysis and preliminary floodplain mapping to provide results for incorporation into revised Flood Insurance Rate Map (FIRM) panels and a new Flood Insurance Study (FIS).

The study limits, per the MAS scope of work, consists of seven tributary segments within Mineral County with a total length of approximately 37.7-miles that discharge to the Clark Fork River. Seven tributary model segments are included in the portion of the Mineral County Modernization project and documented in this report as summarized in Table 1 and shown on Figure 1. All seven reaches were evaluated as Enhanced Level Option E models with Zone AE delineations without a floodway. Each tributary was modeled from its confluence with the Clark Fork River to the termination of terrain data at the upstream scope of work boundary.

Table 1. Clark Fork River Tributary Model Segments

Reach	Tributary	Analysis Approach	Length (miles)
1	Tamarack Creek	Enhanced Level Option E	4.2
	Tamarack Creek Split Flow		0.4
2	Dry Creek	Enhanced Level Option E	2.6
3	Cedar Creek	Enhanced Level Option E	4.2
4	Trout Creek	Enhanced Level Option E	3.9
5	Meadow Creek	Enhanced Level Option E	3.2
	Sunrise Creek		0.6
6	Nemote Creek Mainstem	Enhanced Level Option E	8.5
	South Fork Nemote Creek		1.3
	Nemote Creek Split Flow		0.4
	Miller Creek		1.6
7	Fish Creek	Enhanced Level Option E	6.8
Total			37.7

This 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, structure surveys, and a new hydrologic analysis developed specifically for this mapping update. The LiDAR was provided by Quantum Spatial Inc. in 2017 (QSI 2017). The hydrologic analysis for Clark Fork River Tributaries was completed by the Pioneer Technical Services, Inc. in 2018 (Pioneer 2018) and was approved by FEMA in 2018. The hydraulic structure inventory was completed

by Pioneer in the December of 2017 (Pioneer 2018b) and submitted to FEMA in January 2018.

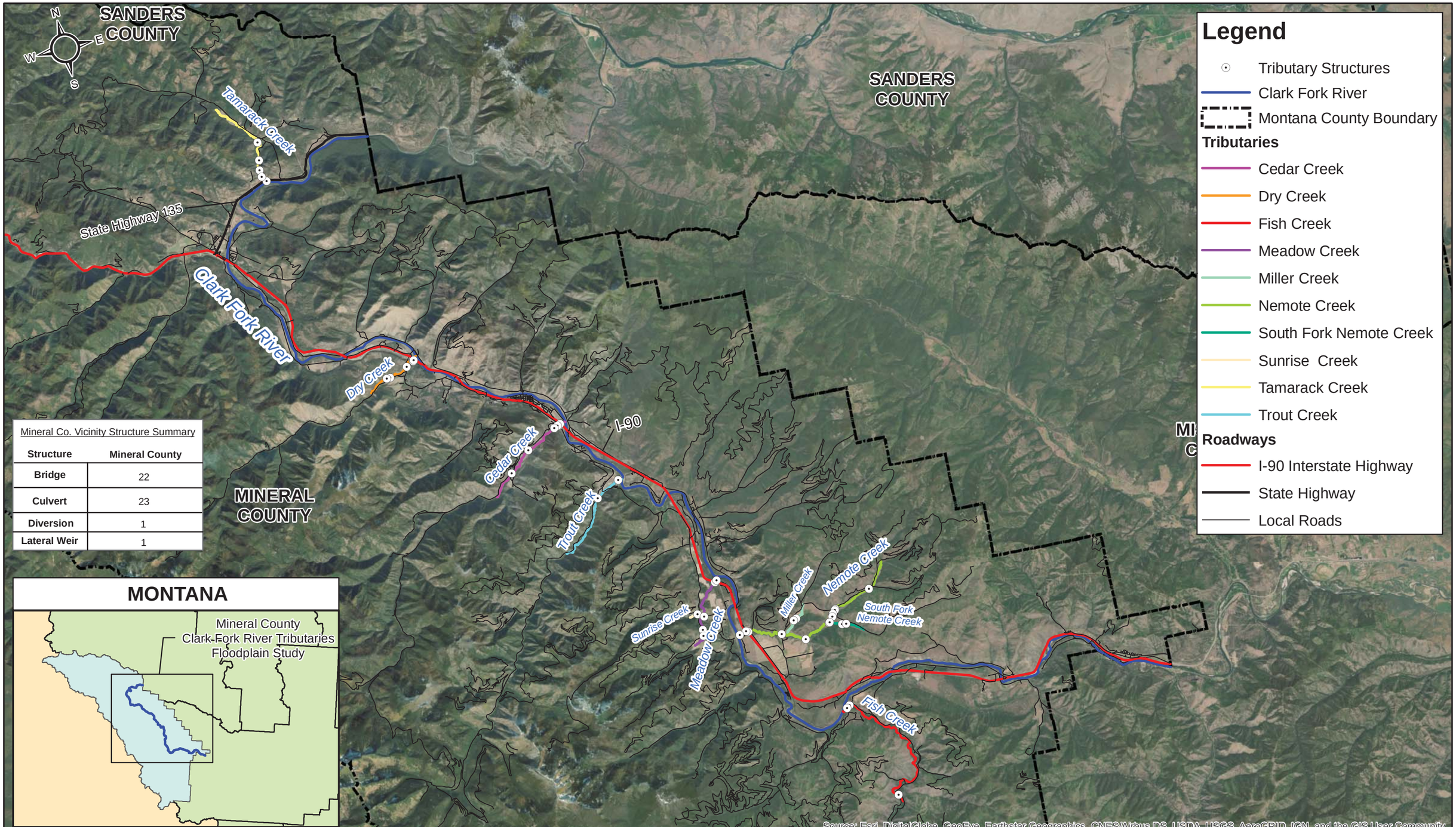
The hydraulic analysis for the seven Clark Fork River Tributaries includes the 10%, 4%, 2%, 1%, 0.2%, and 1% plus annual-chance (AC) flood events. The 1% plus event is defined as a flood event using flood flow rates that include the average predictive error for the discharge calculation for the floodplain study. This flow rate is calculated to provide a confidence range within which the actual 1% annual-chance discharge is likely to fall, given the uncertainty that often exists with estimating discharges (FEMA 2016e). The DNRC and the professional service contractor Morrison-Maierle 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.

1.1 Watershed Description

The hydrology of the basin is primarily snowmelt driven, although significant flows can result from precipitation events. Land use in the Clark Fork River basin is primarily national forest and agricultural with irrigated farming and ranching operations.

The seven Clark Fork River Tributaries in the study area discharge to the Clark Fork River, which is a major tributary to the Pend Oreille River and upper headwaters of the Columbia River located west of the continental divide in western Montana. The river is formed by the confluence of Silver Bow Creek and Warm Springs Creek. The Clark Fork River headwater tributaries originate in the Deerlodge National Forest near the continental divide. The upper watershed is formed by the Bitterroot Mountains to the west, Deer Lodge Mountains to the east, and the Pintler and Highland Ranges to the south. The mainstem of the Clark Fork River begins at Warm Springs, Montana, and flows north for approximately 20-miles through the Deer Lodge Valley before turning west. The Blackfoot and Bitterroot Rivers join the Clark Fork River near Missoula, Montana. Approximately 213-miles downstream of Missoula, the Clark Fork River terminates at Lake Pend Oreille, Idaho. The entire Clark Fork River watershed area encompasses approximately 22,905-square miles. The study watershed basin area from the Missoula County border to the Sanders County border is approximately 1,217-square miles (Pioneer 2018).

The Clark Fork River basin elevations range from over 10,000 feet at the continental divide to 2,060 feet near the confluence with Pend Oreille Lake (Pioneer 2018). The watershed terrain varies from a high alpine environment in its headwaters to a heavily cultivated landscape in the Deer Lodge valley with expansive irrigated pasture lands, bracketed by rolling foothills. The hydrology of the watershed is primarily snowmelt driven. The Clark Fork River Tributaries basin elevations within the study area range from approximately 7,800 feet in the mountains to approximately 2,600 feet near the confluence of Tamarack Creek and Clark Fork River. Land use in the Clark Fork River Tributaries basin is primarily United States National Forest, undeveloped natural land, and agricultural land with irrigated farming and ranching operations.



Mineral Co. Vicinity Structure Summary

Structure	Mineral County
Bridge	22
Culvert	23
Diversion	1
Lateral Weir	1

0 2 4 8 12 16 Miles

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Mineral County Modernization, Phase II

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Clark Fork River Tributaries Study Area

FIG. 1

2.0 Previous Mapping

Flood Insurance Rate Maps (FIRM's) were completed for the Clark Fork River Tributaries in Mineral County, MT in the early 1970s. The flood hazard currently mapped for the Clark Fork River Tributaries is Zone A for approximately 31 creek-miles within Mineral County, Montana. Computer modeling was not completed to determine the Zone A delineations and a Flood Insurance Study (FIS) report was not published with the effective FIRM panels. This Floodplain Study update will be the first FIS report for the Clark Fork River Tributaries in Mineral County.

Zone A flood maps are developed using approximate methodologies and have a flood hazard zone boundary without hydraulic modeling support and do not include Base Flood Elevations (BFEs). This level of flood mapping is often used in rural areas with low populations. Zone A flood maps can be difficult for local communities to manage or administer since they do not include BFE information. This floodplain study will change the flood zones on the maps of the seven Clark Fork River Tributaries to Zone AE and will include BFE's for these streams.

3.0 Hydrology

This flood study, as shown on Figure 1, covers approximately 37.7creek-miles of the Clark Fork River Tributaries within Mineral County, Montana. The hydrologic analyses for Clark Fork River Tributaries was completed as part of the Mineral County Modernization Project, Phase II hydrology provided by Pioneer Technical Services, Inc. in 2018 (Pioneer 2018a).

Three inactive United States Geological Survey (USGS) gaging stations are located in the vicinity of the study area and the summary data for these gages is listed in Table 2.

Table 2. USGS Gaging Stations

Gaging Station Number	Gaging Station Name	Period of Record	Number Of Annual Peaks	Drainage Area (square miles)	Maximum Peak Discharge (cfs / Year)	Minimum Peak Discharge (cfs / Year)
12353820	Dry Creek near Superior, MT	1982 – 1991	10	44.8	560 / 1991	140 / 1988
12353800	Thompson Creek near Superior, MT	1961 – 1979 1982	20	12.0	230 / 1974	4 / 1973
12353400	Negro Gulch near Alberton, MT	1959 – 1973 1984 - 1991	23	8.1	170 / 1965	2 / 1973

cfs: cubic feet per second

For this study, Pioneer conducted flood frequency estimates for both gaged and ungaged sites. Peak flow estimates were calculated at 13 flow nodes within the seven tributaries (1 gaged site and 12 ungaged sites). The flow nodes were located at major sub-tributaries and at the downstream end of study reaches.

At the ungaged flow nodes, Pioneer used the regional regression method to calculate flood frequency peak flow estimates. Only a single stream gage exists on the Clark Fork River tributaries discussed in this report, USGS stream gage 12353820 located on Dry Creek near Superior, Montana. Therefore, the two-station interpolation method or the gage transfer method were not used to estimate peak flows at ungaged flow nodes.

The basin parameters for the flow nodes evaluated in this study all fall within the range of basin and climatic characteristics used to develop the regional regression equations, and, therefore, are applicable to this study. In addition, the study regional regression 1% annual exceedance probability (AEP) estimates fall within one-standard error for stream gages in the study area that had periods of record exceeding 10-years (USGS gage station 12353400 Negro Gulch and 12353800 Thompson Creek), indicating the regional regression estimates are reasonable (Pioneer 2018a).

The Dry Creek gage regional regression 1% AEP estimate was approximately 6-standard errors greater than the 1% AEP gage Bulletin 17C estimate. This difference is interpreted to be attributable to Dry Creek's limited period of record of 10-years (Pioneer 2018a).

Due to the conformance of the parameters at the flow nodes with the basin and climatic characteristics, and the good agreement with gage peak flow estimates that exceed 10-years of record, the regional regression equations were determined to provide the most accurate peak flow estimates for the study (Pioneer 2018a).

Pioneer also developed peak flow 1% plus (1% +) estimates for all flow nodes using standard FEMA methodologies (FEMA, 2016a). The 1% plus is defined as a flood event using flood flow rates that include the average predictive error for the discharge calculation for the floodplain study. This flow rate is calculated to provide a confidence range within which the actual 1% annual-chance discharge is likely to fall, given the uncertainty that often exists with estimating discharges (FEMA 2016e).

The recommended flood frequency discharge rates for the Clark Fork River Tributaries are summarized in Table 3. For the model reaches with split flow paths, the starting condition in the model flow data editor were adjusted based on the optimization results to meet two check goals. First, the entered values should maintain mass continuity with the flow being split. Second, the entered flow values should be in continuity with the calculated split flow rate reported in the model optimization results table. The target agreement for both goals was one cfs, which is well within a reasonable discharge reporting range of 5 to 10 cfs. The recommended 1% annual-chance (1% AC) discharge locations for each Clark Fork River Tributary reach are shown in Figures 2 thru 8.

Table 3. Summary of Discharges for Clark Fork River Tributaries

Upstream River Station (feet)	Reach Location Description	Peak Discharge						
		Cubic Feet per Second (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	n/a
13,069	Tamarack Creek Reach 1 to Confluence with Clark Fork River	167	337	420	491	564	725	880
15,437	Tamarack Creek Reach 2 to Confluence of Split Flow Reach	119	206	241	267	296	360	413
2,049	Tamarack Creek Split Flow Reach	48	131	179	224	268	365	467
22,366	Tamarack Creek to Split Flow Junction	167	337	420	491	564	725	880
13,443	Dry Creek to Confluence with Clark Fork River	663	1,070	1,240	1,380	1,530	1,810	2,387
22,274	Cedar Creek to Confluence with Clark Fork River	1,170	1,760	1,990	2,190	2,380	2,750	3,714
20,724	Trout Creek to Confluence with Clark Fork River	1,470	2,130	2,380	2,600	2,810	3,200	4,384
10,024	Meadow Creek to Confluence with Clark Fork River	192	365	446	515	585	735	913
18,301	Meadow Creek to Confluence with Sunrise Creek	117	228	282	327	373	474	582
3,274	Sunrise Creek to Confluence with Meadow Creek	83	163	202	235	268	340	418
12,803	Nemote Creek to Confluence with Clark Fork River	203	425	539	635	735	961	1,147
25,530	Nemote Creek to Confluence with Miller Creek	157	333	423	500	580	761	905
8,517	Miller Creek to Confluence with Nemote Creek	54	123	161	193	228	307	356
27,069	Nemote Creek to Confluence of South Fork Nemote Creek	115	238	300	352	407	528	635
7,068	South Fork Nemote Creek to Confluence with Nemote Creek	41	98	128	155	183	250	286

Table 3. (cont.) Summary of Discharges for Clark Fork River Tributaries

River Station (feet)	Location Description	Peak Discharge						
		Cubic Feet per Second (cfs)						
		50% Annual Chance	10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	1% +
		2-year	10-year	25-year	50-year	100-year	500-year	n/a
28,573	Nemote Creek to Confluence of Split Flow Reach	111	215	267	311	356	454	541
45,014	Nemote Creek to Diversion of Split Flow Reach	115	238	300	352	407	528	635
2,010	Nemote Creek Split Flow Reach	4	23	33	41	51	74	94
36,038	Fish Creek to Confluence with Clark Fork River	2,850	4,300	4,890	5,380	5,870	6,810	9,159

4.0 Hydraulics

The methods and techniques used to complete the hydraulic analysis for the Clark Fork River Tributaries in Mineral County, Montana are presented in the following sections. The analysis utilized the LiDAR mapping and field hydraulic structure assessments to develop the Enhanced Level Option E 1% AC Zone AE and 0.2% AC Zone X mapping without floodway.

4.1 Hydraulic Analysis

This flood study for the Clark Fork River Tributaries in Mineral County, MT, as shown on Figure 1, consists of reaches of the following seven streams; Tamarack Creek, Dry Creek, Cedar Creek, Trout Creek, Meadow Creek, Nemote Creek, and Fish Creek. The studied length of each Tributary 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 provides 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 (CivilGEO 2018) at flow distances or reach lengths generally ranging from approximately 15 to 500 feet and at structures located within the floodplain study reach. A few locations in the tributary hydraulic models have channel flow lengths exceeding 500 feet. At these locations, the profile baseline meanders and the down valley reach lengths are less than 500 feet (e.g. Nemote Creek RS 21,647). Below is a summary description for the key hydraulic features associated with each Tributary studied.

4.1.1 Tamarack Creek

The Tamarack Creek Tributary hydraulic model begins at the confluence with the Clark Fork River and extends upstream to the north for approximately 4.2 creek-miles (Figure 2). The first 1,300 feet reach of the tributary has a normal depth slope boundary condition of approximately 0.0335 feet/feet. This reach of Tamarack Creek has five hydraulic structure crossings.

A split flow channel reach, as shown on Figure 2, begins at approximately RS 15,600 and conveys flows parallel to the main channel in the right overbank (looking downstream) for approximately 0.4 creek-miles. Flood flows return to the main channel at approximately RS 13,216. A mixing of flood flows occurs along the reach before the split flow confluence due to lower bank elevations between each channel as shown on the preliminary work maps. This mixing of flood flows was modeled with a lateral weir to calculate the flow mixing between the parallel reaches.

4.1.2 Dry Creek

The Dry Creek Tributary hydraulic model begins at the confluence with the Clark Fork River and extends upstream to the southwest for approximately 2.6 creek-miles (Figure 3). The

tributary reach has a normal depth slope boundary condition of approximately 0.0138 feet/feet. No split flow or tributary reaches to Dry Creek were necessary to model this reach of stream.

4.1.3 Cedar Creek

The Cedar Creek Tributary hydraulic model begins at the confluence with the Clark Fork River and extends upstream to the southwest for approximately 4.2 creek-miles (Figure 4). The tributary reach has a normal depth slope boundary condition of approximately 0.0147 feet/feet. No split flow or tributary reaches to Cedar Creek were necessary to model this reach of stream.

4.1.4 Trout Creek

The Trout Creek hydraulic model begins at the confluence of the Clark Fork River and extends upstream to the southwest for approximately 3.9 creek-miles (Figure 5). The tributary reach has a normal depth slope boundary condition of approximately 0.0127 feet/feet. No split flow or tributary reaches to Trout Creek were necessary to model this reach of stream.

4.1.5 Meadow Creek

The Meadow Creek hydraulic model begins at the confluence of the Clark Fork River and extends upstream to the southwest for approximately 3.2 creek-miles. Sunrise Creek extends west approximately 0.6 creek-miles from Meadow Creek RS 10,179 as shown on Figure 6. The first 1,500 feet of Meadow Creek has a steep channel gradient with a normal depth slope boundary condition of approximately 0.1345 feet/feet. No split flow reaches along Meadow Creek were necessary.

4.1.6 Nemote Creek

The Nemote Creek hydraulic model begins at the confluence with the Clark Fork River and extends upstream to the east for approximately 8.5 creek-miles (Figure 7). The first 1,200 feet of the tributary has a steep channel gradient with a normal depth slope boundary condition of approximately 0.2079 feet/feet. The Nemote Creek model also includes the Miller Creek and South Fork of Nemote Creek tributary reaches.

A split flow channel reach begins at Junction 4, as shown on Figure 7, from the backwater of flows from Diversion Structure D1 located at RS 28,560. Flow are conveyed in a canal to the northwest for approximately 0.4 creek-miles and flood flows are discharged to the primary Nemote Creek Floodplain at Junction 3 near RS 13,216. The hydraulic modeling determined that the flood flows stay within the canal floodplain for all the flood events and flows are returned back to the Nemote mainstem floodplain.

Miller Creek, a tributary to Nemote Creek, extends northeast approximately 1.6 creek-miles above its confluence. This tributary to Nemote Creek has two hydraulic structure crossings.

A second tributary, South Fork of Nemote Creek, extends southeast approximately 1.3 creek-miles above its confluence. This tributary to Nemote Creek has two hydraulic structure crossings.

4.1.7 Fish Creek

Fish Creek starts at the confluence with the Clark Fork River and extends upstream to the southeast for approximately 6.8 creek-miles (Figure 8). The tributary reach has a normal depth slope boundary condition of approximately 0.0121 feet/feet. No split flow or tributary reaches with Fish Creek were necessary to model this reach of stream.

Mineral Co. Vicinity Structure Summary

Structure	Mineral County
Bridge	3
Culvert	2
Lateral Weir	1

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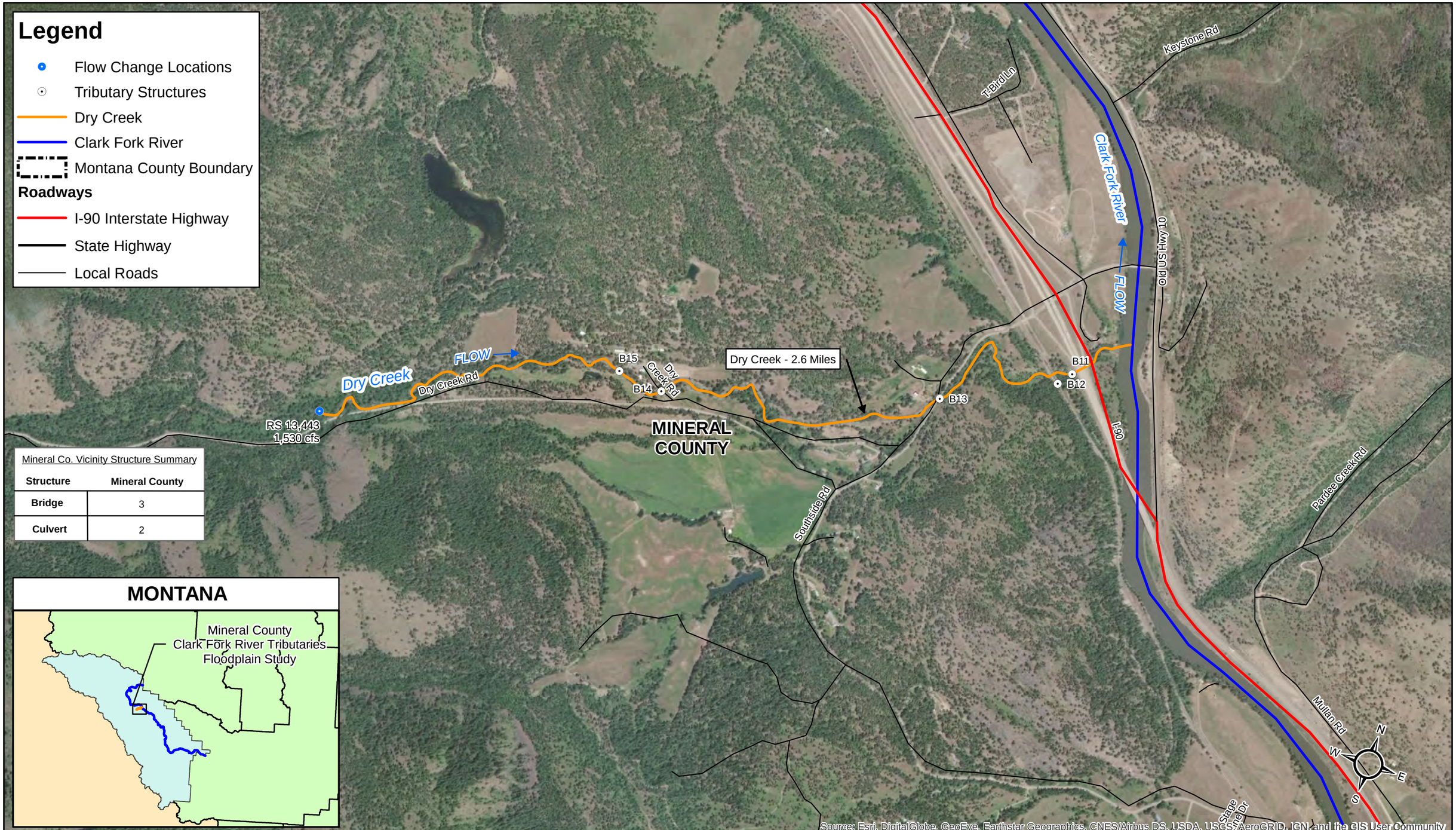
Tamarack Creek Study Area

FIG. 2



Mineral Co. Vicinity Structure Summary

Structure	Mineral County
Bridge	3
Culvert	2

0 0.25 0.5 1 Miles

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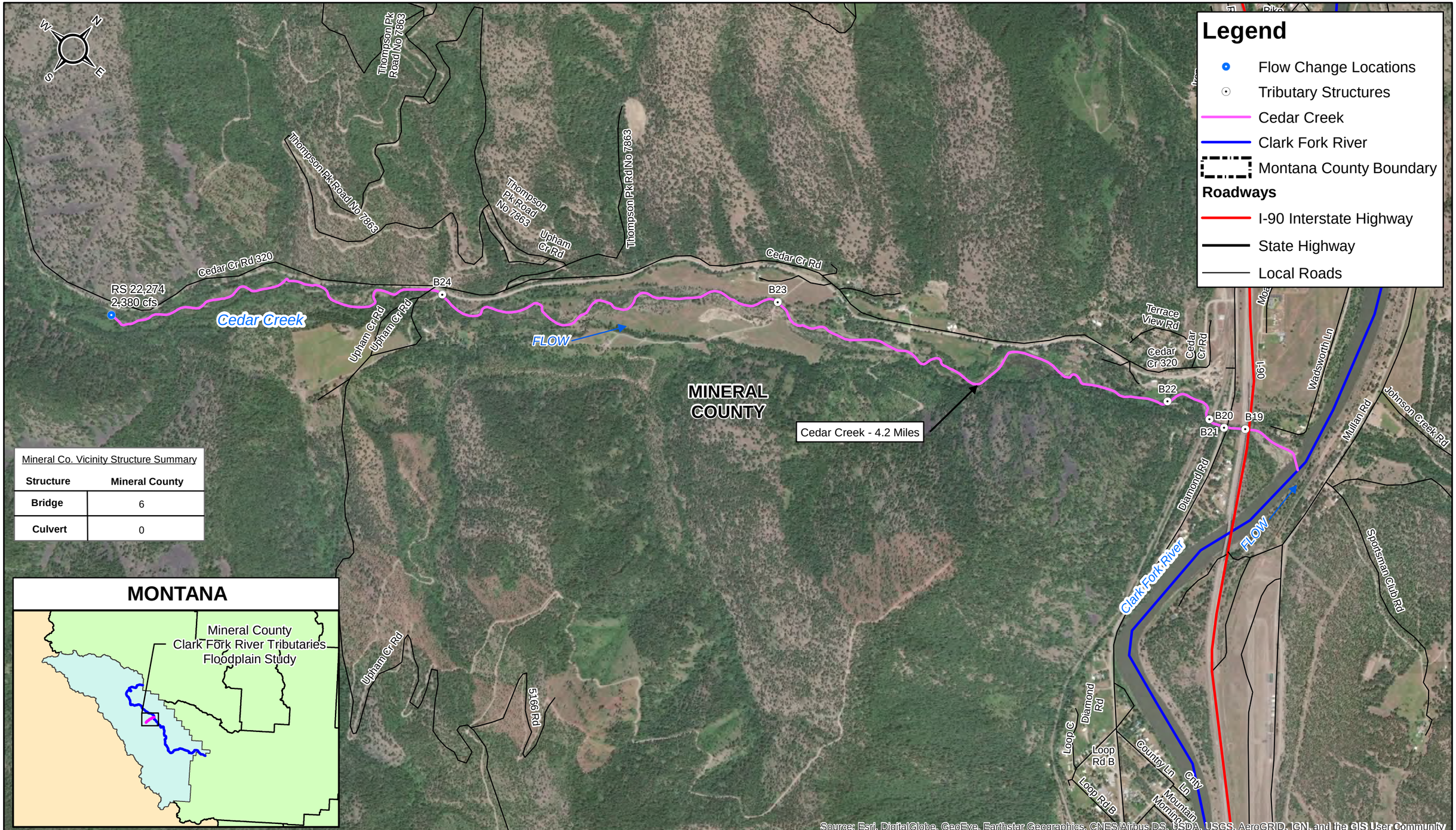
Dry Creek Study Area

FIG. 3



Mineral Co. Vicinity Structure Summary

Structure	Mineral County
Bridge	6
Culvert	0

0 0.25 0.5 1 Miles

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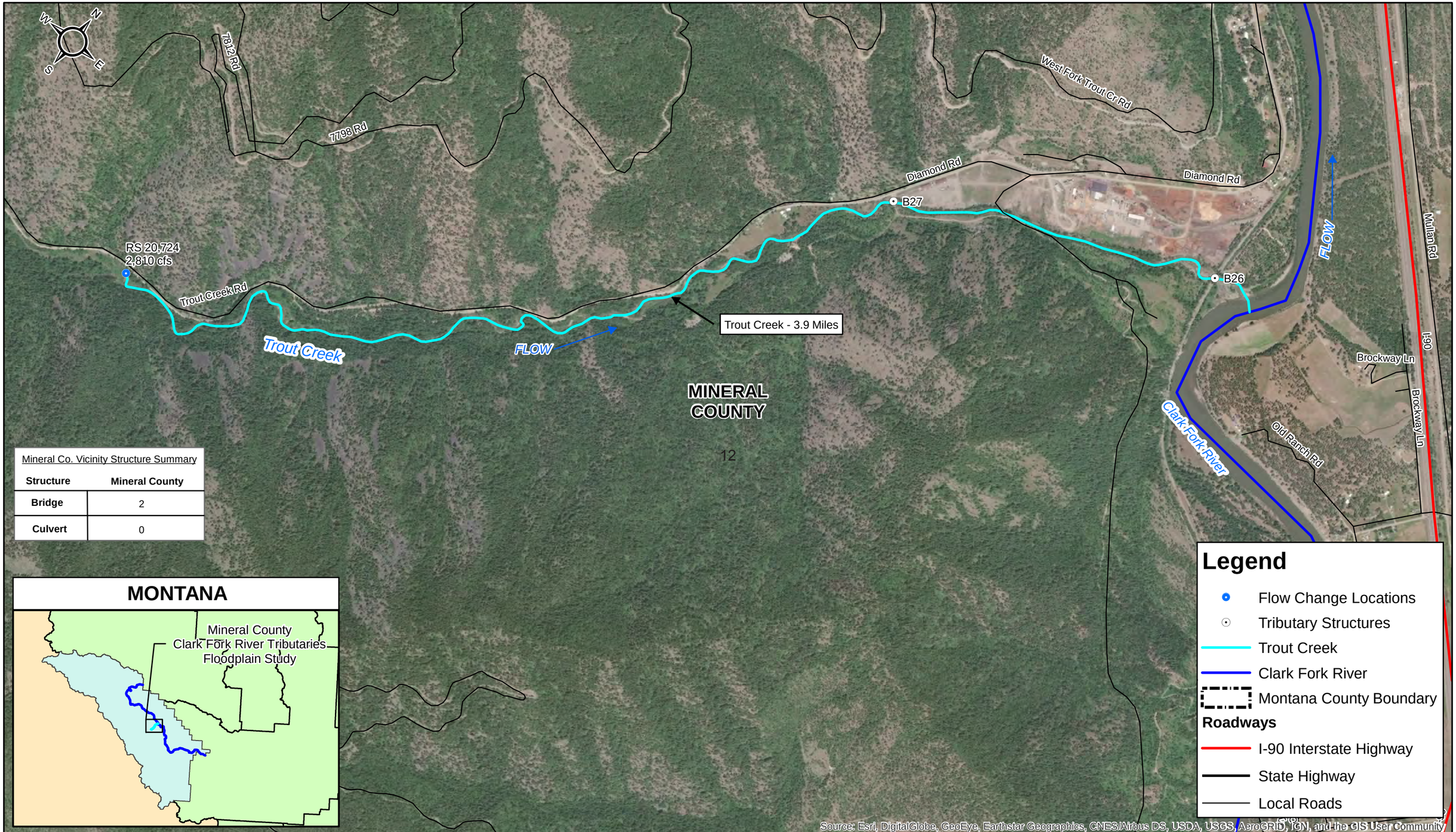
Cedar Creek Study Area

FIG. 4



0 0.25 0.5 1 Miles

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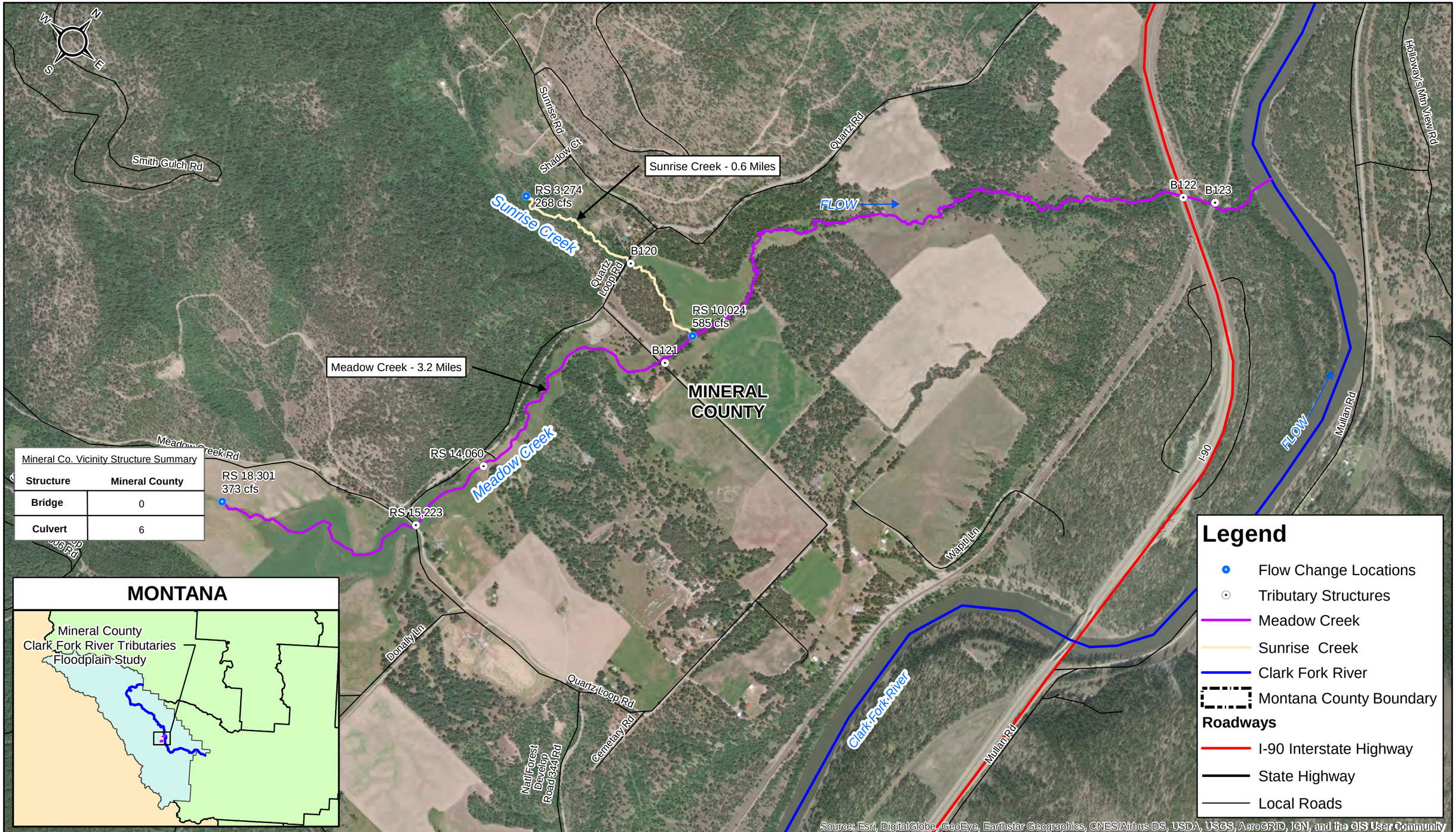
Trout Creek Study Area

FIG. 5



0 0.25 0.5 1 Miles

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Meadow Creek Study Area

FIG. 6

0 0.5 1 2 Miles

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DATE: 09/13/19

Mineral County

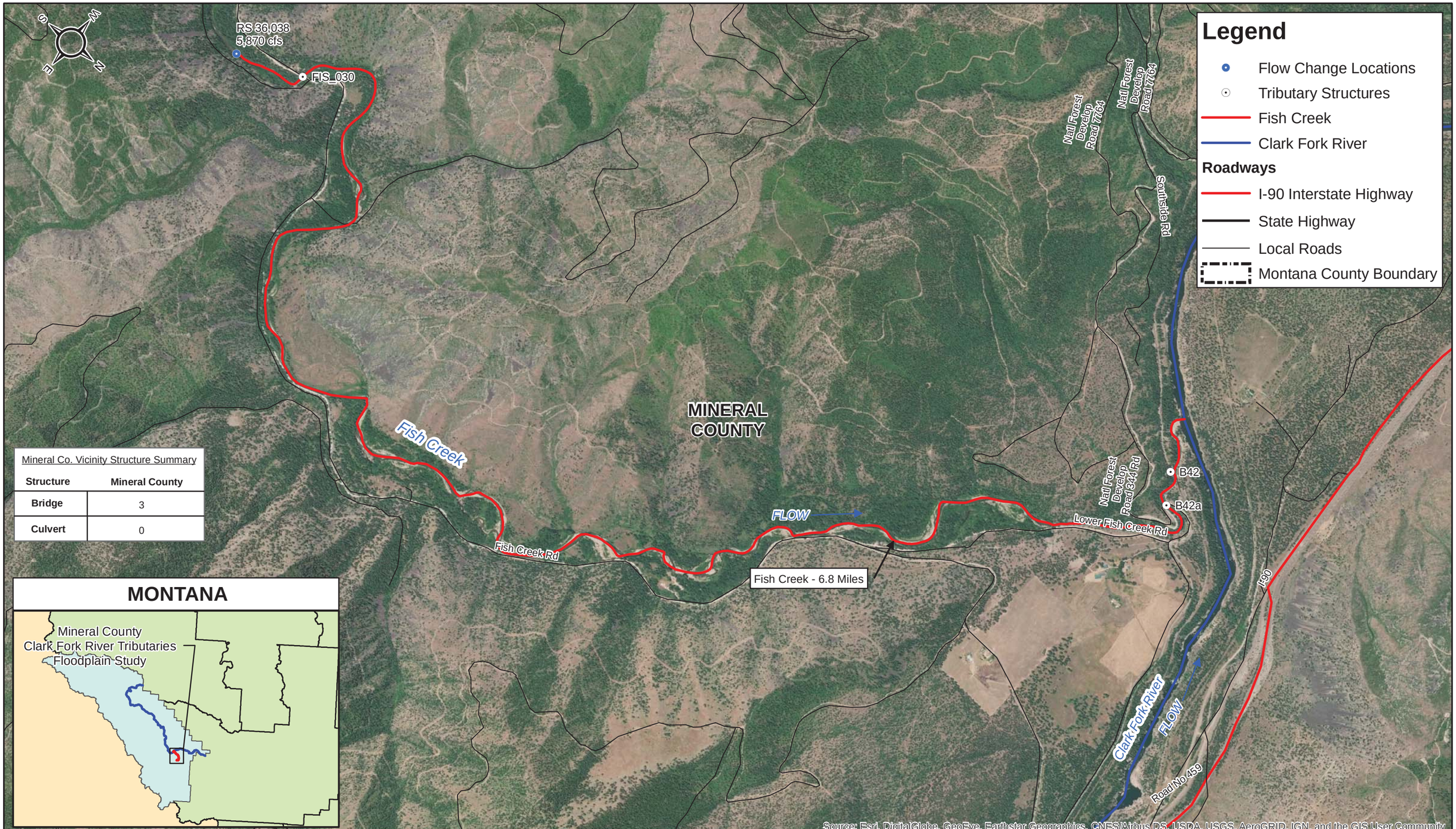
Mineral County Modernization, Phase II

MT

PROJECT NO. 1447.050

Nemote Creek Study Area

FIG. 7



Mineral Co. Vicinity Structure Summary

Structure	Mineral County
Bridge	3
Culvert	0

Morrison Maierle
engineers · surveyors · planners · scientists

1 Engineering Place
Helena, MT 59602

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DATE: 09/12/19

Mineral County

Mineral County Modernization, Phase II

MT

PROJECT NO. 1447.050

Fish Creek Study Area

FIG. 8

4.2 Topographic Data Acquisition

The Montana Department of Natural Resource Conservation (DNRC) contracted with Quantum Spatial, Inc. (QSI) to acquire topographic Light Detection and Ranging (LiDAR) data for the project area. QSI performed a topographic LiDAR survey on the Clark Fork River Tributaries within Mineral County for the DNRC between November 18th and November 26th, 2016. Over 43,000-acres were surveyed by QSI with the upper survey extents beginning upstream of Alberton, MT and ending downstream of St. Regis, MT. The LiDAR survey included near-infrared wavelength for terrestrial topography for the Clark Fork River Tributaries. The specifications for the LiDAR DEM required digital elevation data with a root mean square error (RMSE) less than or equal to 30 centimeters (approximately one foot), (QSI 2017). To verify the LiDAR DEM data met the vertical accuracy criteria, QSI compared ground measured check points with the LiDAR DEM data at the same locations.

The LiDAR DEM data met the vertical accuracy statistics reported in Mineral County LiDAR Technical Data Report as summarized in Table 4 (QSI 2017).

Table 4. LiDAR Accuracy Statistics

Parameter	Result
Sample	67 Points
Average	-0.053 feet
Median	-0.047 feet
RMSE	0.186 feet
Standard Deviation	0.180 feet
95% Confidence (1.96*RMSE)	0.365 feet

The LiDAR deliverables included 3-foot grid bare earth digital elevation models (DEM) for the entire length of the Clark Fork River Tributaries corridors (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

4.3 Field Structure Inventory

A Field Structure Inventory of the hydraulic structures for the Clark Fork River Tributaries study was performed by Pioneer Technical Services, Inc. (Pioneer 2017). Table 5 is a summary of the number of structures inventoried on the Clark Fork River Tributaries.

Table 5. Field Structure Inventory

ID No.	Structure Type	Tributary Reach	Roadway	River Station (feet)
B1	Culvert	Tamarack Creek	Highway 135	286
B2*	Bridge	Tamarack Creek	Private Road	1,819
B3	Bridge	Tamarack Creek	Private Road	3,234
B4	Bridge	Tamarack Creek	Private Road	5,458
B5	Culvert	Tamarack Creek	Tamarack Creek Road	10,085
B11	Culvert	Dry Creek	I-90 East and West	819
B12	Culvert	Dry Creek	MRL Railroad Grade	1,220
B13	Bridge	Dry Creek	South Side Road	3,592
B14*	Bridge	Dry Creek	Private Road	7,954
B15*	Bridge	Dry Creek	Private Road	8,693
B19	Bridge	Cedar Creek	I-90 East and West	1,156
B20	Bridge	Cedar Creek	Diamond Match Road	1,488
B21	Bridge	Cedar Creek	MRL Railroad Grade	1,738
B22	Bridge	Cedar Creek	Private Road	2,713
B23	Bridge	Cedar Creek	Lynch Ranch Lane	10,007
B24	Bridge	Cedar Creek	Upham Gulch Road	16,251
B26*	Bridge	Trout Creek	MRL Railroad Grade	846
B27	Bridge	Trout Creek	Cyr Iron Mountain Road	6,245
B31	Bridge	Nemote Creek	Abandoned Railroad Grade	428
B32	Bridge	Nemote Creek	Private Road	2,016
B33	Culvert	Nemote Creek	I-90 East and West	2,365
B34***	Bridge	Nemote Creek	East Mullen Road	2,507
–**	Bridge	Nemote Creek	Private Road	2,541
B35	Culvert	Nemote Creek	Nemote Creek Road	11,615
B36	Culvert	Nemote Creek	Round Mountain Road	18,070
B37	Culvert	Nemote Creek	South Fork Nemote Creek Road	25,070
B37a	Culvert	Nemote Creek	Private Road	25,250
B38	Bridge	Nemote Creek	South Fork Nemote Creek Road	26,890
B39	Culvert	Nemote Creek	Standing Rock Court	27,315
B39a	Culvert	Nemote Creek	Standing Rock Court	27,420
D1	Diversion	Nemote Creek	Private Diversion	28,560
B40	Culvert	Nemote Creek	U.S. Forest Service Road 9915	28,750
B41	Culvert	Nemote Creek	Sheridan Road	37,860
B42	Bridge	Fish Creek	MRL Railroad Grade	1,436
B42a	Bridge	Fish Creek	Fish Creek Road	2,155
FIS_030	Bridge	Fish Creek	Fish Creek Road	34,490
–**	Culvert	Meadow Creek	Quartz Loop Road	15,223
–**	Culvert	Meadow Creek	Private Road	14,060
B120	Culvert	Sunrise Creek	Quartz Loop Road	1,376

* Unable to survey structure crossing due to access denial or closed gate.
** Structure does not have an ID number.
*** Bridge structure not modeled due spanning over downstream culvert crossing controlling flows.

Table 5. (cont.) Structure Survey

ID No.	Structure Type	Tributary Reach	Roadway	River Station (feet)
B121	Culvert	Meadow Creek	Quartz Loop Road	10,702
B122	Culvert	Meadow Creek	I-90 East and West	1,343
B123	Culvert	Meadow Creek	MRL Railroad Grade	938
B124*	Bridge	Miller Creek	Private Road	4,945
B125*	Culvert	Miller Creek	War Horse Lane	4,270
B126	Culvert	South Fork Nemote Creek	Private Road	3,110
B127	Culvert	South Fork Nemote Creek	Private Road	2,300

* Unable to survey structure crossing due to access denial or closed gate.

4.4 Profile Baseline

The alignment of the Clark Fork River Tributaries Profile Baselines were prepared by Pioneer during the hydrologic analysis for the Clark Fork River (Pioneer 2018a). To appropriately model the streams, the locations of major tributary confluences and other flow change locations were identified. The DNRC coordinated with Pioneer to set the Profile Baselines as stream distance or river stationing in feet above the respective downstream limit. The flow change (flow nodes) of the Clark Fork River Tributaries were set at river station locations as summarized in Table 2. The Profile Baselines were also used to locate cross sections and key features along the streams.

Profile Baselines were added during the hydraulic analysis to the Tamarack and Nemote Creek models to include split flow reaches to appropriately account for hydraulic flow distribution and to prepare the preliminary floodplain mapping.

4.5 Boundary Conditions

To perform a hydraulic analysis in HEC-RAS, a boundary condition is specified at the first downstream cross section of the model reach. Per FEMA's One-Dimensional Hydraulics Guidance for Flood Risk Analysis and Mapping (FEMA 2016b), the downstream boundary condition in a one-dimensional, steady flow, step-backwater model should be taken from a previously established water surface elevation (WSEL), if available. A previously established WSEL is not available for the Clark Fork River Tributaries flood study since the flood events for the tributaries would not coincide with the Clark Fork River Tributaries in Mineral County, Montana (Pioneer 2018a).

To address the use of coincident peaks between the study tributaries and the Clark Fork River mainstem, Pioneer referenced the FEMA guidance requirements. For the use of coincident peaks to be appropriate FEMA guidance documents (FEMA, 2016b) require the following criteria be met:

1. The ratio of the drainage areas lies between 0.6 and 1.4;
2. The arrival times of flood peaks are similar for the two combining watersheds;
3. The likelihood of both watersheds being covered by the storm is high.

The study tributaries do not meet the drainage area ratio stated in criteria No. 1.

Except for Dry Creek, study tributaries and the Clark Fork mainstem are not gaged at the tributary's\mainstem confluence. Therefore, data to determine criteria No. 2 is not available.

The Clark Fork River mainstem drainage area at the tributary confluences are orders of magnitude greater than the tributary basin areas. Therefore, there is a low likelihood that both watersheds would peak simultaneously as required by criteria No. 3. Consequently, Pioneer determined that the tributaries do not meet the FEMA criteria for coincident peaks (Pioneer 2018a).

It was confirmed with the DNRC that normal depth energy slope method would be most appropriate for the Clark Fork River Tributaries hydraulic modeling and applicable backwater from the Clark Fork River mainstem would be shown on the work maps and flood profiles for flood risk documentation purposes.

Therefore, the normal depth energy slope method was used for the starting downstream boundary condition. The normal depth slope is the slope of the Hydraulic Grade Line (HGL) which is calculated by iterative model runs resulting in convergence at the HGL slope.

A summary of the boundary conditions established for each model segment for the Clark Fork River floodplain study in Mineral County are summarized in Table 6.

Table 6. Boundary Condition Summary

Tributary Reach	Segment	Boundary Condition Source
1	Tamarack Creek	Normal Depth Slope = 0.0335 ft/ft
2	Dry Creek	Normal Depth Slope = 0.0138 ft/ft
3	Cedar Creek	Normal Depth Slope = 0.0147 ft/ft
4	Trout Creek	Normal Depth Slope = 0.0127 ft/ft
5	Meadow Creek	Normal Depth Slope = 0.1345 ft/ft
6	Nemote Creek	Normal Depth Slope = 0.2079 ft/ft
7	Fish Creek	Normal Depth Slope = 0.0121 ft/ft

4.6 Cross Section Development

The hydraulic model was predominately based on the terrain data provided by Quantum Spatial, Inc. (QSI). 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-percent annual-chance (500-year) floodplain. 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.

Manual cross section elevation edits within the low flow stream channels were also performed based on structure inventory photos and measurements. This was needed to allow modeling of structures and roadway elevations in accordance with field measured data rather than the LiDAR topography on small streams. For example, the channel bed elevation was deepened from the terrain data at Nemote Creek RS 27,420 for both the internal structure section and the adjacent river station so the hydraulic model would appropriately represent the field photos and measurements. This type of edit was typically needed for narrow and shallow streams where the LiDAR DEM data set appeared to have simplified the ground topography in the raster elevation model development process or was influenced by water in the stream.

4.7 Hydraulic Structures

The geometries of hydraulic structures were modeled based on data collected during the Structure Inventory (Pioneer 2017, 2018b) of the hydraulic structures. The data package included field measurements and as-built drawings. The Structure Inventory data from Pioneer was supplemented with field measurements completed by Morrison-Maierle for one bridge that was identified after the Pioneer field deliverables had been completed. Forty-six hydraulic structures, as listed in Table 5, are located within the study limits. Each structure was assigned an identification code that included a ‘B’ for bridge and a number generally corresponding to the order of the structure beginning at the downstream extent of the tributary stream study reach and progressing upstream. The structures crossing the Clark Fork River Tributaries include highway crossings along I-90, MRL Railroad, and roadway crossings along County and private roadways.

Expansion and contraction coefficients assignments at the two upstream and one downstream cross sections used to model 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. Expansion and contraction coefficients were set at 0.1 and 0.3 for structure crossing RS 846 (MRL Railroad on Trout Creek), and RS 2,155 (Fish Creek Road on Fish Creek). These values were selected to reflect the structures that are located well above the channel and do not have any significant embankment obstruction. Therefore, expansion and contraction losses at these two locations is typical of natural channel conditions.

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 producing a bridge that was perched above the roadway elevation in the overbanks. Otherwise, the Pressure/Weir flow method was the high flow method used when flood waters would impact and/or overtop the bridge structure.

The low flow methods include the Energy, Momentum or Yarnell methodologies. Only the Energy method was utilized for clear-span structure with no piers. The Momentum Balance and Yarnell equation methods were evaluated if the structure was constructed 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 (C_D), and the Yarnell equation required a pier shape coefficient (K).

The pier shapes for the bridge structures consisted of square nose piers, and elongated piers with 90° angle triangular or semicircular nose and tail geometry. The C_D and K coefficients used for the different pier shapes are summarized in Table 7.

Table 7. Pier C_D and K Coefficients

Pier Shape	C_D	K
Triangular nose with 90° angle	1.6	0.9
Semicircular nose and tail	1.33	0.9
Square Piers	2.0	1.25

A summary of the bridge structure and hydraulic model settings for each structure are summarized in Tables 9 and 10, respectively

Culvert crossings were modeled using field measurements of roadway fill above the culvert, 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, due to LiDAR averaging in narrow streams or LIDAR influenced by water in the stream. Internal hydraulic structure cross sections were adjusted as needed to fit with field measured data and field photograph interpretation. This approach provided reasonable backwater elevations caused by the channel elevations bounding the structure by more closely matching culvert invert depth below the roadway deck. A summary of culvert structure hydraulic model settings is provided in Table 11.

The following sections describe the hydraulic structure crossings for the Clark Fork River Tributary reaches.

4.7.1 Tamarack Creek

Tamarack Creek has five hydraulic structure crossings. The first structure crossing at RS 286 consists of a 204 foot long 8-ft x 8-ft reinforced concrete box (RCB) structure crossing for State Highway 135 and Montana Rail Link (MRL) Railroad. The next three upstream crossings at RS's 1,819, 3,234, and 5,458 consist of clear-span bridge structures for private roadway crossings with span lengths of 18, 25, and 36 feet long, respectively. The most upstream structure crossing at RS 10,085 is a 77 foot long 6-ft diameter corrugated metal pipe culvert crossing at Tamarack Creek Road. The bridge and culvert crossing structure and modeling data are summarized in Tables 9, 10 and 11.

A lateral weir model node (Tamarack Creek Split RS 1,070) was used to calculate flood flow sharing of mixing floodplains for the lower portion of the Tamarack Creek split flow. The lateral weir consists of non-elevated natural high ground between the flood flow paths. The lateral weir crest geometry was extracted from the terrain surface. A weir coefficient of 0.39 was selected for the lateral weir in accordance with HEC-RAS modeling guidance for non-elevated natural ground lateral overtopping.

4.7.2 Dry Creek

Dry Creek has five hydraulic structure crossings. The first structure upstream crossing at RS 819 consists of a 294 foot long 17-ft diameter corrugated steel pipe (CSP) culvert crossing for the I-90 Interstate highway east and west lanes. The second upstream crossing at RS 1,220 is a 92 foot long corrugated steel pipe arch (CSPA) culvert under the MRL Railroad. The third upstream crossing at RS 3,592 is a 49 foot long clear-span bridge for the South Side Road. The fourth and fifth upstream crossings at RS's 7,954 and 8,693 consist of clear-span bridge structures for private roadway crossings with respective span lengths of 46 and 60 feet long. The bridge and culvert crossing structures and modeling data are summarized in Tables 9, 10 and 11.

4.7.3 Cedar Creek

Cedar Creek has six hydraulic structure crossings. The first upstream structure crossing at RS 1,156 consists of a 168 foot long three-span bridge crossing under the I-90 Interstate highway east and west lanes. The second upstream crossing at RS 1,488 is a 109 foot long three-span bridge crossing for the Diamond Match Road. The third upstream crossing at RS 1,738 is a 289 foot long six-span bridge for the MRL Railroad. The expansion and contraction coefficients were set at values of 0.1 and 0.3 for this structure crossing due to the elevation the structure well above the channel and the minimal influence of the embankment encroachment on the one-directional (1D) modeling of the floodplain. The fourth upstream crossing at RS 2,713 consists of a clear-span bridge structure for a private roadway crossing. The fifth upstream crossing at RS 10,007 consists of a clear-span bridge structures for the Lynch Ranch Lane crossing. The last upstream structure crossing at RS 16,251 consists of a clear-span bridge structure for the Upham Gulch Road crossing. The bridge crossing structures and modeling data for Cedar Creek are summarized in Tables 9 and 10.

4.7.4 Trout Creek

Trout Creek has two hydraulic structure crossings. The first upstream structure crossing at RS 846 consists of a 252 foot long four-span bridge crossing for the MRL Railroad. The expansion and contraction coefficients were set at typical channel values of 0.1 and 0.3 due to the elevation the structure which is well above the channel and does not influence the floodplain. The last upstream structure crossing at RS 6,245 consists of a 62 foot long clear-span bridge structure for the Cyr Iron Mountain Road crossing. The bridge crossing structures and modeling data for Trout Creek are summarized in Tables 9 and 10.

4.7.5 Meadow Creek

Meadow Creek has five hydraulic structure crossings. The first structure at RS 938 consists of a 116 foot long 16.58-ft x11-ft reinforced concrete pipe arch (RCPA) structure crossing under the Montana Rail Link (MRL) Railroad. A CSPA culvert chart was selected in the hydraulic model as it most closely represented the shape of this culvert. However, culvert coefficients representing the concrete structure material were coded. The second crossing at RS 1,343 is a 369 foot long 11-ft diameter CSP culvert crossing for the I-90 Interstate highway east and west lanes. The third crossing at RS 10,702 is a 40 foot long 3-ft diameter CSP under the Quartz Loop Road. The fourth crossing at RS 14,060 consists of an

approximately 15 foot long by 2-ft diameter CSP for a private roadway crossing. The culvert and crossing data was estimated based on topographic and aerial interpretation since no structure inventory data was available for this crossing. The last upstream crossing at RS 15,223 consists of an approximately 35 foot long by 2.5-ft diameter CSP for a private roadway crossing. The culvert and crossing data was also estimated based on topographic and aerial interpretation since no structure inventory data was available for this crossing. There is one structure crossing on the Sunrise Creek reach hydraulic model at RS 1,376 which consists of a 40 foot long 3-ft diameter CSP for the Quartz Loop Road. The culvert crossing structures and modeling data for Meadow Creek are summarized in Table 11.

4.7.6 Nemote Creek

The mainstem reach of Nemote Creek has fourteen hydraulic structure crossings. Miller Creek and South Fork of Nemote Creek each have two hydraulic structure crossings. The hydraulic structure crossings are summarized by model reaches in Table 8. The bridge and culvert crossing structure and modeling data are summarized in Tables 9, 10 and 11.

Table 8. Nemote Creek Mainstem Hydraulic Crossings

No.	River Station (feet)	Structure Type	Model Reach	Roadway	Length (feet)	Size
1	428	Bridge	Nemote A	Abandon Railroad Grade	200	Three-Span
2	2,016	Bridge	Nemote A	Private Road	18	Clear-Span
3	2,365	Culvert (CSP)	Nemote A	I-90 East and West	140	13’ Dia.
4	2,541	Culvert (RCB)	Nemote A	Private Road	10	4.5’ x 12’
5	11,615	Culvert (CSP)	Nemote A	Nemote Creek Road	28	5’ Dia.
6	18,070	Culvert (RCP)	Nemote B	Round Mountain Road	32	6’ Dia.
7	25,070	Culvert (CSP)	Nemote B	South Fork Nemote Creek Road	60	6’ Dia.
8	25,250	Culvert (CSP)	Nemote B	Private Road	25	4’ Dia.
9	26,890	Bridge	Nemote C	South Fork Nemote Creek Road	10	Clear-Span
10	27,315	Culvert (CSP)	Nemote D	Standing Rock Court	30	Twin 2’ Dia.
11	27,420	Culvert (CSP)	Nemote D	Standing Rock Court	31	Twin 2’ Dia.
12	28,560	Culvert (CSP)	Nemote D	Private Diversion	11	2’ Dia.
13	28,750	Culvert (CSP)	Nemote E	USFS Road 9915	23	Twin 3’ Dia.
14	37,860	Culvert (CSP)	Nemote E	Sheridan Road	42	6’ Dia.
15	4,270	Culvert (CSP)	Miller Creek	War Horse Lane	28	3.5’Dia.
16	4,945	Bridge	Miller Creek	Private Road	8	Clear-Span
17	2,300	Culvert (CSP)	S.F. Nemote	Private Road	30	4’ Dia.
18	3,110	Culvert (CSPA)	S.F. Nemote	Private Road	29	4’ x 6’

Culvert Types:
CSP – Corrugated Steel Pipe,
CSPA – Corrugated Steel Pipe Arch,
RCP – Reinforced Concrete Pipe,
RCB – Reinforced Concrete Box.

4.7.7 Fish Creek

Fish Creek has three hydraulic structure crossings. The first structure crossing at RS 1,436 consists of a 590 foot long four-span steel trestle bridge crossing under the MRL Railroad.

The structure completely spans the Fish Creek valley bottom and does not encroach into channel. The structure was not modeled with the HEC-RAS bridge module, since the structure elevation is 75 to 100 feet above the flood flows. The pier foundations were modeled in the topography of cross sections at RS 1,436 and RS 1,555. The second structure crossing at RS 2,155 consists of a 90-foot long clear-span bridge structure for Fish Creek Road. The expansion and contraction coefficients were set at values of 0.1 and 0.3 for this structure crossing because the structure is located well above the channel there is minimal encroachment of the embankment into the floodplain. The third structure crossing at RS 34,490 consists of a 116-foot long clear span bridge structure for Fish Creek Road. Typical expansion and contraction coefficient values were used for this bridge. The bridge crossing structures and modeling data for Fish Creek are summarized in Tables 9 and 10.

Table 9. Summary of Bridge Structures

ID No.	Roadway	Tributary Reach	River Station (feet)	Spans	Total Span (feet)	Deck Width (feet)	Pier Widths (feet)	Appendix C Photo Page #
B2	Private Road	Tamarack Creek	1,819	1	18	10	n/a	–*
B3	Private Road	Tamarack Creek	3,234	1	25	12	n/a	2
B4	Private Road	Tamarack Creek	5,458	1	36	12	n/a	3
B13	South Side Road	Dry Creek	3,592	1	49	24	n/a	7
B14**	Private Road	Dry Creek	7,954	3**	46**	14**	2**	–*
B15**	Private Road	Dry Creek	8,693	3**	60**	14**	2**	–*
B19	I-90 East and West	Cedar Creek	1,156	3	168	98	2	8
B20	Diamond Match Road	Cedar Creek	1,488	3	109	26	2.5	9
B21	MRL Railroad Grade	Cedar Creek	1,738	6	289	12	1, 4, 6	10
B22	Private Road	Cedar Creek	2,713	1	63	14	n/a	11
B23	Lynch Ranch Lane	Cedar Creek	10,007	1	64	12	n/a	12
B24	Upham Gulch Road	Cedar Creek	16,251	1	66	15	n/a	13
B25	MRL Railroad Grade	Trout Creek	846	4	252	15	Tapered, 8-4.9 & 9.7-5	–*
B27	Cyr Iron Mountain Road	Trout Creek	6,245	1	62	14	n/a	14
B31	Abandoned Railroad Grade	Nemote Creek	428	3	200	15	3	15
B32	Private Road	Nemote Creek	2,016	1	18	17	n/a	16
B34***	East Mullen Road	Nemote Creek	Appx. 2,507	–***	–***	–***	–***	18
B38	South Fork Nemote Creek Road	Nemote Creek	26,890	1	10	18	n/a	23
B124	Private Road	Miller Creek	4,945	1	8	6	n/a	–*
B42****	MRL Railroad Grade	Fish Creek	Appx.1,436	–****	–****	–****	–****	28
B42a	Fish Creek Road	Fish Creek	2,155	1	90	18	n/a	29
FIS_030	Fish Creek Road	Fish Creek	34,490	2	116	29.9	2	38

* Unable to photograph structure crossing due to access denial or closed gate.
** No Structure Inventory Data Available. Bridge and crossing data estimated based on topographic and aerial interpretation.
*** Bridge structure not modeled due spanning over downstream culvert crossing controlling flows.
**** Bridge structure pier foundations modeled in topography of cross sections.

Table 10. Summary of Bridge Model Settings

ID No.	Roadway	Tributary Reach	River Station (feet)	Contraction Coefficient	Expansion Coefficient	Low Flow Method	High Flow Method
B2	Private Road	Tamarack Creek	1,819	0.3	0.5	Energy	Pressure/Weir
B3	Private Road	Tamarack Creek	3,234	0.3	0.5	Energy	Pressure/Weir
B4	Private Road	Tamarack Creek	5,458	0.3	0.5	Energy	Pressure/Weir
B13	South Side Road	Dry Creek	3,592	0.3	0.5	Energy	Energy
B14	Private Road	Dry Creek	7,954	0.3	0.5	Energy, Momentum, Yarnell	Pressure/Weir
B15	Private Road	Dry Creek	8,693	0.3	0.5	Energy, Momentum, Yarnell	Energy
B19	I-90 East and West	Cedar Creek	1,156	0.3	0.5	Energy, Momentum, Yarnell	Energy
B20	Diamond Match Road	Cedar Creek	1,488	0.3	0.5	Energy, Momentum, Yarnell	Energy
B21	MRL Railroad Grade	Cedar Creek	1,738	0.3	0.5*	Energy, Momentum, Yarnell	Energy
B22	Private Road	Cedar Creek	2,713	0.3	0.5	Energy	Pressure/Weir
B23	Lynch Ranch Lane	Cedar Creek	10,007	0.3	0.5	Energy	Energy
B24	Upham Gulch Road	Cedar Creek	16,251	0.3	0.5	Energy	Energy
B25	MRL Railroad Grade	Trout Creek	846	0.1*	0.3*	Energy, Momentum, Yarnell	Energy
B27	Cyr Iron Mountain Road	Trout Creek	6,245	0.3	0.5	Energy	Energy
B31	Abandoned Railroad Grade	Nemote Creek	428	0.1*	0.3*	Energy, Momentum, Yarnell	Energy
B32	Private Road	Nemote Creek	2,016	0.3	0.5	Energy	Pressure/Weir
B34***	East Mullen Road	Nemote Creek	Appx. 2,507	–***	–***	–***	–***
B38	South Fork Nemote Creek Road	Nemote Creek	26,890	0.3	0.5	Energy	Energy
B124	Private Road	Miller Creek	4,945	0.3	0.5	Energy	Pressure/Weir
B42****	MRL Railroad Grade	Fish Creek	Appx. 1,436	–****	–****	–****	–****
B42a	Fish Creek Road	Fish Creek	2,155	0.1*	0.3*	Energy	Energy
FIS_030	Fish Creek Road	Fish Creek	34,490	0.3	0.5	Energy, Momentum, Yarnell	Energy

* Channel contraction/expansion values selected due to structure elevation above the channel having minimal influence on the floodplain width.
** No Structure Inventory Data Available. Bridge and crossing data estimated based on topographic and aerial interpretation.
*** Bridge structure not modeled due to spanning over downstream culvert crossing which controls the flows.
**** Bridge structure pier foundations modeled in topography of cross sections.

Table 11: Summary of Culvert Crossings

ID No.	Roadway	Tributary Reach	River Station (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Appendix C Photo Page
B1	Highway 135 and MRL Railroad Grade	Tamarack Creek	286	204	RCB	Box	8 x 8	1
B5	Tamarack Creek Road	Tamarack Creek	10,085	77	CSP	Round	6	4
B11	I-90 East and West	Dry Creek	819	294	CSP	Round	17	5
B12	MRL Railroad Grade	Dry Creek	1,220	92	CSPA	Arch	30 x 30	6
B120	Quartz Loop Road	Sunrise Creek	1,376	38	CSP	Round	3	32
B121	Quartz Loop Road	Meadow Creek	10,702	40	CSP	Round	3	33
B122	I-90 East and West	Meadow Creek	1,343	369	CSP	Round	11	34
B123	MRL Railroad Grade	Meadow Creek	938	116	RCPA	Arch	16.8 x 11	35
–**	Private Road	Meadow Creek	14,060	15**	CSP**	Round**	2**	–*
–**	Quartz Loop Road	Meadow Creek	15,223	35**	CSP**	Round**	2.5**	–*
B33	I-90 East and West	Nemote Creek	2,365	275	CSP	Round	13	17
–**	Private Road	Nemote Creek	2,541	10	RCB	Box	12 x 4.5	17
B35	Nemote Creek Road	Nemote Creek	11,615	28	CSP	Round	5	19
B36	Round Mountain Road	Nemote Creek	18,070	32	RCP	Round	6	20
B37	South Fork Nemote Creek Road	Nemote Creek	25,070	60	CSP	Round	6	21
B37a	Private Road	Nemote Creek	25,250	25	CSP	Round	4	22
B39	Standing Rock Court	Nemote Creek	27,315	30	CSP	Round	Twin 2	24

* Unable to photograph structure crossing due to access denial or closed gate.
** No Structure Inventory Data Available. Culvert and crossing data estimated based on topographic and aerial interpretation.

Culvert Types:
CSPA – Corrugated Steel Pipe Arch,
CSP – Corrugated Steel Pipe
RCP – Reinforced Concrete Pipe,
RCPA – Reinforced Concrete Pipe Arch
RCB – Reinforced Concrete Box
SMSI – Smooth Steel/Iron Pipe

Table 11 (cont.): Summary of Culvert Crossings

ID No.	Roadway	Tributary Reach	River Station (feet)	Culvert Length (feet)	Culvert Type	Culvert Shape	Culvert Size (feet)	Appendix C Photo Page
B39a	Standing Rock Court	Nemote Creek	27,420	31	CSP	Round	Twin 2	25
D1	Private Diversion	Nemote Creek	28,560	11	CSP	Round	2	30
D1	Private Diversion	Nemote Creek Split	2,000	22	CSP	Round	1	30
B40	USFS Road 9915	Nemote Creek	28,750	23	CSP	Round	Twin 3	26
B41	Sheridan Road	Nemote Creek	37,860	42	CSP	Round	6	27
B125	War Horse Lane	Miller Creek	4,270	28**	CSP**	Round**	3.5**	–*
B126	Private Road	South Fork Nemote Creek	3,110	29	CSPA	Arch	6 x 4	36
B127	Private Road	South Fork Nemote Creek	2,300	30	SMSI	Round	4	37

* Unable to photograph structure crossing due to access denial or closed gate.
** No Structure Inventory Data Available. Culvert and crossing data estimated based on topographic and aerial interpretation.

Culvert Types:
CSPA – Corrugated Steel Pipe Arch,
CSP – Corrugated Steel Pipe
RCP – Reinforced Concrete Pipe,
RCPA – Reinforced Concrete Pipe Arch
RCB – Reinforced Concrete Box
SMSI – Smooth Steel/Iron Pipe

Photographs 1 thru 8 illustrate the different types of roadway hydraulic conveyance structures that were modeled for the Clark Fork River Tributaries Flood Risk Project. Photographs of all the modeled bridge, culvert, and diversion structures which were accessed during the structure inventory are provided in Appendix C.

Photograph 1: Tamarack Creek – Private Road at RS 3,234

Photograph 2: Dry Creek – I-90 East and West at RS 819

Photograph 3: Cedar Creek- I-90 East and West at RS 1,156

Photograph 4: Trout Creek – Cyr Iron Mountain Road at RS 6,245

Photograph 5: Meadow Creek – MRL Railroad Grade at RS 938

Photograph 6: Nemote Creek – I-90 East and West at RS 2,365

Photograph 7: Nemote Creek – Nemote Creek Road at RS 11,615

Photograph 8: Fish Creek – Fish Creek Road at RS 2,155

4.8 Manning's 'n' Values

Manning's 'n' values are coefficients representing the frictional resistance (surface roughness) acting on water when flowing overland or through a channel. The coefficients are used in the calculations to determine water surface elevations. Five land classes were developed for the study area to establish Manning's 'n' values based on ground and cover conditions. Manning's 'n' values assigned within the hydraulic model were determined based on aerial photography, structure inventory photographs, and the USGS publication, 'Guide to Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains' (USGS 1982). The USFS publication, General Technical Report RMRS-GTR-323, on steeply sloped streams S ≥ 0.002 (USFS 2014) was also referenced due to the steep and moderately steep channel gradients found on some portions of the tributary channels.

The USGS and USFS guides were used to develop minimum, maximum, and initial Manning's 'n' values for each land class. The range of Manning's 'n' values used in the study are shown in Table 12. Manning's 'n' values were evaluated at each cross-section and adjustments were made to fit roughness area land class with the terrain data represented by the cross section.

Main channel Manning's 'n' values higher than the maximum value of 0.09 shown in Table 12 were used for the first 1,000 to 2,000 feet of the Meadow and Nemote Creek where the normal depth slope boundary conditions are 0.1345 and 0.2079 feet/feet, respectively. The Manning's 'n' at these locations is on the order of 0.2 for the channel and 0.3 for the overbank based on USFS publication guidance for steep gradient streams.

Table 12. Manning's 'n' Values

Roughness Area Land Class Type	Manning's 'n' Value Range	Initial Value	Description
Main Channel	0.028 – 0.09	0.050	Gravel, cobbles, well-rounded boulders and bedrock sections.
Pasture	0.036 – 0.142	0.063	Grasses, alfalfa, intermixed with weeds.
Willows	0.051 – 0.148	0.080	Willows with stems of herbaceous vegetation.
Urban-Developed	0.042 – 0.143	0.078	Herbaceous & woody vegetation with manmade structures.
Forest	0.052 – 0.129	0.075	Vegetation is primarily trees and shrubs.

4.9 Areas of Non-Conveyance

As indicated on the Hydraulic work maps in Appendix A, there are reaches where no flow or backwater conditions exist. These conditions provide limited or non-conveyance in the downstream direction. For these areas, the ineffective flow area method was implemented to calculate the total effective conveyance for each cross section in the hydraulic simulation.

The areas of non-conveyance included the following:

- Backwater and ponded areas.
- Flow constriction or expansion.
- Areas isolated by non-accredited earthen berms or railroad and roadway embankments.

- Presence of high topography either upstream or downstream that eliminates flow in a topographically low area.

Where ineffective areas have been set in the hydraulic models, a comment was included in the cross section description noting the reason the ineffective area was utilized.

Review of the modeled cross sections in HEC-RAS identified connected backwater depression areas that are not hydraulically connected to the stream body. These areas were also classified as ineffective flow areas so that the model calculated the appropriate conveyance at the cross section. The river stations where connected backwater occurs are discussed in more detail in Section 5.1.

4.10 Split Flow Modeling

During the hydraulic analysis, two split flow reaches were identified and included in the floodplain study. The Nemote Creek split flow was caused by a small irrigation diversion headworks along Nemote Creek at approximately RS 28,585. This structure was noted as D1 in the structure inventory. A HEC-RAS model junction node for a flow split was used to balance the energy equation at the flow split location. The automatic junction optimization routine in HEC-RAS was used to calculate the split flows to each reach. Each of the embankments and culverts associated with the diversion was modeled as a structure on its reach to simulate the combined backwater created by the structures. Flood flows were routed down each flow split until the floodplains converged at approximately Nemote Creek RS 27,110. The flow split discharges are summarized in Table 3 in section 3 above.

The Tamarack Creek split flow at approximately RS 15,600 was necessary due to divided flood flows along approximately 2,300 feet of the valley where the valley floor elevations were dissimilar between the east and west sides of the valley. A HEC-RAS model junction node for a flow split was used to balance the energy equation at the flow split location for this flow split as well. The automatic junction optimization routine in HEC-RAS was used to calculate the split flows to each reach.

The two split flow floodplains remain separate for approximately 1,000 feet through the upper half of the flow split. The lower half of the flow split (approximately 1,000 feet) experiences mixing between the two floodplains over the non-elevated natural ground overbank. The mixing of flood flows was modeled using a lateral weir. The later weir was also modeled using optimization routines within HEC-RAS that balance flood flows at each cross section along the lateral weir element. The split flow section converges back to the primary Tamarack Creek floodplain at approximately RS 13,216. The flow split discharges are summarized in Table 3 in section 3 above.

4.11 Critical Depth & Profile Smoothing

Critical depths have been allowed to remain in the model at locations where a critical or supercritical flow regime is hydraulically reasonable and follows the research results that the USFS has published for moderately steep and steep streams (USFS 2014). Generally, these critical depths are at locations where the channel profile drops at a significant gradient or where a flow regime change could occur. As this model has been completed using sub-critical calculation routines in HEC-RAS, a super-critical profile is not provided in the model.

Profile smoothing is required where minor modeling numerical idiosyncrasy or, structural effects result 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 2016b) Locations where smoothing was completed are shown in Table 13 for the 1% AC regulatory flood profile. The hydraulic model is adjusted for the 1% AC flood profile, other profiles were smoothed both at the locations noted below and at other locations where model inputs resulted in a drawdown for the non-regulatory flood profile.

Table 13. 1% AC Profile Smoothing River Stations

Tributary Reach	River Station (feet)	Reason for Profile Smoothing
Tamarack Creek	286	Drawdown within Highway 135 and MRL Railroad culvert crossing. Smoothed to downstream calculation node water surface.
Tamarack Creek	1,819	Drawdown within private road bridge crossing. Smoothed to downstream calculation node water surface.
Cedar Creek	16,264	Drawdown and hydraulic jump within Upham Gulch Road bridge crossing. Smoothed profile to upstream cross section node.
Trout Creek	6,245	Drawdown and hydraulic jump within Cyr Iron Mountain Road bridge crossing. Smoothed to downstream calculation node water surface.
Meadow Creek	938	Drawdown and hydraulic jump within MRL Railroad culvert crossing. Smoothed to downstream calculation node water surface.
Meadow Creek	1,343	Drawdown and hydraulic jump within I-90 East and West culvert crossing. Smoothed to downstream calculation node water surface.
Nemote Creek	2,365	Drawdown and hydraulic jump within I-90 East and West culvert crossing. Smoothed to downstream calculation node water surface.
Fish Creek	34,490	Drawdown and hydraulic jump within Fish Creek Road crossing. Smoothed to downstream calculation node water surface.

4.12 Model Calibration

Stream gage data at USGS Gage 1235820 for Dry Creek near Superior, Montana was used to compare the HEC-RAS model for the Dry Creek analysis. Reference marks for the USGS gage were surveyed in March 2018 by Pioneer Technical Services, Inc., (Pioneer). Water surface elevations were calculated for the highest available flow record based on the USGS gage height records and the 2018 Pioneer survey in NAVD88 datum. The Dry Creek model water surface was within 0.9 feet for the peak flow rate of 560-cfs recorded on June 19, 1991. The modeling results for Dry Creek are reasonably calibrated for the purposes of a floodplain study.

This was the only calibration data available for the Clark Fork River Tributaries flood study. The other six other tributary reaches were generally similar in land use and geomorphic setting to Dry Creek. Therefore, the modeling parameters selected for Dry Creek were also

applied to the other six tributaries as the best available information for model verification and validity. Additionally, the resulting floodplain mapping was compared with aerial imagery and terrain using engineering judgement. The floodplain mapping generally appeared to be consistent with the imagery and terrain floodplain interpretation.

4.13 Floodways

Floodways for the Mineral County Modernization Clark Fork River Tributaries floodplain study were not required per the Mapping Activity Statement (MAS) 2017-04 scope of work.

4.14 Flood Profiles

Flood profile panels were developed in accordance with FEMA Guidance and Standards. The moderately steep to very steep stream gradient and the amount of variation in gradient of the Clark Fork River tributary streams was not conducive to fit to a consistent scale for all stream reaches in this study. Horizontal and vertical scales were selected at 1”:100’ and 1”:5’ respectively. The horizontal and vertical scales were selected to provide profile panels where all six profiles could be distinguished in most locations.

Several very steep sections of stream resulted in flood profile panels where the ground and profile lines do not intersect the elevation axis at the left side of the sheet (e.g. Nemote Creek Profile panels 078P – 079P, Appendix B). Where the flood profiles were extremely steep due to the steep ground slope for Meadow Creek and Nemote Creek near the confluence with the Clark Fork River, a horizontal scale change was utilized to improve the readability of the profiles. To more efficiently use profile panel page space, two profile sections were shown on some panels. Additionally, there are several locations where the profile panels overlap in river station to allow all segments of all six profiles to be presented on the profile panels (e.g. Tamarack Creek Profile panels 129P-130P). The selected scale and panel layout were chosen to provide easily interpretable flood profiles for public review and community floodplain administration. Flood profiles for all twelve named stream segments are provided in Appendix B.

4.15 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. Files from the HEC-RAS version 5.0.3 analyses were uploaded into cHECk-RAS. Several messages in cHECk-RAS are incorrect and appear to be related to the loss of output reading functionality when the current version of cHECk-RAS reads HEC-RAS 5.0.3 data. These messages were checked to verify that a cHECk-RAS read error exists and are noted on the cHECk-RAS report.

cHECk-RAS evaluates 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 Clark Fork River model were reviewed and each issue was either resolved or investigated to confirm that the modeling was correct and that the cHECk-RAS message was not applicable. Appendix E includes the list of cHECk-RAS messages and responses to each message for each tributary model.

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 delineation by intersecting the LiDAR Digital Elevation Model with a separate Digital Elevation Model (DEM) representing the water surface elevations of the 1% and 0.2% annual-chance events. The results of the hydraulic modelling 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 from the 1% 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 imagery. Along with the flooding extents, the stream profile baseline along with the cross sections utilized during the hydraulic analysis are displayed on the work maps. 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 the 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 and non-mapped cross sections are noted as NL/NM-for not labeled and not-mapped. Zone AE symbolized polygons are the floodplain delineated for the regulatory floodplain.

Typically, islands that were marginally higher than the adjacent 1% annual-chance water surface profile and less than one-half acre in size were not delineated. Large backwater areas that extended through multiple cross sections were also 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 model at selected locations. A table of the 1% AC flood event backwater elevations and the corresponding profile baseline station is included in Table 14.

Table 14. Backwater Elevation Summary

Tributary Reach	River Station (feet)	1% AC (feet)
Tamarack Creek	11,260	2,871
Tamarack Creek Split	2,180	2,919
Cedar Creek	11,320	2,837
Meadow Creek	13,740	3,042
Meadow Creek	15,380	3,056
Nemote Creek	23,540	3,063
Fish Creek	20,680	2,944
Fish Creek	24,320	2,963
Dry Creek	3,560	2,715

5.2 Map Tie-in Locations

The Clark Fork River Tributaries study was revised to provide study limits that fully encompass the effective mapping on all primary tributary reaches. See the Correspondence folder of this submission for documentation of this approach from the MT DNRC. The floodplain mapping products included with this submittal fully exceed the effective mapped stream lengths and will replace all effective Zone A floodplain mapping on the primary tributaries to the Clark Fork River. There is a small lobe of Zone A floodplain mapping along Nemote Creek at cross section AH. This Zone A area is related to a minor drainage tributary to Nemote Creek that was not included in this study.

The Clark Fork River mainstem study is associated with the tributaries study and is slightly ahead in schedule. The tributaries floodplain mapping has been trimmed where regulatory water surface elevations on the Clark Fork River exceed the regulatory flood elevations of the tributary stream. The revised preliminary mapping for the Clark Fork River has been included in these tributaries work maps and show as existing floodplain for reference.

5.3 Floodplain Boundary Smoothing

Floodplain Boundary Smoothing was generally 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 September of 2017. 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 and engineering best practices.

Due to the narrow and steep topography of much of the Clark Fork River tributaries, final regulatory mapped widths were expanded to a minimum of 50 feet (5% of the FIRM panel scale). Most of the 0.2% AC floodplain was a very narrow fringe along the regulatory floodplain and was removed from the final mapping. This was necessary to provide mapping visible at the FIRM panel scale of 1:1000.

Two exceptions to the typical practice described above are included in the final mapping.

- At a few locations, the best practice for floodplain widths (and gaps/slivers) necessary for viewing at the FIRM map scale conflicted with FEMA Standards requiring mapped widths to match the modeled widths at cross sections. At these locations, the requirement for mapped width at the cross section was prioritized over typical best practices for gaps or dry slivers included in the floodplain mapping.
- As noted above, the tributaries floodplain mapping was trimmed to the Clark Fork River floodplain mapping recently updated as part of the larger study. Consequently, narrow sliver areas of tributary stream mapping have been included in the final mapping. These areas will meet the sliver width best practices (5% of FIRM map scale) once these two mapping tasks have been combined on the FIRM panels.

The Quality Control process for floodplain boundary preparation was documented in review checklists which have been included in Appendix E.

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 assist public entities and landowners in interpreting the changes to the floodplain mapping proposed for the new study compared to the effective mapping being replaced. CSLF spatial files are provided in the Supplemental Data folder of the digital submission.

5.5 Letters of Map Change

A review was made of the Letters of Map Change (LOMC) along the Clark Fork River Tributaries within the study area to identify locations where previously issued LOMC may need to be considered in the context of the changes proposed by this updated study. No LOMC along the Clark Fork River tributaries study reaches were identified.

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 97% of the test points passed the audit criteria for this project. Test points were deleted from the floodplain boundary at study termination where the boundary was perpendicular to the flood flow direction. When the initial FBS Audit resulted in a pass rate greater than the required 85% threshold, the 38-foot radius horizontal tolerance additional check was not completed. FBS Audit summary reports have been included in Appendix E and test point shapefiles have been included in the Supplemental Data folder of the digital submission.

5.7 Depth & WSE Grids

Depth and WSE Grids were prepared for each profile included in the hydraulic model (10%, 4% 2%, 1%, 1plus, & 0.2% AC). The grid data are raw depth grids ready for further processing in accordance with the FEMA Guidance *Flood Depth and Analysis Grids* once the final mapping products have been approved. These grid data products 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%-plus, and 0.2% annual-chance water surface elevations were created using FEMA's RASPLOT software (FEMA 2016d). Additional information, edits and formatting were made using AutoCAD. Profiles were developed using the guidance found in Flood Profiles: FEMA Guidance for Flood Risk Analysis and Mapping (FEMA 2016a). The water surface profiles illustrating the results of the study are provided in Appendix B and in the FIS_Report folder under the Task_Documentation folder of the digital submission.

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APPENDICES