AUGUSTA FLOOD MITIGATION

ENGINEERING RECOMMENDATIONS REPORT

LEWIS AND CLARK COUNTY, MONTANA

JUNE 2022

PREPARED FOR

Lewis and Clark County
Public Works Department
3402 Cooney Drive
Helena, MT 59602

PREPARED BY

RESPEC Company LLC
3810 Valley Commons Drive, Suite 4
Bozeman, MT 5971

Professional Engineer Certification and Approval

Professional Engineer Certification

I hereby certify this analysis and report was prepared by me or under my direct supervision and meets technical engineering standards for hydrologic and hydraulic modeling.

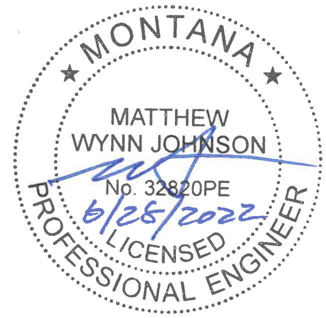
Company: RESPEC Company, LLC

Name: Matthew Wynn Johnson, P.E., CFM

Title: Montana Registered Professional Engineer, # PEL-PE-LIC-32820

Signature:

Date: 6/28/2022



Document History

Version	Date	Description
01	06/10/2022	Draft Report
02	06/28/2022	Final Report

TABLE OF CONTENTS

RESPEC

FIGURES

TABLES

1.0 INTRODUCTION

Augusta, Montana has historically suffered from widespread flooding of Elk Creek, causing repeated damage to infrastructure and agricultural lands. Following the back-to-back floods in 2018 and 2019, Lewis and Clark County (LCC), supported by a grant from Montana Department of Emergency Services (DES) and the Federal Emergency Management Agency (FEMA), embarked to develop a flood mitigation study and engineering recommendations for the town of Augusta.

In 2021, Lewis and Clark County contracted with RESPEC Company, LLC to develop the flood study, along with a suite of flood mitigation alternatives for Elk Creek near Augusta. This task includes:

- Communication with Augusta residents to explore viable mitigation alternatives to increase the community's resiliency to future floods;
- Development of a detailed hydraulic analysis of Elk Creek existing conditions in the Augusta area;
- Establishment of a suite of mitigation alternatives simulated in the hydraulic analysis to evaluate their effectiveness; and
- Documenting the analysis and providing engineering recommendations in a report aimed to support flood mitigation grant funding request when those opportunities arise.

This report describes the methods, results, and recommendations for Elk Creek flood mitigation alternatives in Augusta.

1.1. WATERSHED DESCRIPTION

Elk Creek drains 157 square miles just upstream of the town of Augusta and includes the major streams of Elk Creek, Ford Creek, and Smith Creek. Elk Creek itself is approximately 32 miles long and originates from the northern flank of Steamboat Mountain along the Rocky Mountain Front. It is a tributary to the Sun River, coming to a confluence five miles northeast of Augusta. In the upper reaches of the Elk Creek watershed, the channels are steep, confined, and have the capability to carry substantial amounts of sediments downstream. Through the study reach, Elk Creek is a low gradient, sinuous channel with large deposits of stream gravels. There is evidence of several channel avulsions through the study area, along with a large split, known as the Elk Creek Overflow, which splits just downstream of Elk Creek's crossing with Lovers Lane and continues to parallel Main Street before it joins back with Elk Creek 0.25 miles upstream of MT 21. Elk Creek Overflow was most likely formed as a result of a flood event and is a highly sinuous, debris filled channel that directs water towards the town of Augusta.

Elk Creek is also a major irrigation source and contains many headgates and irrigation canal diversions. The two major irrigation canals are Florence Canal, which begins 1 mile southwest of the Elk Creek and Smith Creek confluence, and Hogan Slough, which begins 0.7 miles southwest of Elk Creek's crossing with Augusta Clemons Road. Hogan Slough is a major source of irrigation for the northeastern part of the floodplain and begins as a diversion from Elk Creek through headgates just upstream of Augusta Clemons Road. Hogan Slough eventually ties back in with Elk Creek downstream of MT 21. Figure 1 shows the Elk Creek watershed from its confluence with the Sun River and the studied area in relation to the Elk Creek along with major infrastructure features.

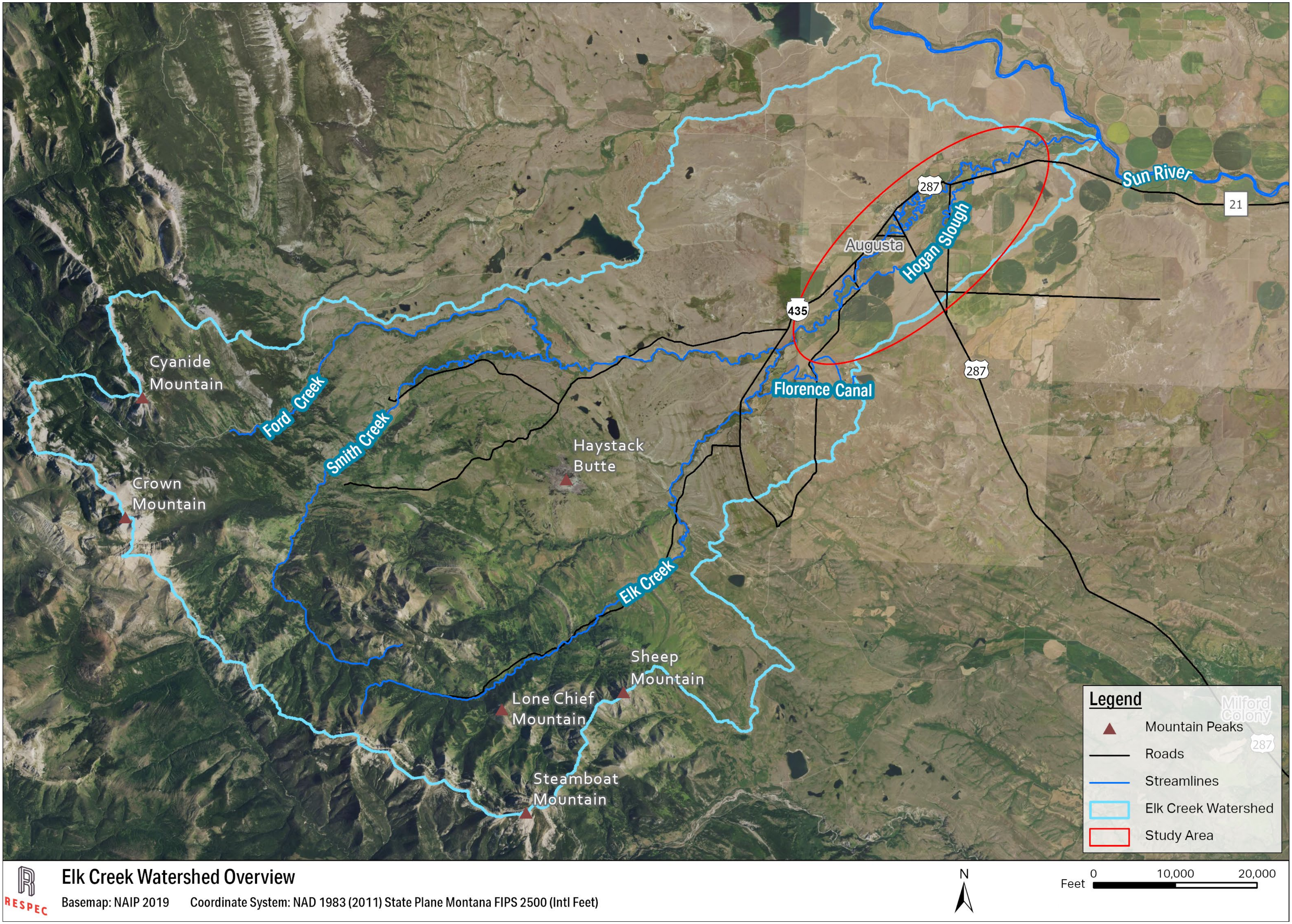


Figure 1. Overview of the Elk Creek Watershed with the location of the study area.

1.2. FLOOD HISTORY

Since Augusta was founded in the late 1800s, the community has suffered from numerous floods. Historical floods occurred in 1953, 1964, 1975, 2011, 2018, and 2019. Most flooding along the Rocky Mountain Front results from cool spring temperatures and higher-than -normal spring snowfall followed by rapid warming and abundant rainfall in late May and early June. Historically, Elk Creek has been characterized by long stretches of dry periods with short flood events that cause dramatic alignment and morphological changes to the creek. The largest recorded flood was on June 8, 1964 and was estimated to be an approximately 50- to 100-year event for the Elk Creek watershed. The flooding on Elk Creek was closely related to that of the Sun River and was the same year the Gibson Dam overtopped. Figure 2 shows the 1964 flooding around the rodeo arena in Augusta and Figure 3 shows the Gibson Dam overtopping.

Figure 2. Aerial imagery of the 1964 flood around the rodeo arena in Augusta (left), courtesy of MDT.

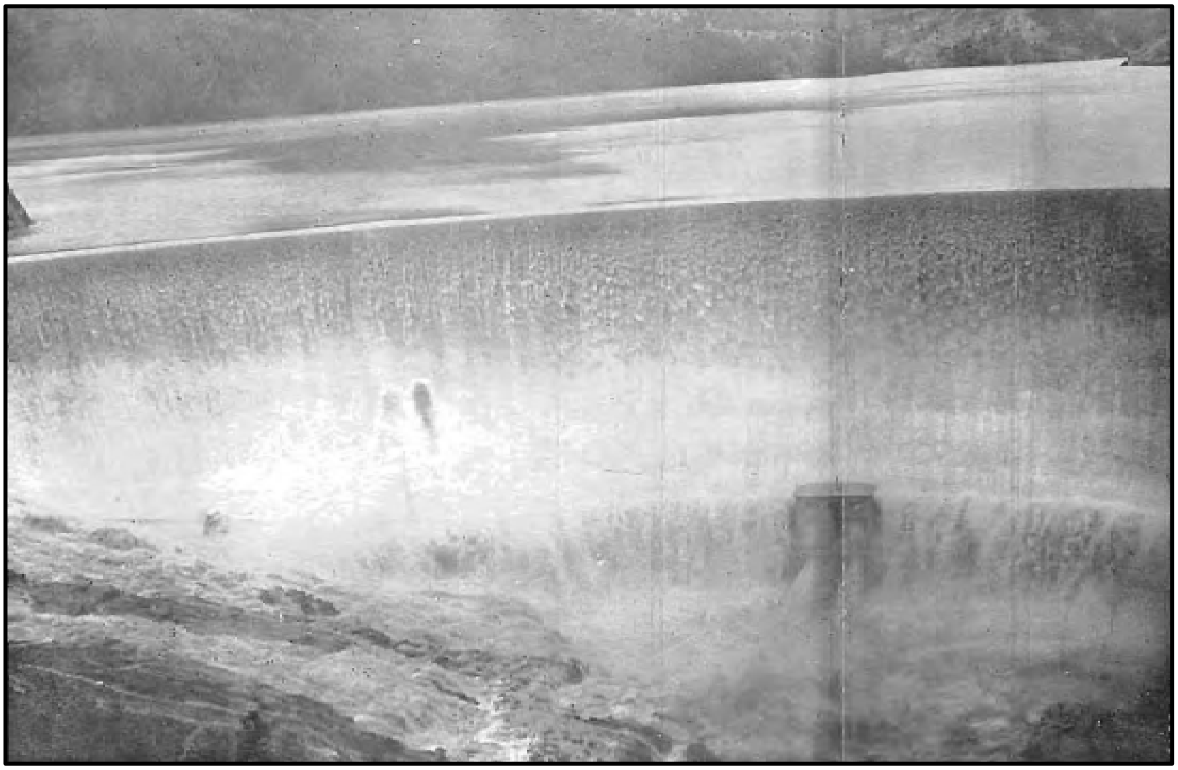


Figure 3. Imagery of the Gibson Dam overtopping during the 1964 flood event.

The most recent flood events were the back-to-back floods in 2018 and 2019. The sequence of the back-to-back events left the community in an extended period of disrepair. The magnitude of the 2018 event—the larger of the two recent floods—is estimated to have only been between a 10- and 25-year event. Figure 4 shows an aerial view of the 2018 flooding of Augusta from just upstream of US 287 to MT 21.

Figure 4. Aerial flood imagery from the 2018 flood event of Augusta from just upstream of US 287 to MT 21, courtesy of MDT.

These flooding events caused widespread infrastructure damage; large-scale stream morphology changes; and significant emotional and physical distress to farmers, ranchers, and townspeople. During the 2018 and 2019 floods, substantial amounts of sediment were carried downstream, causing bank erosion, damage to fences, diversion structures, town infrastructure, destruction of beaver dams, and deposition of gravel bars. Because the floodplain of Elk Creek has low gradient slopes, substantial amounts of debris were deposited as water spread and decreased in velocity, causing damage to rancher's fields that are still noticeable today. The town of Augusta experienced high floodwaters flowing down Main Street and the surrounding residential area, as well as extensive damage to structures. Figure 5 shows the floodwaters on Main Street and Figure 6 illustrates the water level in the floodplain adjacent to Lovers Lane during the 2018 flood event.

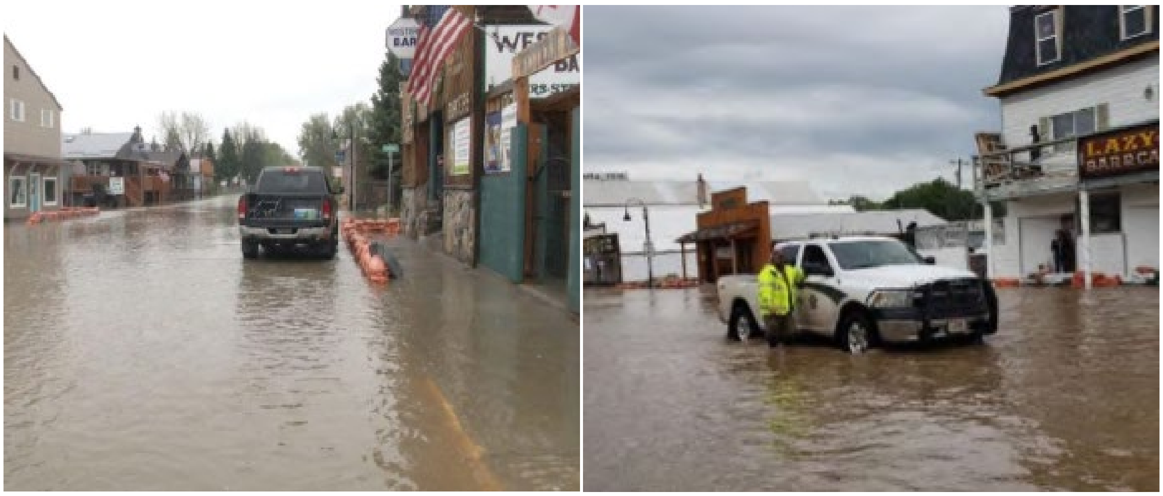


Figure 5. Floodwaters on Main Street in Augusta during the 2018 flood, courtesy of Great Falls Tribune.

Figure 6. Flooding adjacent to Lovers Lane in Augusta during the 2018 flood event, courtesy of Carol Fechter.

1.3. FLOODING FACTORS

Elk Creek flooding in Augusta and the surrounding floodplain can be attributed to three major factors:

- Elevation of the town of Augusta relative to the surrounding stream and floodplain;
- Backwatering effects from the three major roadways; and
- Undersized infrastructure and inefficient channel conveyance in the Elk Creek Overflow channel.

Augusta is situated in the Elk Creek floodplain and during periods of flooding, floodwater will seek its way into town. The major roadways further complicate flooding in Augusta. US 287 has two bridges and a series of overflow culverts. During flooding, these conveyance features develop backwater and combined with the skewed alignment of the highway, direct floodwaters towards town and the Elk Creek Overflow channel. Highway 435 upstream of town acts as a containment berm, preventing water from spreading to the left overbanks of Elk Creek and accessing the left side of the floodplain as it nears town. Figure 7 illustrates the elevation of the Elk Creek floodplain and these flooding factors.

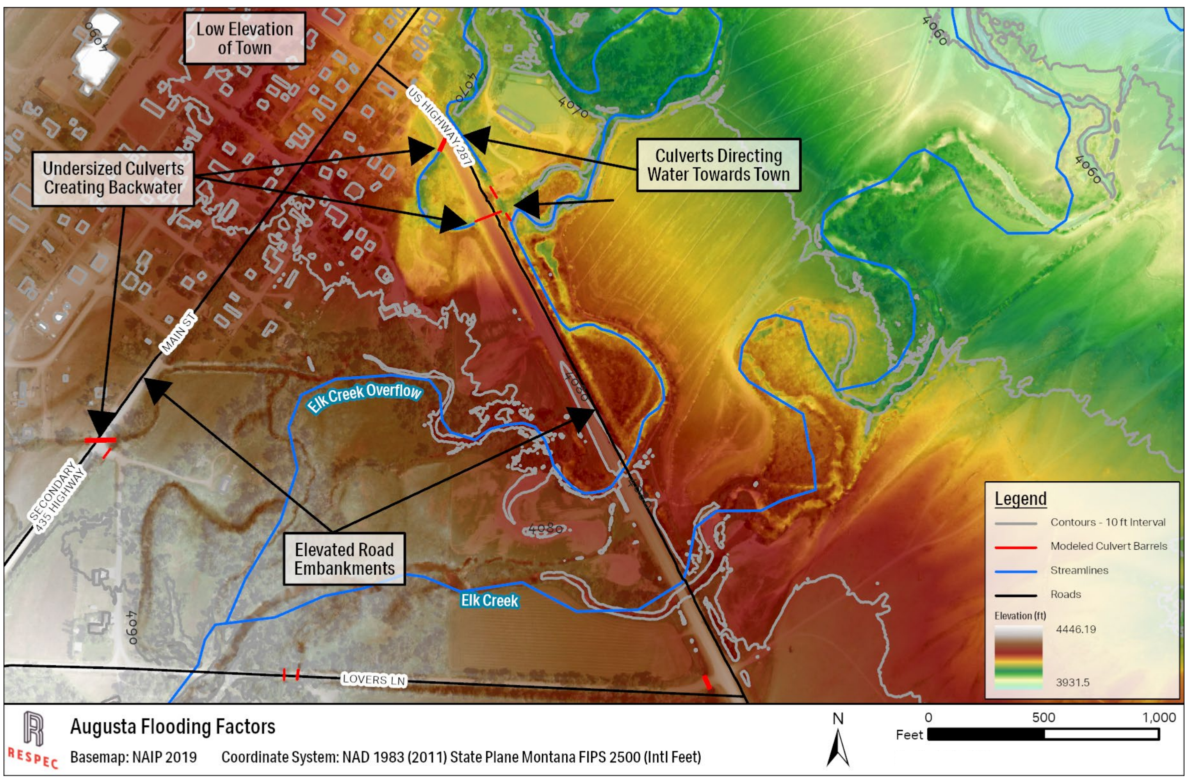


Figure 7. Factors contributing to flooding within Augusta.

1.4. COMMUNITY NEEDS

The town of Augusta will benefit from active measures to decrease the flood risk and damage to infrastructure when a major flood occurs. They have repeatedly experienced the devastating effects large flood events have had on their community and are looking for solutions to make flood events more manageable on the community. Based on discussions with the residents who participated in the public meetings, the residents understand large scale projects such as reservoirs or widespread levee systems will require extensive capital investment which may not be financially feasible or cost-effective. They understand that flooding cannot be fixed, but also that flooding can be reduced through flood mitigation.

1.5. STUDY AREA

The study area for this report was defined primarily based on the availability of existing topographic Light Detection and Ranging (LIDAR) data, as it is not possible to develop a two-dimensional hydraulic model without seamless topographic data. With the goal of developing recommended alternatives that provide the largest benefits for the greatest amount of Augusta area residents, much focus was placed within the Augusta core area. However, the study extends just downstream of the Elk Creek and Smith Creek confluence, as it was important to understanding existing flooding extents and effects, as well as determining areas for potential mitigation. As modeled, the study area extends from approximately 0.8 miles downstream of the Elk and Smith Creeks confluence to 2 miles downstream of MT 21. Figure 8 shows the area evaluated in the study with the defined LIDAR footprint.

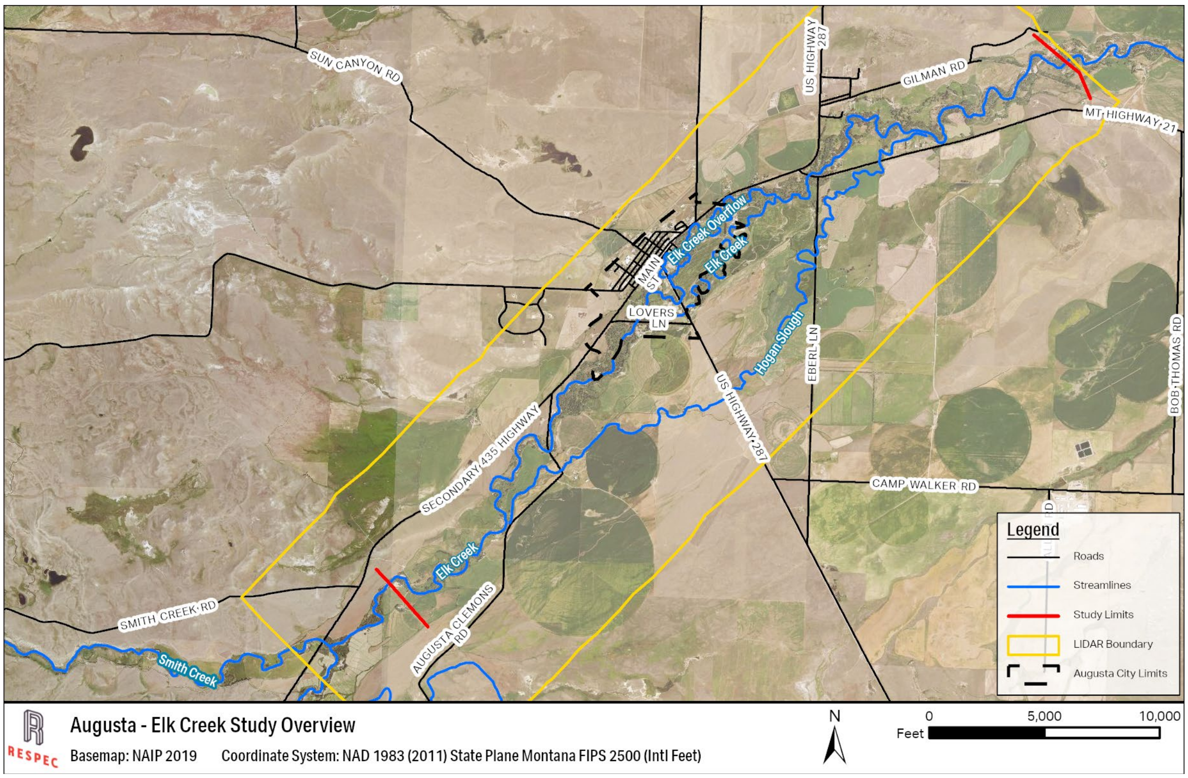


Figure 8. Study area for the Augusta - Elk Creek flood mitigation project.

1.6. PREVIOUS STUDIES

There are several existing studies that are relevant to this study. The FEMA Flood Insurance Study for Elk Creek was developed in late 1970s and finalized in 1985 (Reference 1). A detailed study was developed that identified a Special Flood Hazard Area that included regulatory base flood elevations and designated a floodway shown on the Flood Insurance Rate Map.

In 2012, Watershed Consulting and Great West Engineering completed a stream assessment of Elk Creek (Reference 2). The assessment began at the Elk Creek bridge on Montana Highway 435 and ended at the Elk Creek crossing of MT 21. The report examined and assessed stream channel conditions, irrigation diversions, and provided potential project sites. From their analysis, many of the sites were ranked as high priority sites.

In 2020, Confluence Consulting and Applied Geomorphology completed a post-flood hydrologic assessment of several streams within the Elk Creek watershed including Elk Creek for the Lewis and Clark Conservation District (Reference 3). This assessment evaluated stream conditions, channel avulsions, and headgate damage, and provided recommendations for addressing future flooding near Augusta. These recommendations included preventing water from accessing the roadside ditches along Montana Highway 435, diverting floodwaters to

Florence Canal to allow it to infiltrate into fields, and several bank stabilization methods to prevent further avulsions from occurring.

Following the floods in 2018 and 2019, the Montana Department of Transportation (MDT) collected topographic data and developed existing ground surfaces along MT 21. MDT infrastructure was damaged during the two floods and required repairs and replacements. Most of the MDT work focuses on the MT 21 alignment downstream of Augusta. Data acquired from this project consists of topographic survey, bathymetric survey, aerial imagery of previous flooding, site photographs, and a Light Detection and Ranging (LIDAR) dataset of Augusta and the surrounding area. In combination with the MDT work on MT 21, DOWL conducted a hydrologic analysis for Elk Creek and Hogan Slough at their crossings with MT 21 in 2020 (Reference 4). In this memorandum, both previously published flows were addressed, and new hydrologic analyses were completed. For the new hydrologic analyses, they utilized nine nearby streamgages to develop regional frequency equations and a regional regression analysis for peak flow frequencies on Elk Creek.

1.7. SITE OBSERVATIONS

On September 30 of 2021 RESPEC performed a site visit to examine channel and structure conditions on Elk Creek within the study area. In many of the channels within the limits formed by Lovers Lane, Highway 435, and US 287, as well as in the Elk Creek Overflow downstream of US 287, substantial amounts of woody debris fill the channels, enough to create large obstructions to flow in some locations. An example of the large woody debris on Elk Creek near the Lovers Lane bridge is shown in Figure 9.

Figure 9. Large woody debris observed on Elk Creek upstream of the Lovers Lane bridge.

In addition to the observed debris, downstream of US 287, several small wooden bridges spanning elk creek were noted to be undersized or have structural damage. Indication that the bridges were undersized came from observation of large scour holes, caused by constriction of flows during the mentioned flood events.

It was also observed that an extensive culvert network exists in Augusta, between both Elk Creek and Elk Creek Overflow. Many of these culverts, especially those crossing US 287 or those running adjacent to the roadway, help to guide water towards town either by spanning high ground between channels or by diverting into the roadway ditches along US 287.

Many of the culverts within the study area were observed to contain sediment accumulation from flood events and spring runoff, which was often blocking sizeable amounts of the culvert openings. An example of this sediment clogging upstream of Augusta and in Elk Creek Overflow is shown in Figure 10.

Figure 10. Sediment clogging within a box culvert on Elk Creek Overflow (left) and a circular culvert upstream of Augusta (right).

2.0 PUBLIC ENGAGEMENT

2.1. INITIAL PUBLIC MEETING AND SURVEY

An initial public meeting was held at the Youth Community Center in Augusta on February 18, 2022. The meeting was intended to engage the public and receive information about their experiences with recent flooding, their input on problematic locations throughout the study area, and their ideas for potential mitigation solutions. The meeting began with a presentation on the existing conditions hydraulic model developed by RESPEC for this project. The model simulated measured USGS flows from flood events in 2018, 1975, and 1964. The meeting closed with a discussion and question and answer session. The presentation is included in Appendix D. Following this meeting, an online community survey was opened to allow further comments from residents not in attendance at the meeting. The survey was open from February 18th – March 4th, 2022. The survey consisted of an open response box for community members to write their thoughts and recommendations. Survey results were combined and analyzed and used to assist in the development of flood mitigation alternatives. Survey results from the residents that participated in the survey are attached in Appendix E. Comments including any personal information were redacted from the attachment.

2.2. ALTERNATIVES PUBLIC MEETING AND SURVEY

After completion of the development and evaluation of flood mitigation alternatives, alternatives were presented to several officials from the county for feedback and revision. Once those revisions were completed, alternatives were presented to the community on May 6, 2022. Following the meeting, verbal comments were discussed, presentation slides were released, and a two-week period was provided for the community to comment on the presented alternatives. Comment opportunities were given to the community by an online survey or collection of written comments at LCC's monthly Government Day on May 13, 2022; however, no comments were received. The presentation slides are attached in Appendix F.

3.0 HYDROLOGIC ANALYSIS

Flood frequency for Elk Creek near Augusta has been developed by several different entities over time. In general, a streamgage with record of annual peak flow events is generally considered the best source of information from which to develop flood frequency. There is one streamgage on Elk Creek at the HW 287 bridge crossing (USGS 06084500) Elk Creek at Augusta, MT; however, the gage has a disjointed period of record. The gage's period of record spans from 1905-2018 but the gage was only maintained from 1905-1924. The remaining period of record consisted of intermediate measurements taken by USGS personnel during floods. The measured flood events are a critical data source for this study, since the events were quantified, there is increased confidence for using those flows in hydraulic simulations of flood mitigation alternatives. What remains ambiguous, is assigning a definitive recurrence interval (RI) to the past and recent flood events, as RI changes over time as new data is collected, and also is dependent upon which methodology is used to develop flood frequency.

The 1985 FEMA FIS study used the streamgage record to develop flood frequency. The major floods of 1964 and 1975 were included in that analysis. There is a statement in the FIS that by including the 1964 and 1975 flood events, the effective period of record for the gage was extended to 71 years.

In 2016, the USGS developed flood frequencies for majority of streamgages statewide and updated regional regression equations in *Scientific Investigations Report 2015-5049* that is based on gage records through water year 2011 (Reference 5). The statistical streamgage analyses were conducted under methods outlined in Bulletin 17B. In 2018, USGS published updated flood frequencies for the Elk Creek gage under *Scientific Investigations Report 2018-5046* (Reference 6). This update to the 2016 flood frequencies was requested by the Montana Department of Natural Resources (DNRC) for new floodplain mapping studies conducted elsewhere. The flood frequency analyses were conducted under methods outlined in Bulletin 17C and included the 2018 flood event on Elk Creek, as measured by USGS. USGS developed flood frequency at the Elk Creek streamgage based on record alone, but because of the limited record, the analysis was weighted with regional regression results, to improve confidence in results, as recommended in Bulletin 17C.

Because of the disjointed period of record at the gage, other methods for determining flood frequency should be considered. The StreamStats online application, which uses regional regression equations developed in SIR-2015-5049 (Reference 5) was reviewed. Because of StreamStats exclusion polygons observed at HWY 287, flows were estimated just downstream of Augusta at MT 21. The StreamStats report is provided in Appendix A. Flood frequency results from various studies are compared to the StreamStats estimates in Table 1.

Table 1. Comparison between the USGS published updated peak flood frequencies and StreamStats peak flood frequencies for Elk Creek.

Event Frequency	1985 FEMA FIS	2016 USGS Published Flows at Gage	2018 USGS Published Flows at Gage	2018 Weighted USGS Published Flows at Gage	StreamStats Flows at MT 21
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
2-Year	-	882	857	913	1,970
10-Year	3,400	2,870	3,080	3,400	4,370
25-Year	-	4,620	5,090	6,620	6,830
50-Year	6,860	6,360	7,120	9,130	9,450
100-Year	8,610	8,560	9,690	12,500	13,000
200-Year	-	11,300	12,900	17,200	17,900

In DOWL's 2020 hydrologic analysis to support MDT flood repair work along MT 21, multiple methods were used to analyze peak flood frequencies. Their report summarizes the same existing studies shown in Table 1, however, the report includes development of additional methods, as well. The first method was development of regional frequency equations using nine nearby streamgages to represent the Elk Creek drainage, using basin area as the only explanatory parameter. The second method was to develop a regional regression analysis using those same nine streamgages but with drainage area and mean basin elevation as two explanatory variables. The third hydrologic analysis method was to evaluate an analysis on a gaged basin with similar basin characteristics to those of the Elk Creek basin. The chosen basin drains to the Dearborn River and is located adjacent to the Elk Creek drainage basin. The USGS streamgage 06073500 for the Dearborn River is located near Craig, Montana and has 43 years of historical record. Because the drainage area for the Dearborn River drainage basin is approximately double the size than that of the Elk Creek drainage basin, a gage transfer was needed to scale results to Elk Creek. Their report recommended that the FEMA FIS flows be adopted for design due to precedence, and general alignment in results between the 2016 USGS gage analysis, 2018 USGS gage analysis, and the Dearborn River gage transfer analysis. Those comparisons are shown in Table 2.

Table 2. The Dearborn River gage transfer compared with the 2016 USGS and the 2018 USGS flood frequencies.

Event Frequency	1985 FEMA FIS	2016 USGS Published Flows at Gage	2018 USGS Published Flows at Gage	Dearborn River Gage Transfer
	(cfs)	(cfs)	(cfs)	(cfs)
2-Year	-	882	857	1,239
10-Year	3,400	2,870	3,080	3,527
25-Year	-	4,620	5,090	5,276
50-Year	6,860	6,360	7,120	6,886
100-Year	8,610	8,560	9,690	8,753
200-Year	13,200	11,300	12,900	11,300

In the Confluence and Applied Geomorphology's 2020 *Post-Flooding Hydrologic Assessment of Elk, Ford, and Smith Creeks*, frequency estimates were assigned to the three largest floods recorded by USGS, shown in Table 3. These flood frequencies were estimated in that report by comparing recorded flood measurements to USGS StreamStats estimated flood frequencies for Elk Creek. The StreamStats drainage basin for Elk Creek is suspected to have been delineated near the existing Elk Creek streamgage location.

Table 3. Flood event estimated flood frequencies presented in the 2019 *Post-Flooding Hydrologic Assessment of Elk, Ford, and Smith Creeks.*

Recorded Year	Discharge (cfs)	Estimated Frequency
2018	6,580	10 to 25-year
1975	8,500	25 to 50-year
1964	12,000	50 to 100-year

As mentioned, this study relied primarily on measured flow from the flood event in 2018. That event has served as the target for understanding effectiveness of various mitigation alternatives. Based on the summary of existing studies, RESPEC believes the USGS *Scientific Investigations Report 2018-5046* should be used for recurrence interval determination, which places that event between a 25- and 50-year event.

4.0 HYDRAULIC ANALYSIS

HEC-RAS Versions 6.1 (Reference 8) and 6.2 (Reference 9) were used to model surface water hydraulics throughout the study area. A two-dimensional (2D) model was developed for the study area to aid in understanding the complex, shallow sheet flow nature of the overbank flows. The model was developed according to guidelines in the HEC-RAS 2D User Manual (Reference 10).

From the existing conditions two-dimensional models, ten alternative models were created to compare different alternatives to the existing conditions. The following sections describe modeling for the existing and alternative conditions models.

4.1. TOPOGRAPHIC DATA

4.1.1. DATA ACQUISITION AND DATA PROCESSING

Quantum Spatial, Inc. acquired LIDAR data for the project area under contract with MDT. The LIDAR was collected and processed to meet the National Standard for Spatial Data Accuracy (NSSDA) in 2018. The LIDAR data was converted to the following specifications for use in this project:

HORIZONTAL PROJECTION:	Montana State Plane	Units
	Horizontal – NAD83 (2011)	International Feet
VERTICAL DATUM:	Vertical – NAVD88, Geoid 12A	US Survey Feet

The LIDAR Bare Earth "model key points" were used to create a Triangular Irregular Network (TIN), and the water surface was hydro-flattened using channel polygons. Hydroflattening was determined necessary due to the high variability in LIDAR points within the channel. Channel polygons were created in small segments along banklines and drew from the lowest LIDAR return point elevation to represent the hydro-flattened water surface elevations (WSEL). Bridge decks were also removed from the LIDAR to ensure their elevations would not interfere with cross-sectional profiles in the HEC-RAS models. For larger culverts where LIDAR points were variable, small areas were modified at culvert inverts to represent the elevations of the surveyed inverts. The LIDAR was then converted to a Digital Elevation Model (DEM) with a cell size of 1 feet x 1 feet and served as the primary topographic source for development of the hydraulic models for this study, in conjunction with field survey. Figure 11 shows the extents of the LIDAR produced surface, zoomed in on US 287 and the town of Augusta.

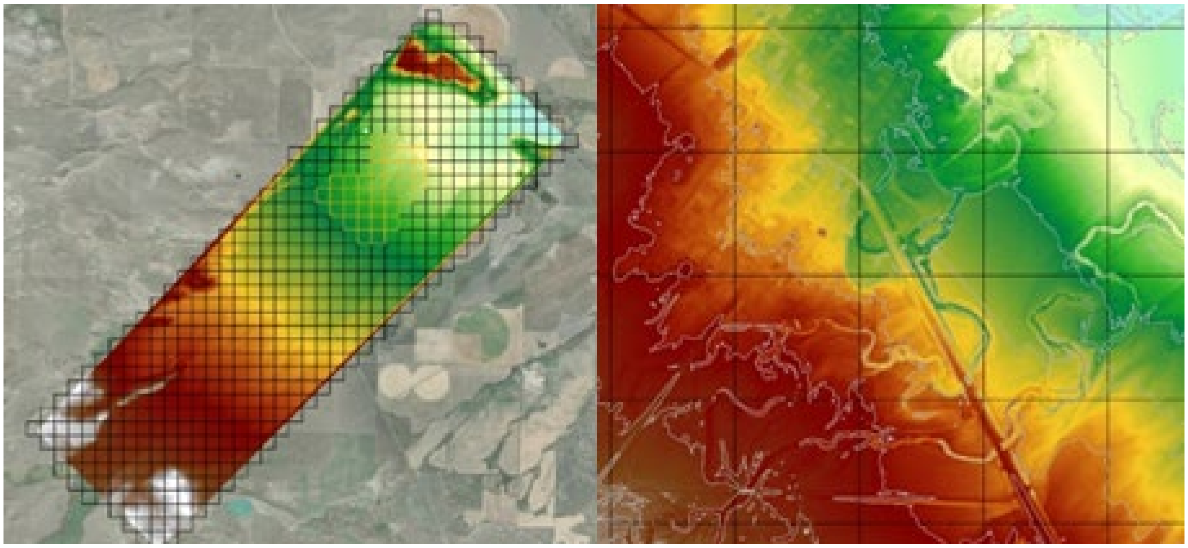


Figure 11. Processed LIDAR surface full extents (left) and focused view on US 287 and the town of Augusta (right).

During the initial field visit, culverts and bridges were investigated to obtain structure location, type, and size. In addition to this field visit, topographic survey was conducted throughout the project area by Robert Peccia Associates (RPA) on November 17, 2021. Culverts, bridge decks and abutments, and cross sections on either side of the bridges were surveyed and incorporated into the hydraulic analysis. The field survey was collected with the following specifications:

HORIZONTAL PROJECTION:	Montana State Plane	Units
	Horizontal – NAD83 (2011)	International Feet
VERTICAL DATUM:	Vertical – NAVD88, Geoid 12A	US Survey Feet

Existing ground and bathymetric surfaces were collected from MDT for the MT 21 area, where they are conducting a project to replace several of the existing bridges on MT 21. These were received as DEMs and superimposed over the LIDAR to create a more detailed terrain.

4.1.2. DEVELOPMENT OF BATHYMETRIC SURFACES

The surveyed channel cross sections points were used to create bathymetric surfaces under each bridge structures. Using ESRI's ArcGIS Pro software, those bathymetric surfaces were clipped to the hydro-flattened water surface edges and adjusted so elevations above the hydro-flattened water surface were reduced to the hydro-flattened water surface elevation (Reference 11). This ensured no terrain features were added above the elevation of the hydro-flattened surface, as well as to preserve terrain features such as islands in the channel. Figure 12 shows an example of the superimposed bathymetric bridge channel surfaces on the hydro-flattened surface.

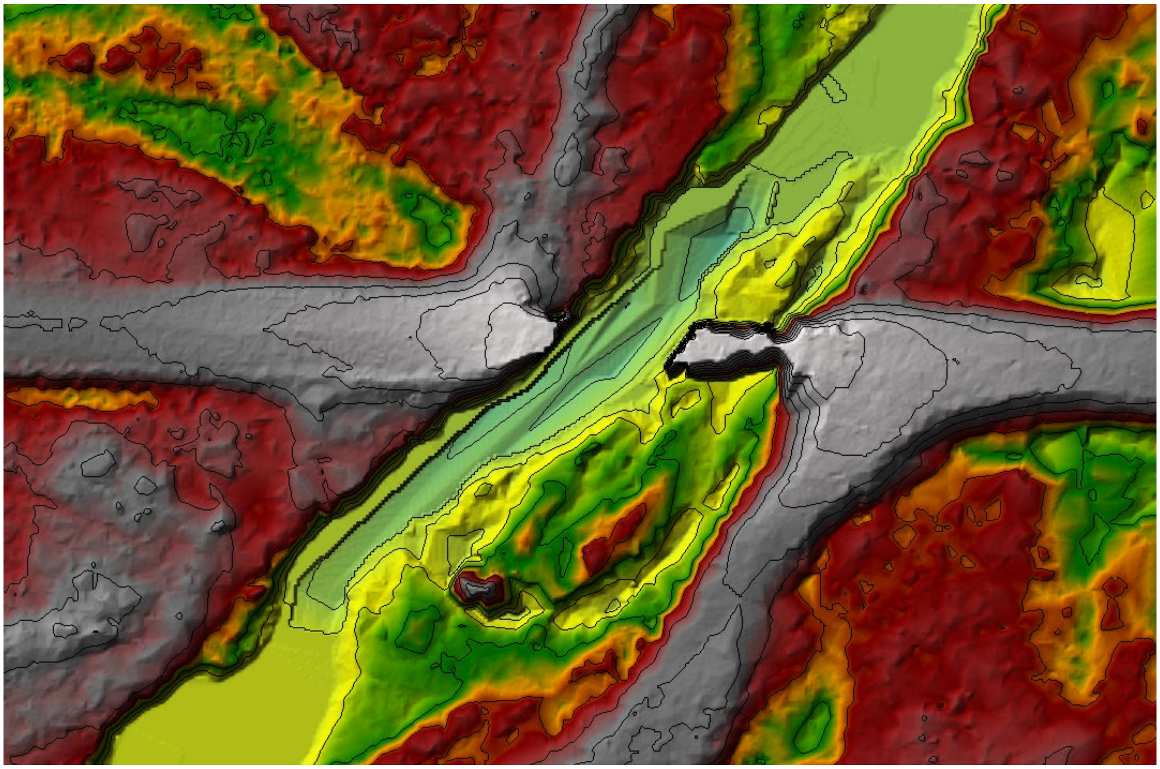


Figure 12. Example of the bathymetric surveyed cross section surfaces superimposed over the hydro-flattened water surface.

4.1.3. COMPOSITED SURFACE

A terrain was constructed in HEC-RAS Version 6.1.0 utilizing the processed and hydro-flattened LIDAR Bare Earth DEM as a base surface for the model. Field survey collected by RPA, MDT bathymetric channel and overbank surfaces, RESPEC created bathymetric surfaces, and building footprints were superimposed over the LIDAR to create a more detailed surface to improve topographic accuracy for alternatives analysis.

4.2. COMPUTATIONAL PARAMETERS

4.2.1. TWO-DIMENSIONAL MESH REFINEMENT

One computational mesh was generated for the entire study area. The computational mesh was generated in HEC-RAS 6.1.0 with a 75 foot x 75 foot cell spacing. Break lines were added to the computational mesh to further refine the mesh in areas of hydraulic significance. Breaklines were placed along banklines and raised topographic features to add computational detail in channels and other topographic breaks. Most breaklines utilized a reduced cell spacing, which was largely controlled by model error in cells surrounding the breaklines. The maximum breakline cell spacing was 75 feet, while the minimum breakline spacing was 10 feet.

4.2.2. EQUATION SET

The Diffusion Wave equation set was utilized to perform all simulations with an initial time step of 30 seconds. To adequately capture steady state conditions, the computational time window was established to ensure enough time was provided to allow flows through the system to stabilize. Stabilization was determined by evaluating time series flow results throughout the domain utilizing profile lines in RAS Mapper.

4.2.3. COMPUTATIONAL TIME STEP AND WINDOW

The mesh cell size and computation time step are related factors for developing a 2D model. Early iterations of the model were coarse. As detail was added to the 2D domain, the cell spacing decreased to capture localized hydraulics, while decreasing the time step to target a Courant number of 1. Optimizing the computation to target a Courant number of 1 lowered the time step to 4 seconds.

All computation time windows were set to an 18 hour simulation, starting at 0000 and ending at 1800. The simulation date was set to the day the peak floods were recorded at. 1964 was set to June 8, 1964, 1975 was set to June 19, 1975, and 2018 was set to June 19, 2018.

4.3. BOUNDARY CONDITIONS

The 2D domain requires boundary conditions to allow the inflow of water and to allow water to leave the model. The upstream boundary condition uses the USGS gage-measured flow rate. An inflow hydrograph was used to quickly ramp up flows until the hydrograph reached a steady state for the duration of the model run time. An outflow downstream boundary condition was extended beyond the hydraulic controls to ensure all backwater created by the hydraulic controls was captured, the flood was contained, and no bias was present within the model.

4.4. ROUGHNESS COEFFICIENTS

A land cover dataset was obtained from the U.S. Geological Survey (USGS) National Land Cover Database and used to delineate base roughness values within the model limits. Land cover override polygons were drawn in RAS Mapper to more accurately delineate channels and other locations within the models using aerial imagery. The Manning's roughness values assigned within the hydraulic models were determined based on aerial photography, the HEC-RAS 2D Hydraulic Reference Manual, and Chow's Open Channel Hydraulics (Reference 12). The ranges of values used in the updated modeling are shown in Table 4.

Table 4. Assigned roughness values for land cover types within the model.

Land Cover Type	Assigned Roughness Value
Pasture	0.035
Shrub/Scrub	0.100
Grassland	0.038
Cultivated Crops	0.038
Developed, Low Intensity	0.100
Developed, Medium Intensity	0.120
Developed, High Intensity	0.150
Evergreen Forest	0.160
Barren Land	0.025
Wetlands	0.075
Channel	0.035 – 0.050

4.5. HYDRAULIC STRUCTURES

The structures evaluated during the initial 2021 field investigation conducted by RESPEC and the 2021 field survey conducted by Robert Peccia Associates were incorporated into the two-dimensional model. For bridges, all survey points were projected onto the surveyed bridge centerlines to obtain stationing for the model. Bridge decks, low chords, piers, and abutment were modeled using surveyed elevations. Upstream and downstream cross sections were cut from the underlying terrain and modified using projected channel survey points. Culvert roadway crossings were drawn using aerial imagery and surveyed culvert barrel locations. Culvert barrel centerlines were created based on the location of the surveyed inverts and imported into HEC-RAS. Surveyed inverts were mostly maintained, however due to LIDAR and survey elevation differences on the roadway embankments, some invert elevations were modified. In these cases, culvert slope was maintained between upstream and downstream inverts.

4.6. EXISTING CONDITIONS

Existing conditions were assessed for the three USGS recorded events: 2018, 1975, and 1964. The 2018 existing conditions model showed three major flooding regions within the Augusta area: Elk Creek, Elk Creek Overflow, and Hogan Slough. Results split between those three regions showed that just downstream of US 287, the Elk Creek Overflow and its overbanks containing the greatest amounts of floodwaters, approximately 44% of the total flood volume. Elk Creek contained approximately 37% of the flood volume, and Hogan Slough approximately 19%. Significant amounts of backwater were observed behind the US 287 and MT 21 road embankments. The skewed alignment of US 287, combined with its elevation profile being lowest at the intersection with Highway 435, causes backwater to route towards town. The modeled flood also demonstrated which structures influence the amount of flow into the Elk Creek Overflow channel, as well as where floodwaters are overtopping US 287. Also observed in the model and as described in the hydrologic assessment, floodwaters are accessing the Highway 435 borrow ditches and routing floodwaters into town.

The model extents were compared to aerial imagery taken during the 2018 flood event. Flood extents were similar in the model as to those shown in the aerial imagery. It is important to note that because the modeled hydrographs were run under steady-state conditions for the duration of the run time and not fluctuating like they do in nature, flow volumes are not representative of an actual flood event. The models may portray slightly worse flood extents than was experienced during the 2018 flood event. The 2018 existing conditions flood model is shown in Figure 13.

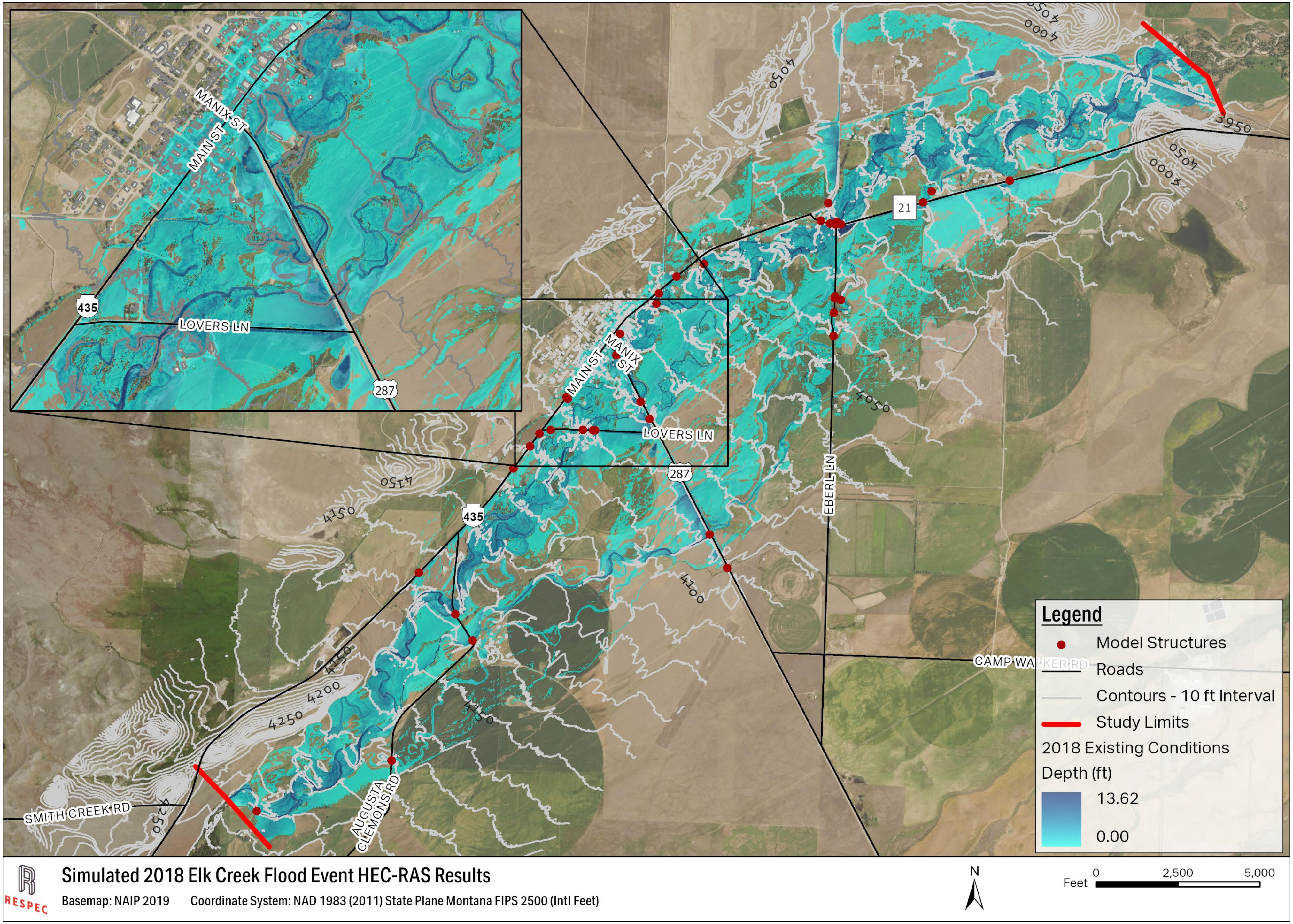


Figure 13. Existing conditions HEC-RAS results from the simulated 2018 flood event.

5.0 FLOOD MITIGATION ALTERNATIVES

5.1. ALTERNATIVES DEVELOPMENT

Following the assessment of the existing conditions model results, comments received at the first public meeting, and information gathered from previous studies, eleven alternatives were developed and considered as potential flood mitigation solutions. The following areas were identified as problematic flooding areas and used to develop flood mitigation alternatives:

- **Elk Creek Overflow**, primary focus is to decrease flow accessing this channel;
- **Main Street of Augusta**; primary focus to decrease velocities and depths of floodwaters flowing in this area;
- **US Highway 287**, primary focus was to investigate the effects of backwater caused by US 287 and determine intervention needed to decrease;
- **Existing irrigation canals**, to use large irrigation canals like Hogan Slough as diversion channels during flood events with focus on avoiding overburdening farmers and ranchers with increased flooding effects by decreasing the amount of water flowing through town center.

The alternatives created were split into three categories for presentation to the community; backwater improvement, diversion, and berm implementation alternatives. The alternatives are as follows:

- Backwater Improvement Alternatives
  - Channel and Floodplain Debris Removal
  - US 287 Removal and Re-Alignment
  - US 287 Existing Bridge Channel Widening
  - US 287 Bridge Replacement
- Diversion Alternatives
  - Existing Irrigation Canal Diversions
  - Flow Diversion from Elk Creek Overflow to Elk Creek
  - Hogan Slough Diversion
  - Flood Bypass Channel
- Berm Implementation Alternatives
  - Flow Containment Berm and Upstream of Augusta Clemons Road
  - Flow Redirection Berm
  - Flow Redirection Berm with Extension

All alternatives were analyzed using hydraulic models and compared to the existing model results. Alternatives were evaluated based on feasibility and constructability, effectiveness at mitigating flooding damages, and overall public benefit. Results of the alternatives analyses were presented at the town meeting on May 6, 2022. Figure 14 outlines the alternatives presented at the second town meeting. The following sections provide an overview and results of the evaluated flood mitigation alternatives. Larger results images are provided in Appendix B.

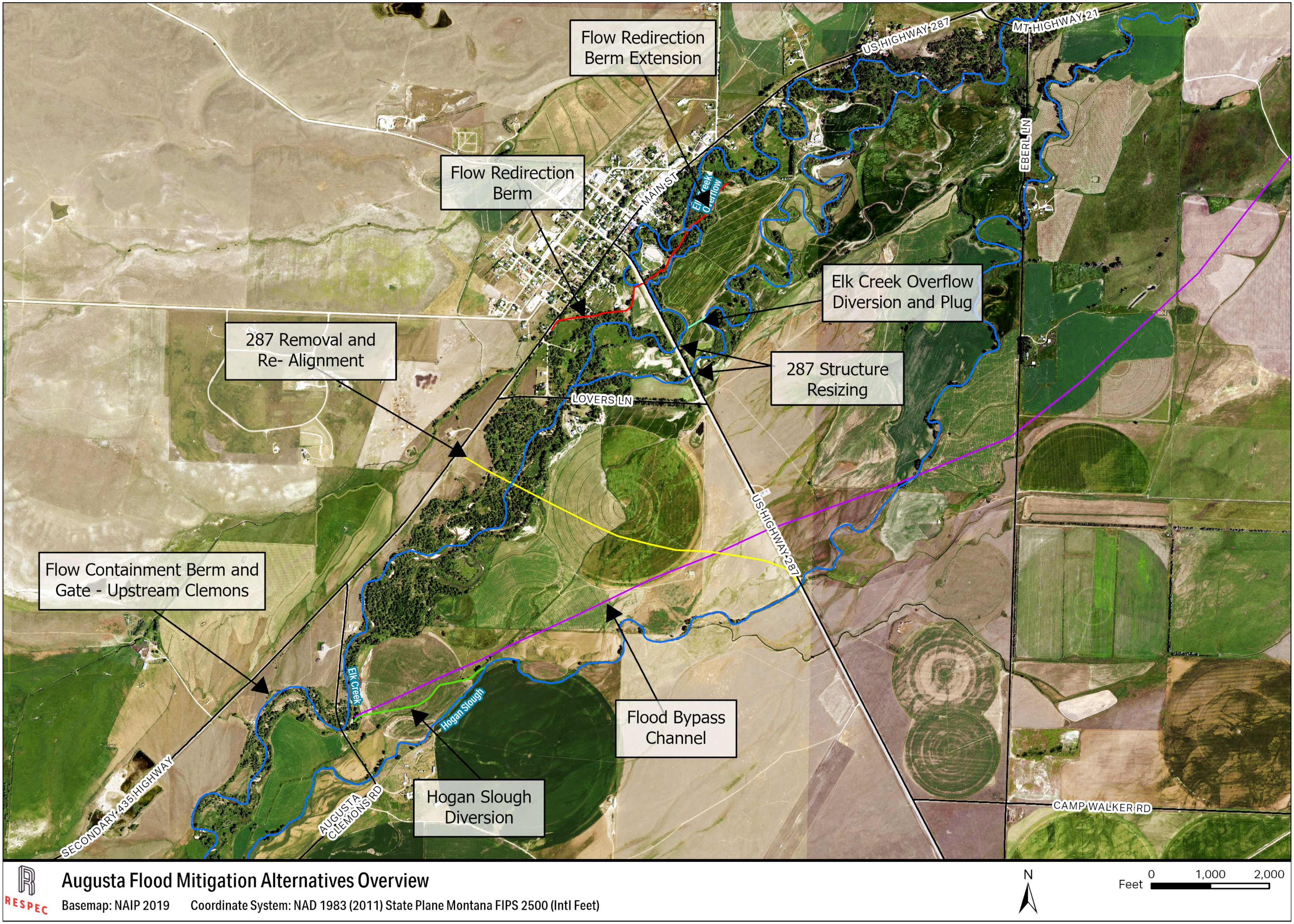


Figure 14. Overview of the Augusta flood mitigation alternatives.

5.2. ALTERNATIVES OVERVIEW AND ANALYSIS

The following sections provide an overview of evaluated flood mitigation alternatives for Elk Creek in the town of Augusta. The presented flood mitigation alternatives below do not portray a detailed design, but rather conceptual designs that were simulated to draw comparisons and provide recommendations. It should be noted that flood mitigation implementation needs to be designed, modeled, and permitted since flood reduction in a specific area has potential to increase flooding in other areas. Any activity in the FEMA designated floodplain must be authorized with a floodplain development permit issued by LCC. It is also important to note that these simulations and results are not that of the regulated base flood event (100-year flood). Changes to flooding conditions presented from these simulations do not imply the same or worse changes would occur during the regulatory base flood event. Additional permits are also likely required. For example, any work within the bed and banks of a perennial stream must be authorized by a 310 Permit from the Conservation District. Any work in a regulatory wetland or within Waters of the US, as defined under Section 404 of the Clean Water Act, must be authorized by the US Army Corps of Engineers. Other permits may also be applicable.

The eleven alternatives are organized into an overview section to describe the alternative and a results section to present the results of the two-dimensional models. The results of the alternatives presented in this section were evaluated on WSEL changes, flow changes, velocity changes, and flooding extent changes. Raster calculators were used to determine WSEL, velocity, and flooding extent changes across the entire model domain and compared to the simulated 2018 existing conditions. The results figures placed in the text area are available as full size figures in Appendix B. Flow changes were evaluated at specific locations within the model domain because evaluating flow changes within a two-dimensional model can be difficult. Specifically, evaluation lines were created to assess flow changes just downstream of US 287. This location was chosen because it is in an ideal location to compare both the town of Augusta flooding down Main Street, the surrounding residential area, and in the Elk Creek Overflow to the flooding occurring in the channels and floodplains of Elk Creek and Hogan Slough. Figure 15 shows the flow evaluation lines chosen for this analysis.

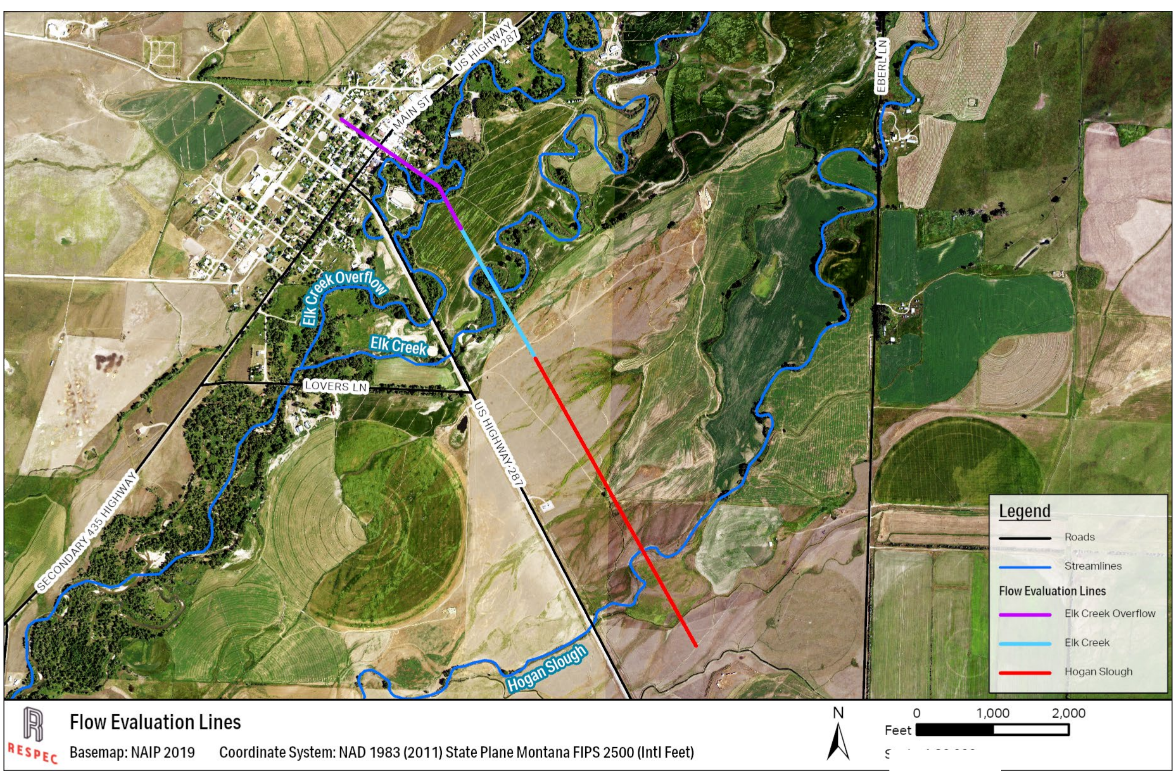


Figure 15. The evaluation lines drawn in HEC-RAS to evaluate flow change between 2018 existing conditions and the alternatives.

5.2.1. CHANNEL AND FLOODPLAIN DEBRIS REMOVAL

5.2.1.1. OVERVIEW

As outlined in the 2020 *Post-Flooding Hydrologic Assessment of Elk, Ford, and Smith Creeks*, flood events have deposited a large amount of sediment and debris within the Elk Creek channel and on its floodplains. Deposition of debris at bridges and culverts has led to the creation of choke points, causing backwater at structures consequentially increasing upstream flooding. Debris deposition and erosion has a large effect on function of irrigation headgates, canals, and ditches, which are crucial to the residents of Augusta.

Woody debris jams within the channel after the 2018 and 2019 floods were indicated by landowners to cause major changes in the channel. These woody debris jams can contribute to backwater effects, as well as to cut/fill patterns exhibited in those flood events.

5.2.1.2. RESULTS

Modeling of an overall debris removal scenario was attempted using modified roughness values within the channel and its floodplain. Results showed small decreases in depths throughout the model domain; however, it is more likely that debris deposition occurs on smaller scales, and should be assessed on a targeted, localized scale in the field.

5.2.2. US 287 REMOVAL

5.2.2.1. OVERVIEW

US 287 from existing model results, topographic analysis, and comments from the residents of Augusta, was identified to be a major source of backwater and a contributor to increased flooding. Due to its location and the elevation profile sloping towards Main Street, US 287 directs water towards town. Removing this highway would help to lessen backwater consequentially decreasing the amount of water flowing towards the intersection of US 287 and MT 435. This scenario was modeled to quantify the effects US 287 has on flooding and assess the benefit the removal would have. Modeling of this alternative consisted of removal of the road embankment, bridges, and culverts through terrain modification and grading techniques. Effected channels that cross US 287 through culverts were cut into the terrain with US 287 removed and were modified to have the same shape and size as upstream of the existing culverts. Figure 16 shows the terrain with the removed highway.

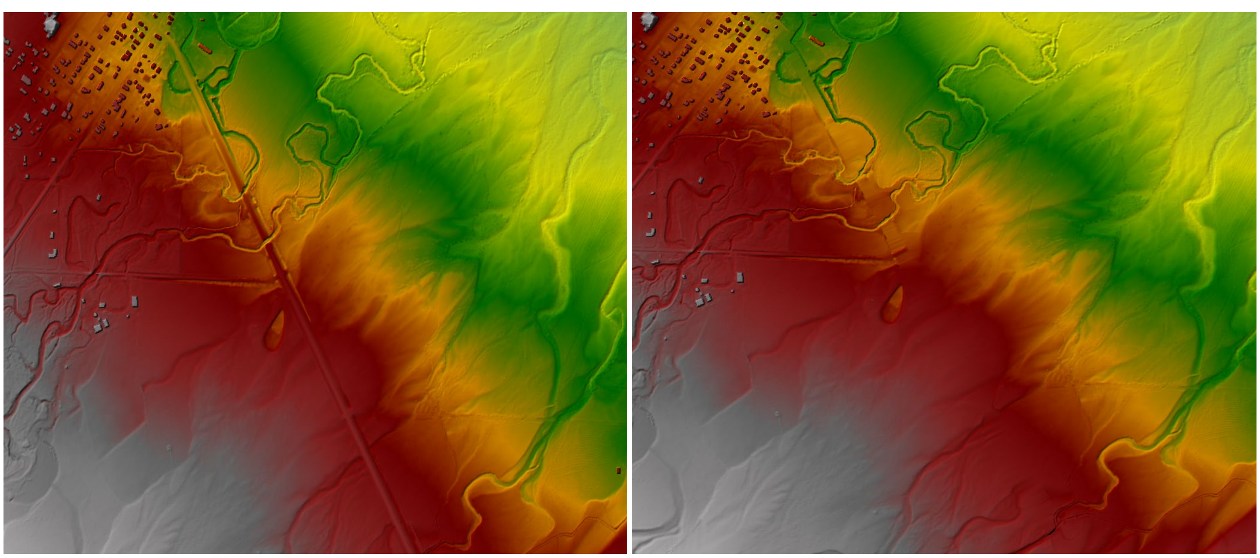


Figure 16. Comparison of the terrain before (left) and after (right) US Highway 287 removal.

5.2.2.2. RESULTS

Results of removing US 287 showed a smaller flood footprint behind the highway because of removed backwater. Large water surface elevation reductions were observed where backwater was in the 2018 existing conditions models, as well as along the Elk Creek Overflow evaluation line. Figure 17 illustrates the flood areas removed and added as result of removing US 287. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the US 287 Removal results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

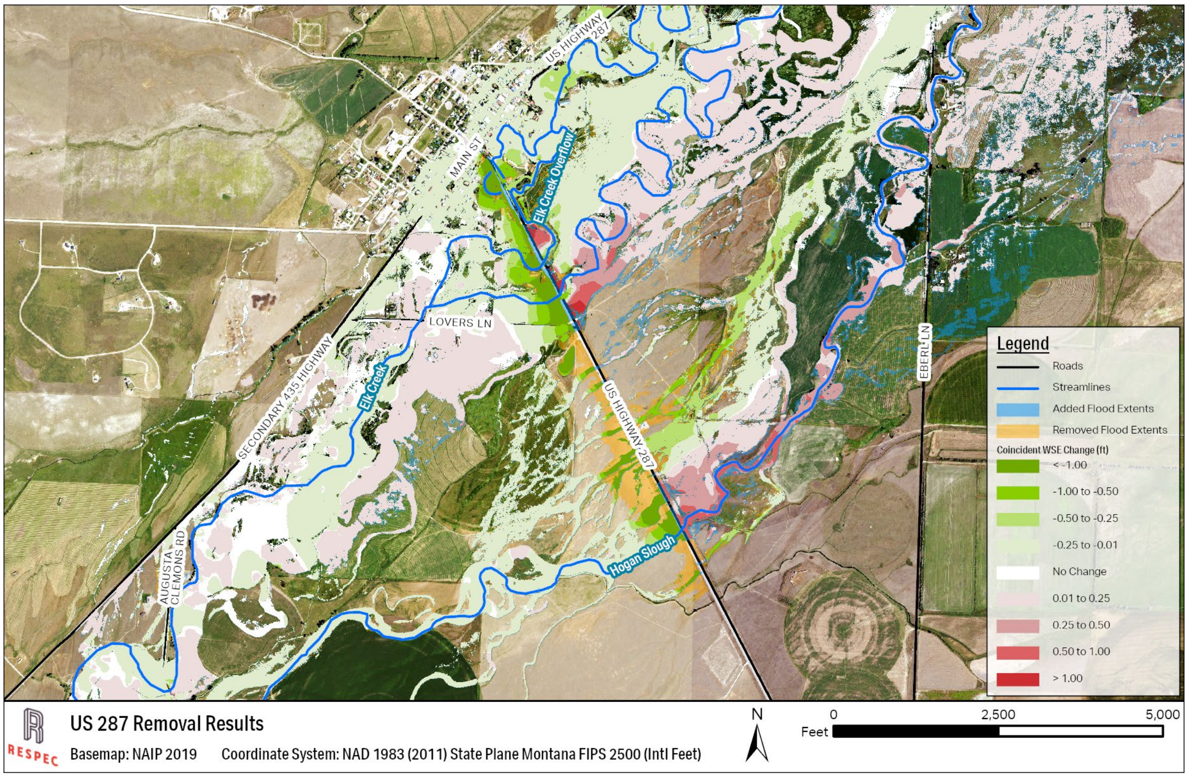


Figure 17. HEC-RAS output WSEL comparison between the US 287 removal alternative and the 2018 existing conditions.

Flow reductions occurred along the Elk Creek Overflow evaluation line, but increases were observed along the Elk Creek and Hogan Slough evaluation lines. Table 5 summarizes flow changes along the evaluation lines.

Table 5. Depth and flow comparison between the US 287 removal alternative and the 2018 existing conditions.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	US 287 Removal
Elk Creek Overflow	2,443	1,888
Elk Creek	2,823	3,282
Hogan Slough	1,326	1,427

5.2.3. US 287 BRIDGE ALTERNATIVES

5.2.3.1. OVERVIEW

The bridges along US 287 spanning Elk Creek and Elk Creek Overflow are often a problem during large flood events as described in the 2020 *Post-Flooding Hydrologic Assessment of Elk, Ford, and Smith Creeks*, observed in existing conditions model results, and expressed in comments from residents of Augusta. The bridges are a contributor to backwater during flood events because of the topography and relatively small opening size of the structures themselves. Photographs of flooding during the 2018 event showed floodwaters on US 287 up to the bridge deck elevations and overtopping in some locations. Two scenarios were assessed in this alternative to increase efficiency of the two bridges: widening the channel under the existing bridges and replacing the existing bridges with larger span bridges. The first scenario includes excavating the channel to remove aggradation and widening it to increase the existing bridge opening size. The second scenario includes the replacement of the existing bridges and creation of benches matching the elevation of the surrounding floodplain on either side of the active channel. The two scenarios for the US 287 bridge spanning Elk Creek are shown in Figure 18.

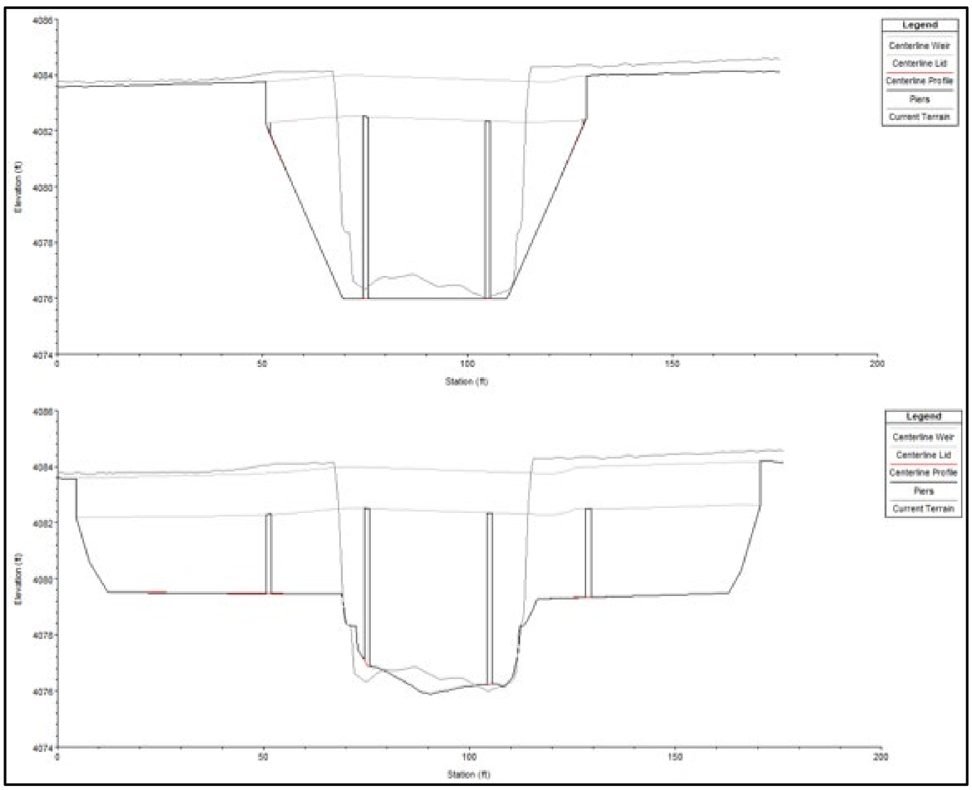


Figure 18. The modeled cross section alignments of the two US 287 Elk Creek bridge opening increases: excavation and widening of channel (top), and replacement with addition of floodplain benches (bottom).

5.2.3.2. US 287 EXISTING BRIDGE CHANNELWIDENING RESULTS

The flooding extents did not change in comparison to the 2018 existing conditions model. Small depth decreases were observed just upstream and downstream of the bridges as a result of some reduction in backwater. Figure 19 illustrates the flood areas removed and added to the floodplain because of widening the existing channel around the US 287 bridges. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the US 287 Existing Bridge Channel Widening results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

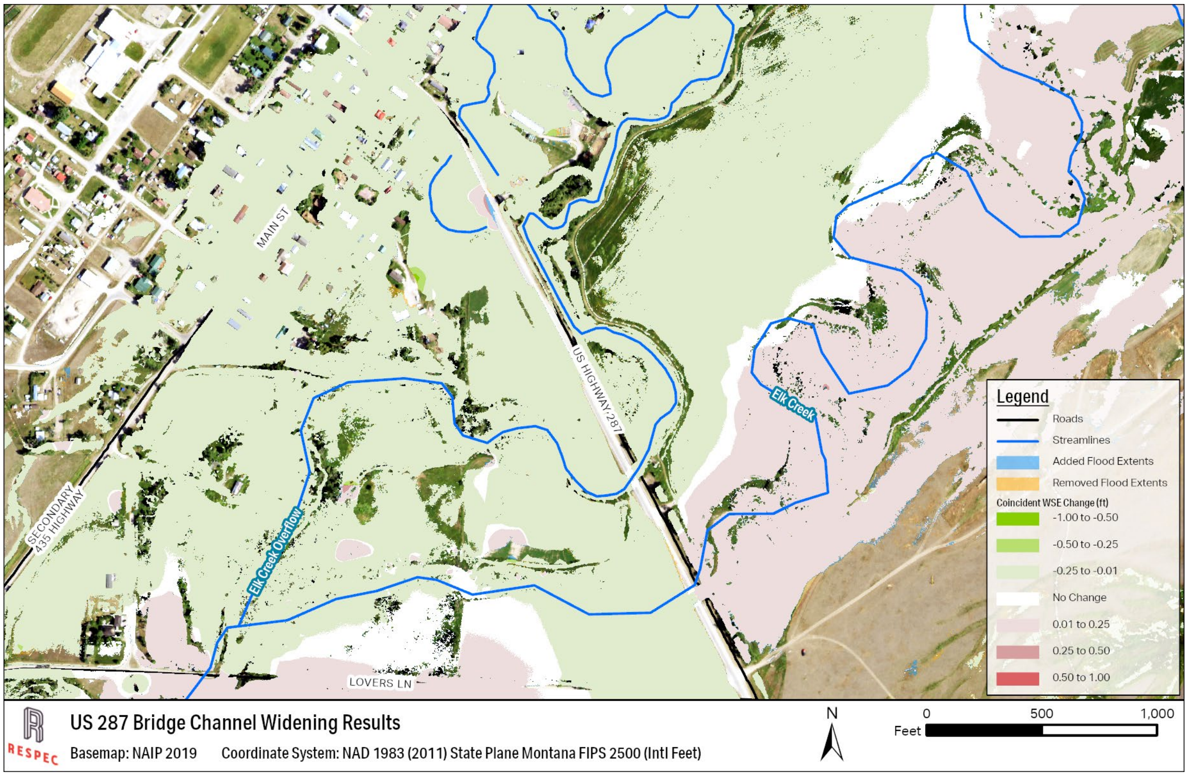


Figure 19. HEC-RAS output WSEL comparison between the US 287 bridge channel excavation alternative and the 2018 existing conditions.

Small flow reductions occurred along the Elk Creek Overflow, small flow increases at Elk Creek, and no flow change at Hogan Slough because of increasing bridge capacities. Table 6 summarizes the depth and flow changes along the evaluation lines.

Table 6. Depth and flow comparison between the US 287 bridge channel widening alternative and the 2018 existing conditions.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	287 Channel Widening
Elk Creek Overflow	2,443	2,361
Elk Creek	2,823	2,905
Hogan Slough	1,326	1,323

5.2.3.3. US 287 BRIDGE REPLACEMENT RESULTS

The flooding extents did not change in comparison to the 2018 existing conditions model. Small depth decreases were observed just upstream and downstream of the bridges. Figure 20 shows the same but for the US 287 Bridge Replacement scenario. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

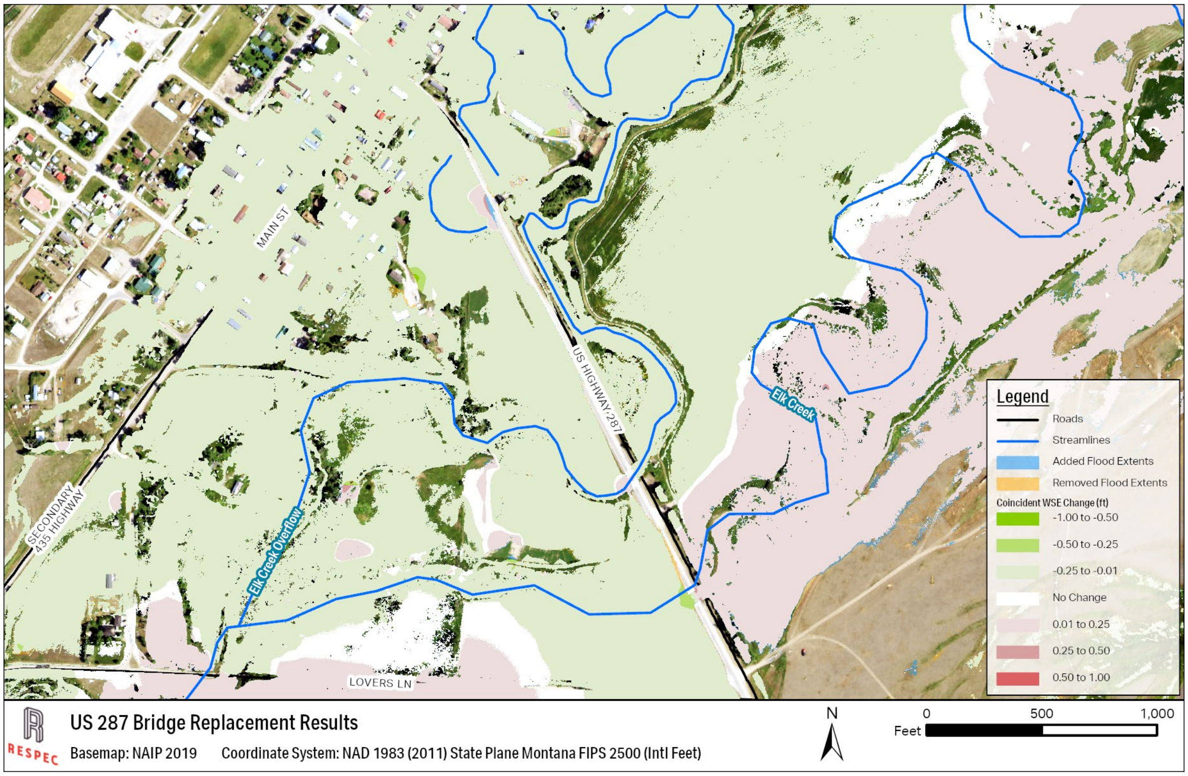


Figure 20. HEC-RAS output WSEL comparison between the US 287 bridge replacement alternative and the 2018 existing conditions.

Small flow reductions occurred along the Elk Creek Overflow, small flow increases at Elk Creek, and no flow change at Hogan Slough. Table 7 summarizes the depth and flow changes along the evaluation lines.

Table 7. Depth and flow comparison between the US 287 bridge replacement alternative and the 2018 existing conditions.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	287 Bridge Replacement
Elk Creek Overflow	2,443	2,350
Elk Creek	2,823	2,919
Hogan Slough	1,326	1,322

5.2.4. US 287 RE-ALIGNMENT

5.2.4.1. OVERVIEW

In combination with removing US 287 closer to Main Street, the re-alignment of US 287 starting after its crossing over Hogan Slough was evaluated to reduce the skew of the highway to the floodplain and decrease backwater near town. Modeling of this scenario utilized the same terrain used in the US 287 Removal alternative with the addition of a road embankment created using terrain modification tools. The new 287 alignment was created to the same dimensions as the existing road and included the addition of two bridges to span the Elk Creek channel at its crossings. Figure 21 shows the modeled US 287 re-alignment alternative.

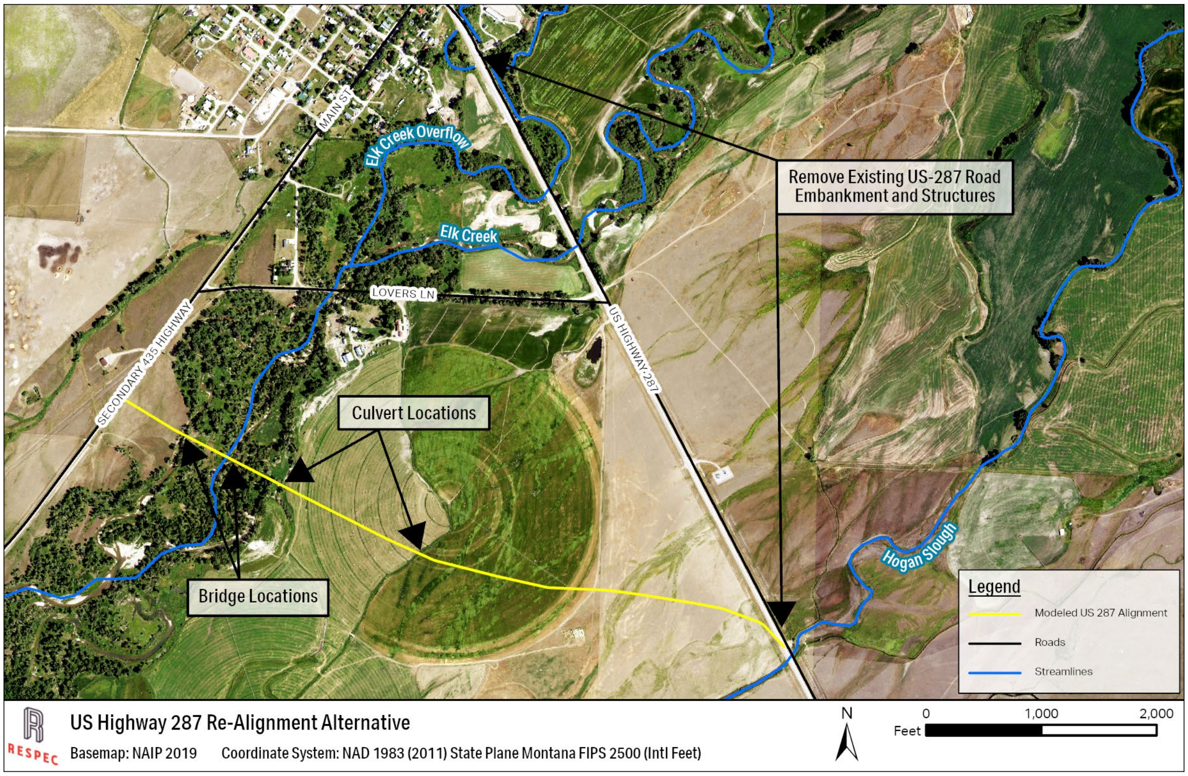


Figure 21. The modeled US Highway 287 re-alignment alternative with approximate bridge and culvert locations.

5.2.4.2. RESULTS

Similar to the results of the US 287 removal, large depth decreases were observed just upstream of the existing US 287 road embankment. Depth decreases were observed between the new alignment and the existing US 287, through the Elk Creek Overflow, and through the town center. Increases in depth were created upstream of the new alignment due to backwater caused by the road embankment. Hogan Slough also saw an increase in depths due to the increase flow towards that area. Figure 22 illustrates the flood areas removed and added to the floodplain because of re-aligning US 287. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the US 287 Re-Alignment results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

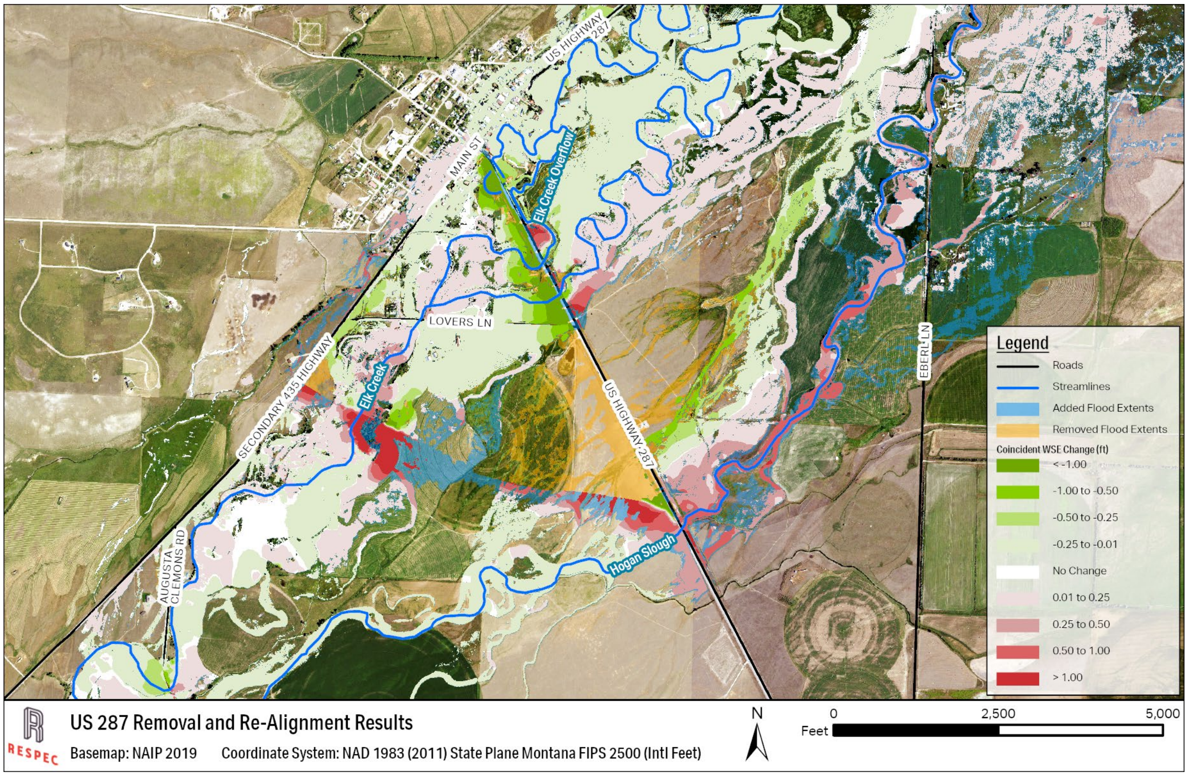


Figure 22. HEC-RAS output WSEL comparison between the US 287 re-alignment alternative and the 2018 existing conditions.

Significant flow reductions were observed for the Elk Creek Overflow and its floodplain. Flow increases were observed for Elk Creek and Hogan Slough. Table 8 summarizes the flow increases occurring along the flow evaluation lines.

Table 8. Depth and flow comparison between the US 287 removal and re-alignment alternative and the 2018 existing conditions.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	US 287 Re-Alignment
Elk Creek Overflow	2,443	1,997
Elk Creek	2,823	2,953
Hogan Slough	1,326	1,646

5.2.5. EXISTING IRRIGATION CANAL DIVERSIONS

5.2.5.1. DESCRIPTION

Utilization of existing infrastructure to route excess floodwaters away from Elk Creek for strategic release and infiltration was presented in the hydrologic analysis. Florence Canal was used as a specific example in that report and thought of as one of the larger existing irrigation channels within the Elk Creek floodplain to route water by the residents of Augusta. This canal was used as an example alternative because LIDAR was available to obtain channel information. This alternative was evaluated using an at-section analysis of cross sections cut from the LIDAR to determine channel capacity. A scenario was modeled in HEC-RAS where Florence Canal's flow capacity was removed from the total volume of flow entering Elk Creek at the upstream model limits to determine flow and depth effects in Augusta. Floodwaters would be routed from Elk Creek once reaching a certain stage. Elevated gravel benches along Florence Canal were identified as locations where water could be released and allowed to percolate into the underlying aquifer. Available web soil data was utilized to determine infiltration rates and limitations to infiltration. Figure 23 outlines the evaluated Florence Canal alternative and recommendations made in the hydrological report.

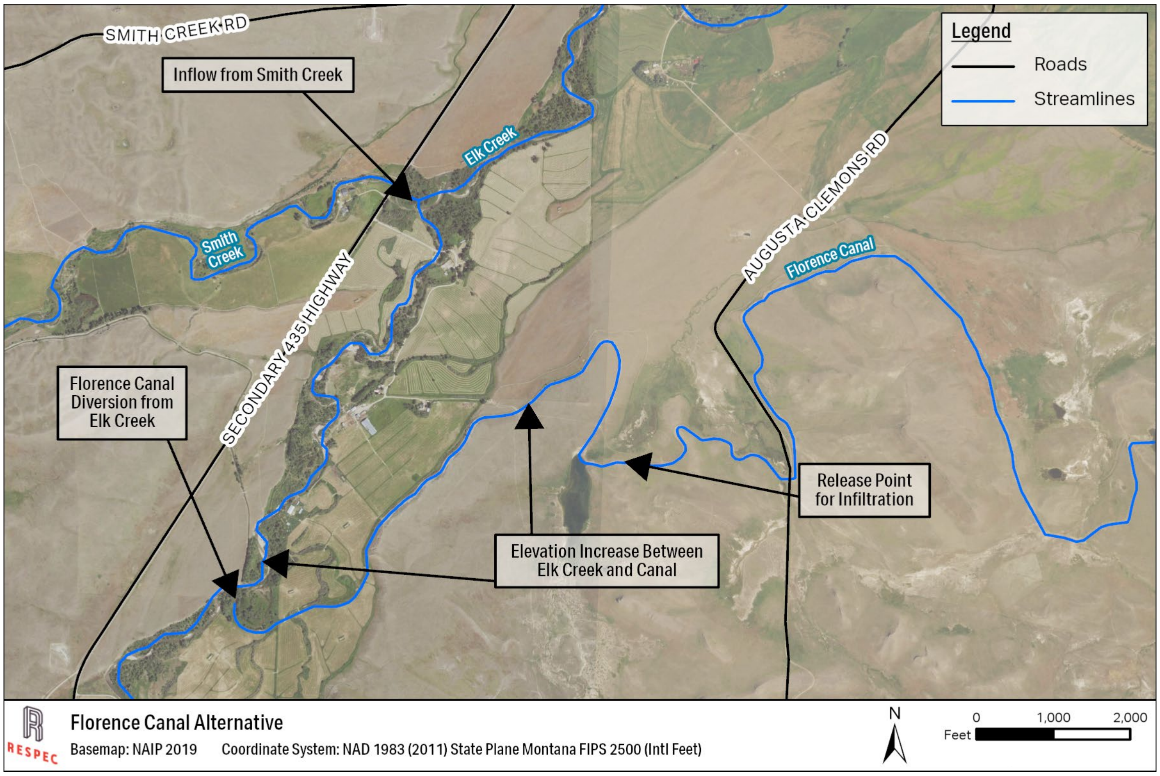


Figure 23. Overview of the evaluated Florence Canal alternative.

Comments from both the public meetings reflected positively and in favor of using existing irrigation canals to divert floodwaters away from the floodplain to decrease the volume of water flowing through Augusta during flood events. Anecdotally, it was also mentioned by long-term residents that diverting floodwaters into these channels was a flood mitigation technique used during past historic floods. Following the second public meeting, five additional irrigation canals were identified as potential flow diversion and infiltration options. These canals lack detailed data to accurately determine their flow capacity. Consequently, capacities were reasonably estimated, and a scenario ran with a reduced flow in Elk Creek. Figure 24 shows the potential flow diversion locations, where additional data is needed for further study and consideration.

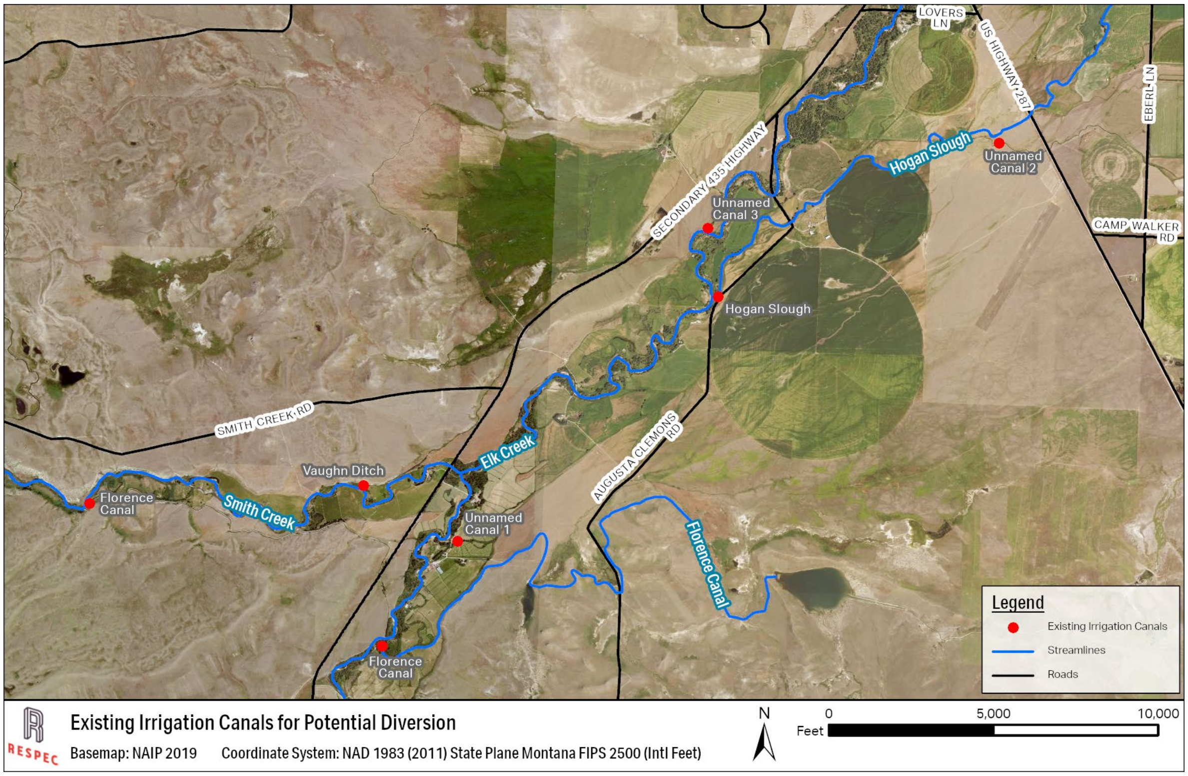


Figure 24, Existing irrigation canals for potential flow diversion from Elk Creek.

5.2.5.2. RESULTS

The channel capacity of Florence Canal was calculated to be a maximum of 500 cfs. When 500 cfs was removed from the 6,580 cfs entering the model at the upstream boundary, the model domain experienced a slight decrease in water surface elevations. On average, the depth decreases for Elk Creek Overflow and its floodplain was 0.05 feet.

Small flow decreases were observed along all the flow evaluation lines. Flow changes between the 2018 existing conditions and Flow Containment Berm Upstream of Augusta Clemons Road are shown in Table 9.

Table 9. Flow comparison between the 2018 existing conditions and the Florence Canal diversion.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Florence Canal Diversion
Elk Creek Overflow	2,443	2,274
Elk Creek	2,823	2,654
Hogan Slough	1,326	1,167

Quick at-section analyses on other feasible canals that divert water away from the floodplain were conducted to determine potential channel capacity. Estimated flow capacities for the other diversion canals shown above are summarized in Table 10. It should be noted that channel capacities are calculated from cross sections pulled from LIDAR data. Within the channels, LIDAR is variable and contains high uncertainty. To obtain capacities with larger certainty, multiple surveyed cross sections are needed along each channel.

Table 10. Summary table of existing irrigation canal estimated capacities from at-section analyses.

Irrigation Canal Name	Assumed Capacity (cfs)
Florence Canal	500
Vaughn Ditch	325
Hogan Slough	1200
Unnamed Canal 1	125
Unnamed Canal 2	125
Unnamed Canal 3	250

Overall, water surface elevations decreased for the entire model domain. Small flood extent changes occurred throughout the entire model domain. Figure 25 illustrates the flood areas removed and added to the floodplain because of the removed irrigation canal flow volumes. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the Existing Irrigation Canal Diversion results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

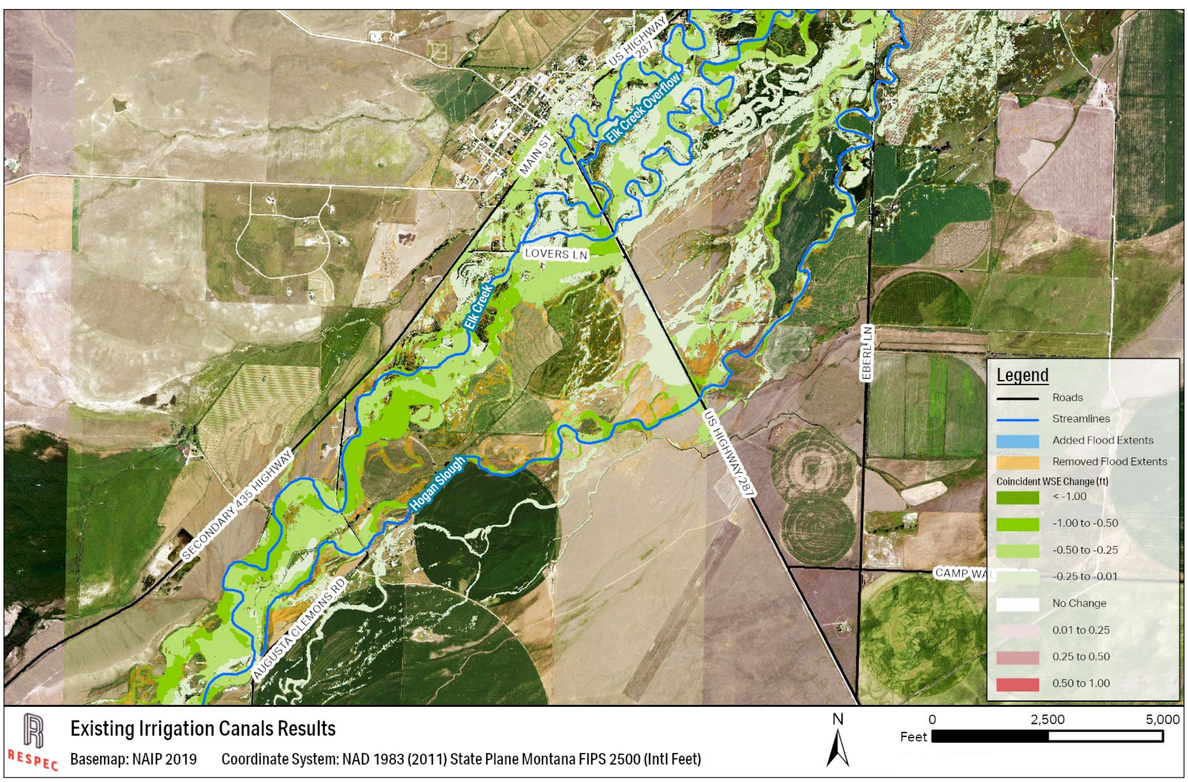


Figure 25. HEC-RAS output WSEL comparison between the existing irrigation canal alternative and the 2018 existing conditions.

Significant flow decreases were observed along all the flow evaluation lines. Flow changes between the 2018 existing conditions and upstream of Augusta Clemons Road berm are shown in Table 11.

Table 11. Flow comparison between the 2018 existing conditions and the Existing Irrigation Canal diversions.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Existing Irrigation Canal Diversions
Elk Creek Overflow	2,443	1,568
Elk Creek	2,823	1,886
Hogan Slough	1,326	640

5.2.6. ELK CREEK OVERFLOW DIVERSION

5.2.6.1. OVERVIEW

In efforts to decrease the amount of water accessing the Elk Creek Overflow channel in its segment through town, a 30 foot wide channel was created to divert water from the Elk Creek Overflow just downstream of its bridge crossing with US 287 back to the main Elk Creek Channel. A plug in the channel was placed just downstream of the channel and tied into the road embankment elevation to keep water from further accessing the channel. This location to divert water was chosen because of the proximity of the two channels, the simple channel alignment needed to divert water at this location, and to avoid modifying existing road infrastructure. Figure 26 shows the diversion channel alignment between the two channels.

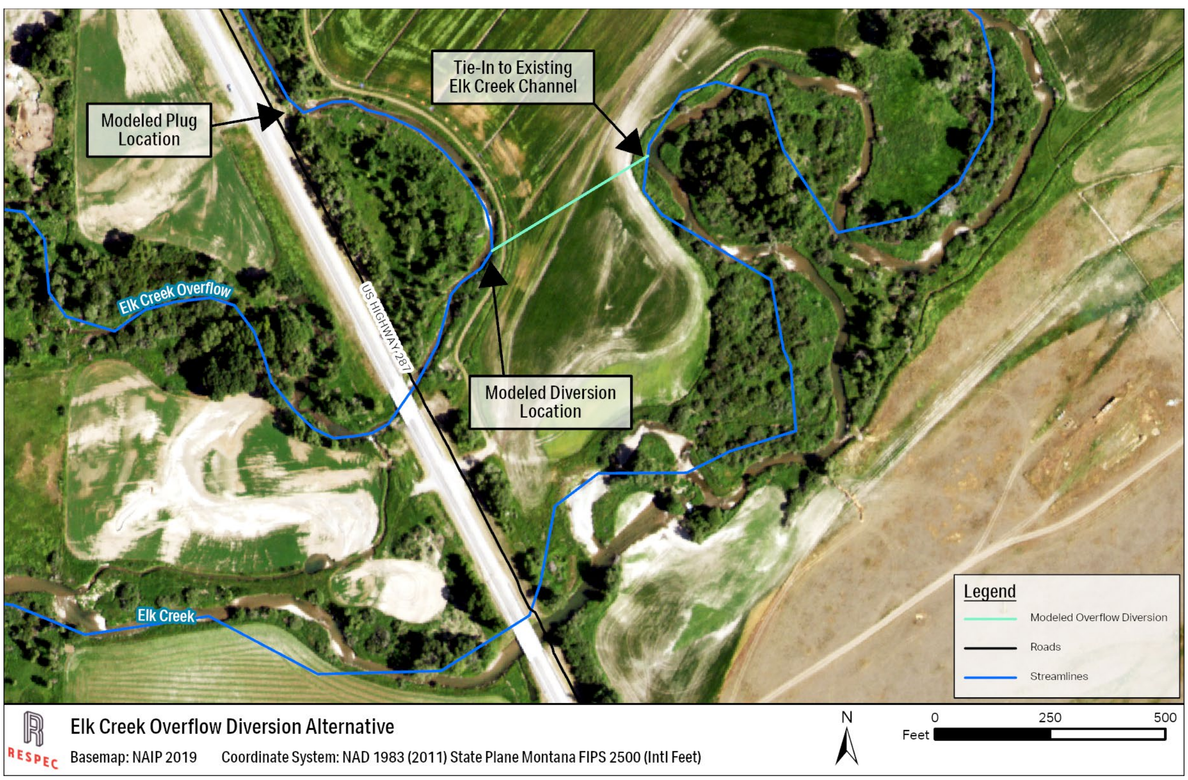


Figure 26. The modeled Elk Creek Overflow diversion alignment.

5.2.6.2. RESULTS

The flooding footprint of the Elk Creek Overflow diversion results experience slight change, if any compared to the 2018 existing conditions model results. Water surface elevation increases were observed behind the US 287 road embankment near the locations of the Elk Creek and Elk Creek Overflow bridges. Larger increases also occurred in the Elk Creek channel downstream of the highway, slightly diminishing in extremity as the model continued downstream. Decreases were observed along the Hogan Slough and Elk Creek Overflow channels downstream of US 287. Figure 27 illustrates the flood areas removed and added to the floodplain because of the addition of the Elk Creek Overflow diversion channel and plug. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the Elk Creek Overflow Diversion results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

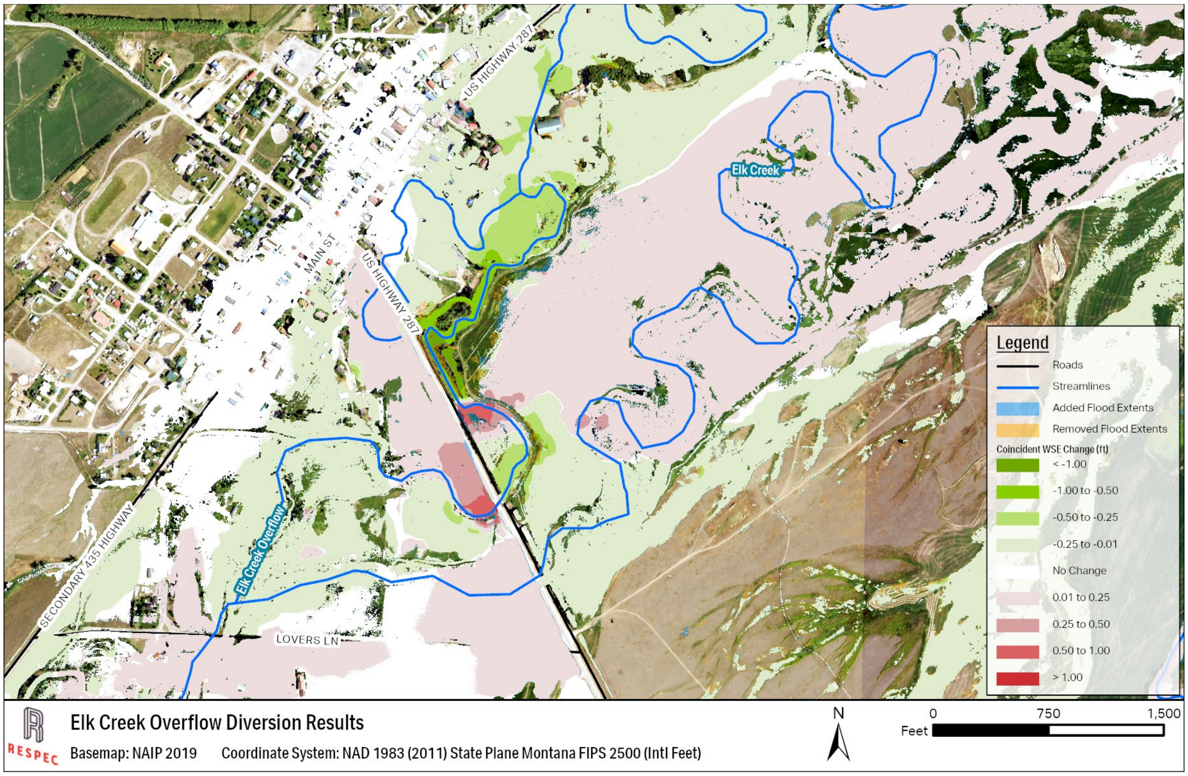


Figure 27. HEC-RAS output WSEL comparison between the Elk Creek Overflow diversion alternative and the 2018 existing conditions.

Flow increases were observed along the Elk Creek line, decreases along the Elk Creek Overflow line, and almost no change along the Hogan Slough line. Flow changes between the 2018 existing conditions and Elk Creek Overflow Diversion alternative are shown in Table 12.

Table 12. Flow comparison between the 2018 existing conditions and the Elk Creek Overflow diversion alternative.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Elk Creek Overflow Diversion
Elk Creek Overflow	2,443	2,064
Elk Creek	2,823	3,207
Hogan Slough	1,326	1,322

5.2.7. HOGAN SLOUGH DIVERSION

5.2.7.1. OVERVIEW

Like the Florence Canal alternative, diversion of water to Hogan Slough just downstream of Augusta Clemons Road would allow for the utilization of existing irrigation infrastructure. Hogan Slough is the third largest channel downstream of the Smith and Elk Creek confluence within the Elk Creek watershed. As mentioned previously, Hogan Slough is a major source of irrigation for the Elk Creek valley and contains several headgate locations along its reach. The Hogan Slough diversion alternative begins just downstream of Augusta Clemons Road and connects Elk Creek to Hogan Slough through a 2,785′ long channel with a 3000 cfs capacity and 60′ top width. Increased flow would be pushed into Hogan Slough once flows in Elk Creek reach a certain stage. As part of this alternative, the existing box culvert at the Hogan Slough crossing of US 287 was upgraded to a 60′ span bridge to handle increased flows through Hogan Slough. Three headgate structures exist just downstream of US 287 on Hogan Slough, splitting the channel into three. If proposed, this alternative would need to be evaluated further to determine irrigation options and channel improvements due to the existing irrigation infrastructure. Figure 28 outlines the modeled Hogan Slough alternative.

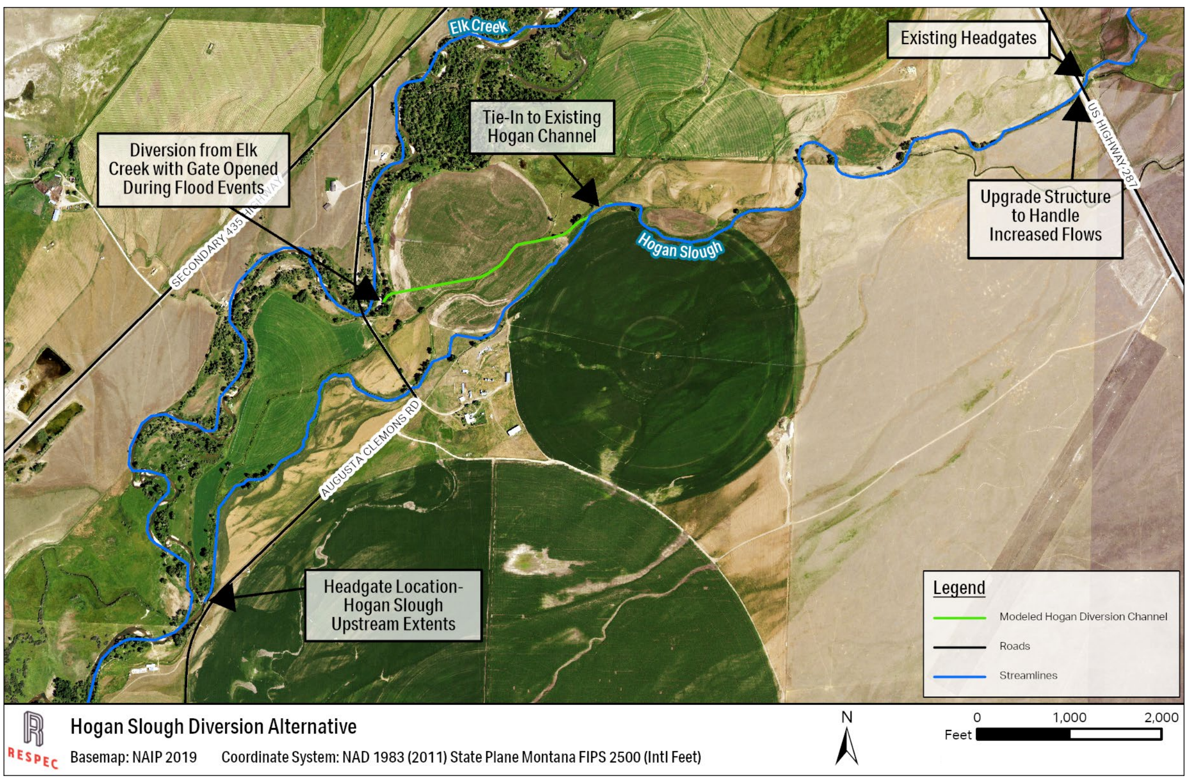


Figure 28. The modeled Hogan Slough diversion alignment and alterations.

5.2.7.2. RESULTS

Flooding extent increases were observed on the floodplains of Hogan Slough and downstream of US 287. Floodplain extents decreased in the Elk Creek floodplain upstream of the Hogan Slough headgates and along the left overbanks where flow was previously spilling out towards the Highway 435 borrow ditches. Large water surface elevation decreases were observed in the Elk Creek and Elk Creek Overflow areas, where increases were seen in Hogan Slough and on its floodplains. The water surface elevation changes from existing conditions are continued until Hogan Slough joins Elk Creek downstream of MT 21. Figure 29 illustrates the flood areas removed and added to the floodplain because of the Hogan Slough diversion, as well as the changes to water surface elevations where coincident flooding occurs between the 2018 existing conditions results and the Hogan Slough Diversion results.

Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

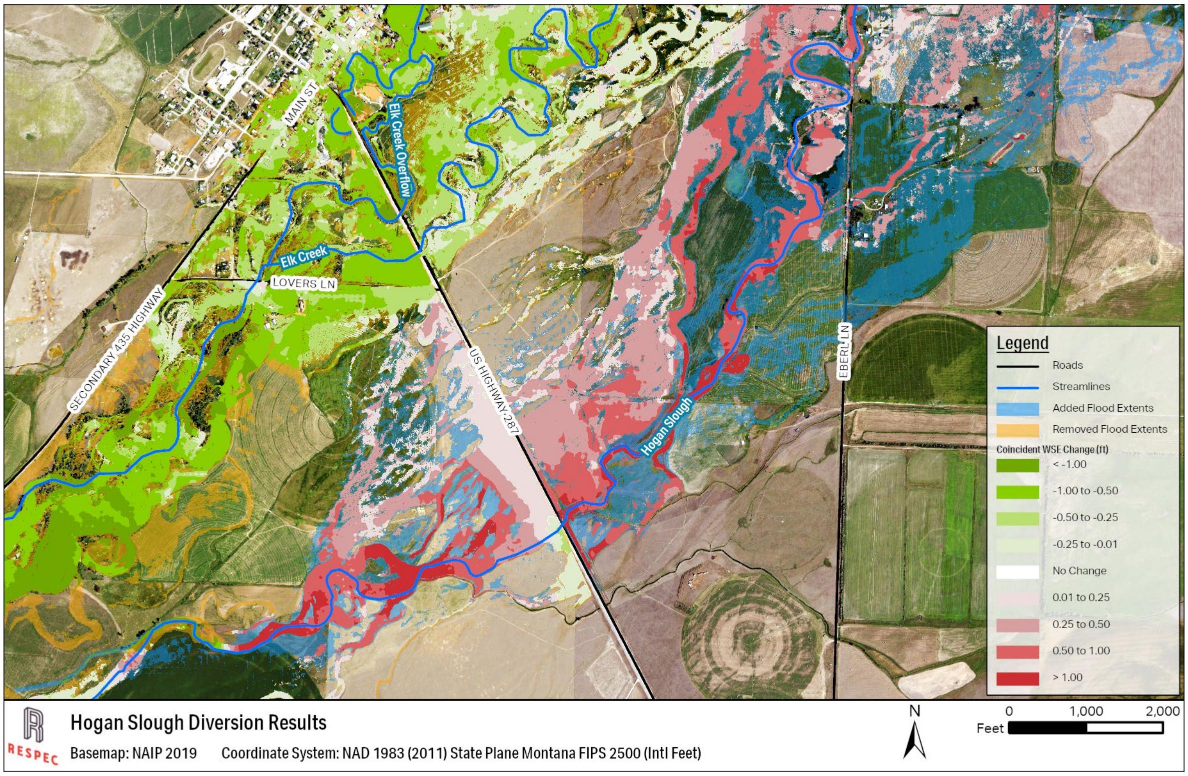


Figure 29. HEC-RAS output WSEL comparison between the Hogan Slough diversion alternative and the 2018 existing conditions.

Large flow increases were observed along the Hogan Slough flow evaluation line, and large decreases occurred along the Elk Creek and Elk Creek Overflow lines. Flow changes between the 2018 existing conditions results and the Hogan Slough diversion results are shown in Table 13.

Table 13. Flow comparison between the 2018 existing conditions and the Hogan Slough diversion alternative.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Hogan Slough Diversion
Elk Creek Overflow	2,443	990
Elk Creek	2,823	1,440
Hogan Slough	1,326	4,180

5.2.8. FLOOD BYPASS CHANNEL

5.2.8.1. OVERVIEW

The creation of a flood bypass channel was considered as an option to funnel floodwaters up to a certain capacity and only leave bankfull flows within the Elk Creek channel. The flood bypass channel would divert waters out of Elk Creek upstream of town and convey floodwaters until the channel joins with Elk Creek downstream of MT 21. The diversion would be designed to only allow floodwaters once the flows in Elk Creek reached a certain stage, in which a gate would be opened allowing floodwaters to access the flood bypass channel. The modeled flood bypass channel begins just downstream of Augusta Clemons Road and would divert floodwaters away from the floodplain until it can join Elk Creek downstream of Augusta. For modeling purposes, the channel was designed as a trapezoidal channel with 3:1 side slopes, a top width of 71 feet, and a capacity of 7,000 cfs. This channel alignment crosses both US 287 and MT 21, requiring bridges sized to span the channel, as well as one put in place to span Eberl Lane's crossing with the channel. The flood bypass channel was modeled as a conceptual alternative to determine the channel size necessary to divert floodwaters away from town and quantify the effects a flood bypass channel would have. Other alternatives such as a farmable flood swale are potential considerations if this alternative is favorable. Figure 30 outlines the modeled flood bypass channel with approximate tie-in locations marked.

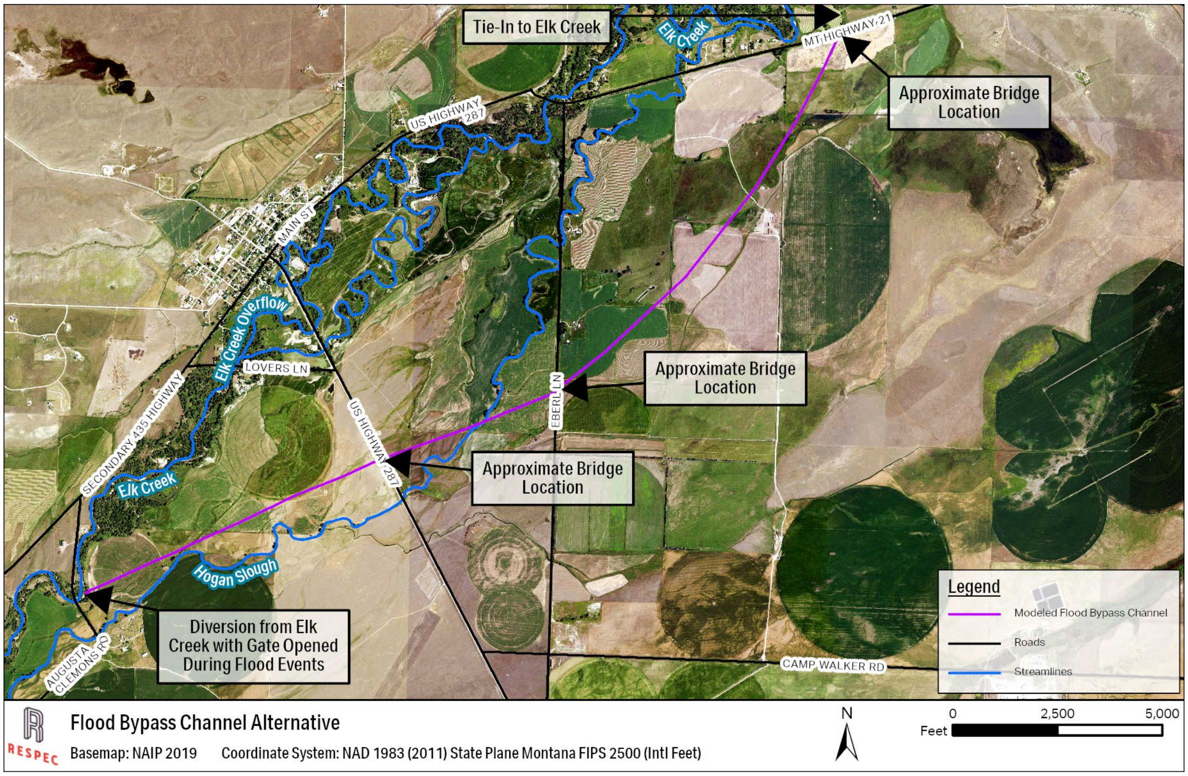


Figure 30. Modeled flood bypass channel alternative.

5.2.8.2. RESULTS

Flooding extents drastically decreased for the flood bypass channel in comparison with the 2018 existing conditions results. A small flood footprint remains outside the channel on the overbanks of Elk Creek and Hogan Slough. Similar to the flooding extents, water surface elevations also dramatically decreased for the entire model domain, except for in the flood bypass channel itself. Figure 31 illustrates the flood areas removed and added to the floodplain because of the Flood Bypass Channel. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

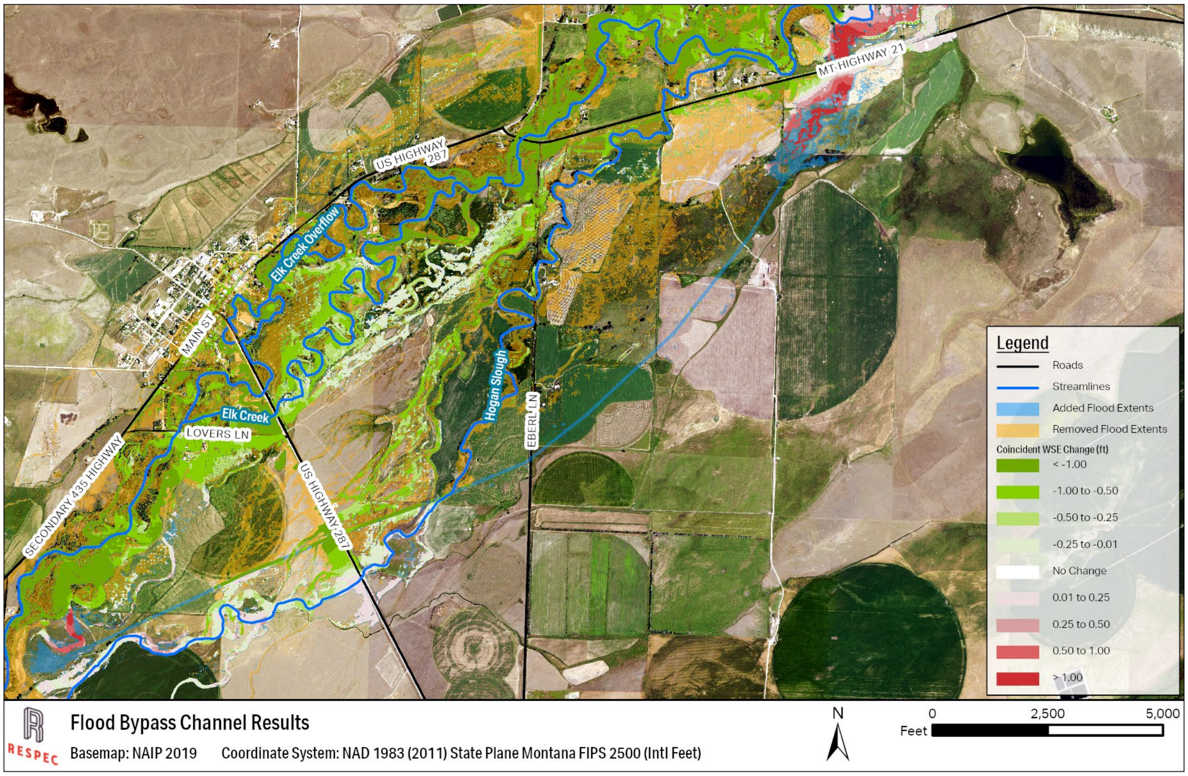


Figure 31. HEC-RAS output WSEL comparison between the flood bypass channel alternative and the 2018 existing conditions.

Large flow increases occurred along the Hogan Slough flow evaluation line, mainly within the flood bypass channel itself. The flow along the Elk Creek Overflow line was reduced to less than 300 cfs, and the flow along the Elk Creek line was reduced to less than 1,000 cfs. Flow changes between the 2018 existing conditions and flood bypass channel models are shown in Table 14. In addition to flow changes, high velocities of approximately 12 feet per second occurred within the flood bypass channel.

Table 14. Flow comparison between the 2018 existing conditions and the flood bypass channel alternative.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Flood Bypass Channel
Elk Creek Overflow	2,443	292
Elk Creek	2,823	944
Hogan Slough	1,326	5,360

5.2.9. FLOW CONTAINMENT BERM UPSTREAM OF AUGUSTA CLEMONS ROAD

5.2.9.1. OVERVIEW

Aerial imagery and residents of Augusta reported floodwaters accessing the borrow ditches along both side of Highway 435 west of Augusta and routing water toward down. The hydrologic analysis pointed out a specific location just upstream of the Augusta Clemons bridge over Elk Creek where floodwaters are overtopping a headgate and accessing the borrow ditches alongside Highway 435. 2018 existing conditions model results showed floodwaters are spilling out over the mentioned headgate and the channel just downstream of the headgate and flowing into the borrow ditches. A flood mitigation alternative was formed with the creation of a 680′ berm to redirect floodwaters back to the Elk Creek channel, and to prevent water from overtopping the channel banks and accessing the borrow ditch. The modeled berm extended 3′ on average above the existing ground profile. This alternative also includes the reconstruction of the upstream headgate to increase the overtopping elevation and adding a gate to the berm for irrigation purposes when flood events are not occurring. Figure 32 outlines the modeled alternative and headgate locations.

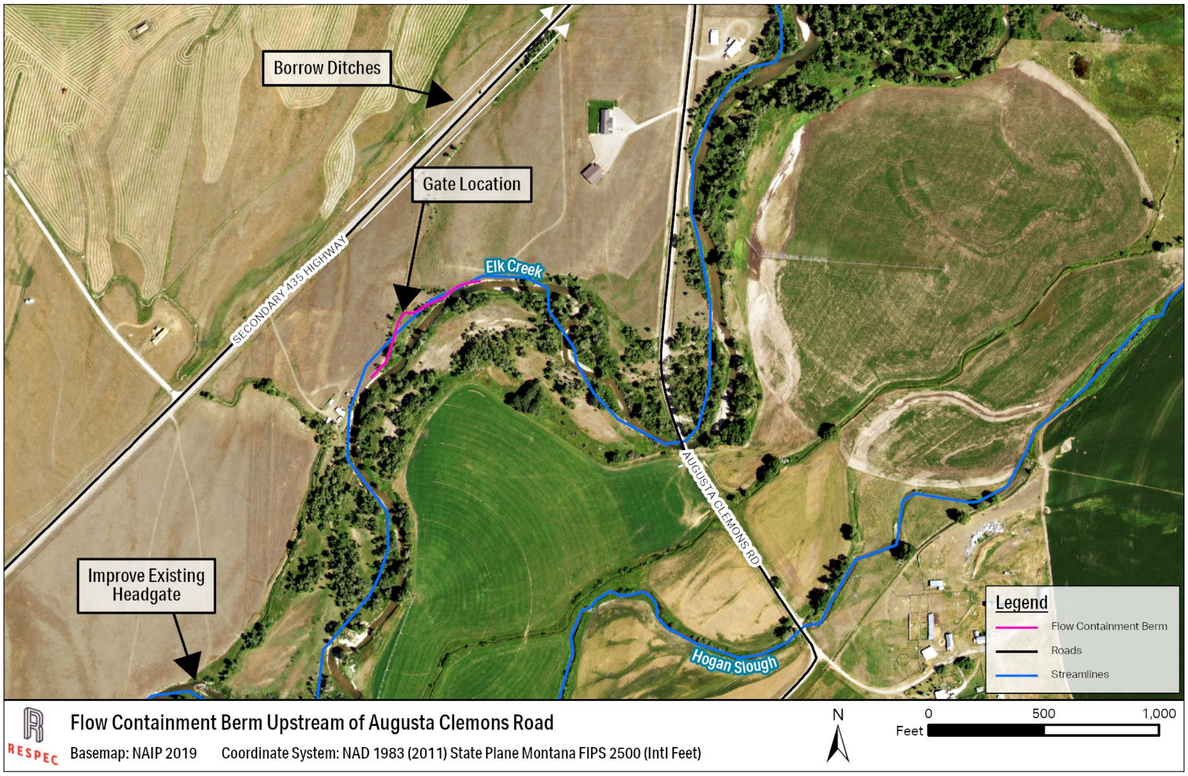


Figure 32. The modeled Elk Creek berm implementation upstream of Augusta Clemons Road.

5.2.9.2. RESULTS

Downstream of the modeled berm, floodwaters surface elevations increased slightly because water was not allowed to spill out of the channel. Flood extents downstream of the berm did not experience any significant changes, however floodwaters were eliminated from the left overbanks where the berm was placed. Figure 33 illustrates the flood areas removed from the floodplain with the berm implementation and the changes in the coincident water surface elevations within the immediate alternative location. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

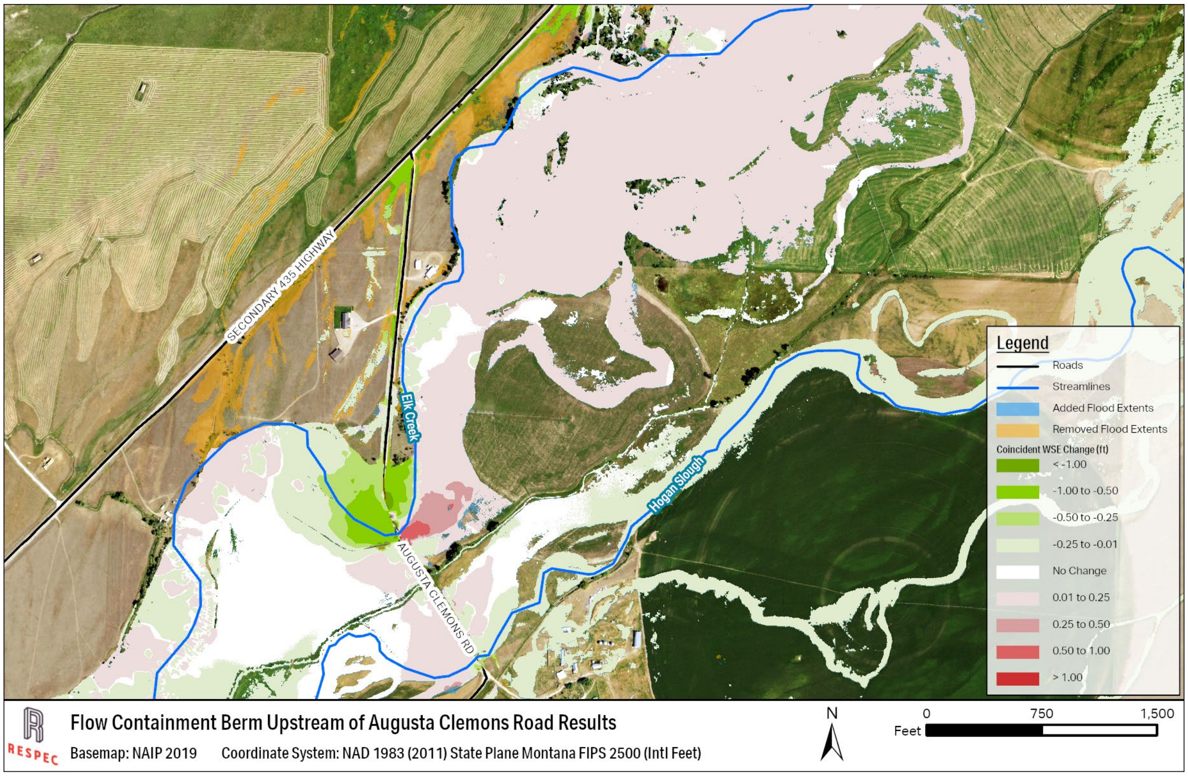


Figure 33. HEC-RAS output WSEL comparison between the flow containment berm alternative and the 2018 existing conditions.

Small flow increases were observed along the Elk Creek Overflow line and reductions along the Elk Creek and Hogan Slough lines. Flow changes between the 2018 existing conditions and upstream of Augusta Clemons Road berm are shown in Table 15.

Table 15. Flow comparison between the 2018 existing conditions and Elk Creek berm upstream of Augusta Clemons Road results.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Berm Upstream of Augusta Clemons Road
Elk Creek Overflow	2,443	2,509
Elk Creek	2,823	2,766
Hogan Slough	1,326	1,324

5.2.10. FLOW REDIRECTION BERM

5.2.10.1. OVERVIEW

Floodwaters impact the greatest number of residents who live within the Augusta core area, or along Main Street and the Elk Creek Overflow downstream of US 287. A flow redirection berm was imposed to evaluate if floodwaters could be either eliminated or greatly reduced through the area where it impacts the greatest amount of people and infrastructure. The berm was connected to the existing highway elevations of Highway 435 and US 287 and drawn along the natural high ground within the terrain between the two highways. The berm height is variable, but on average is approximately 5′ high, and has sloping sides that tie into existing ground. The berm was designed to withstand the simulated 2018 flood event, approximately 25-year event, but will need to be adjusted and re-modeled if another design event is chosen. If favorable, careful design will need to occur to ensure the berm can hold up against the design flood event. As expressed in the second public meeting, public concern is had over what would happen when the berm is overtopped. Figure 34 shows the modeled flow redirection berm.

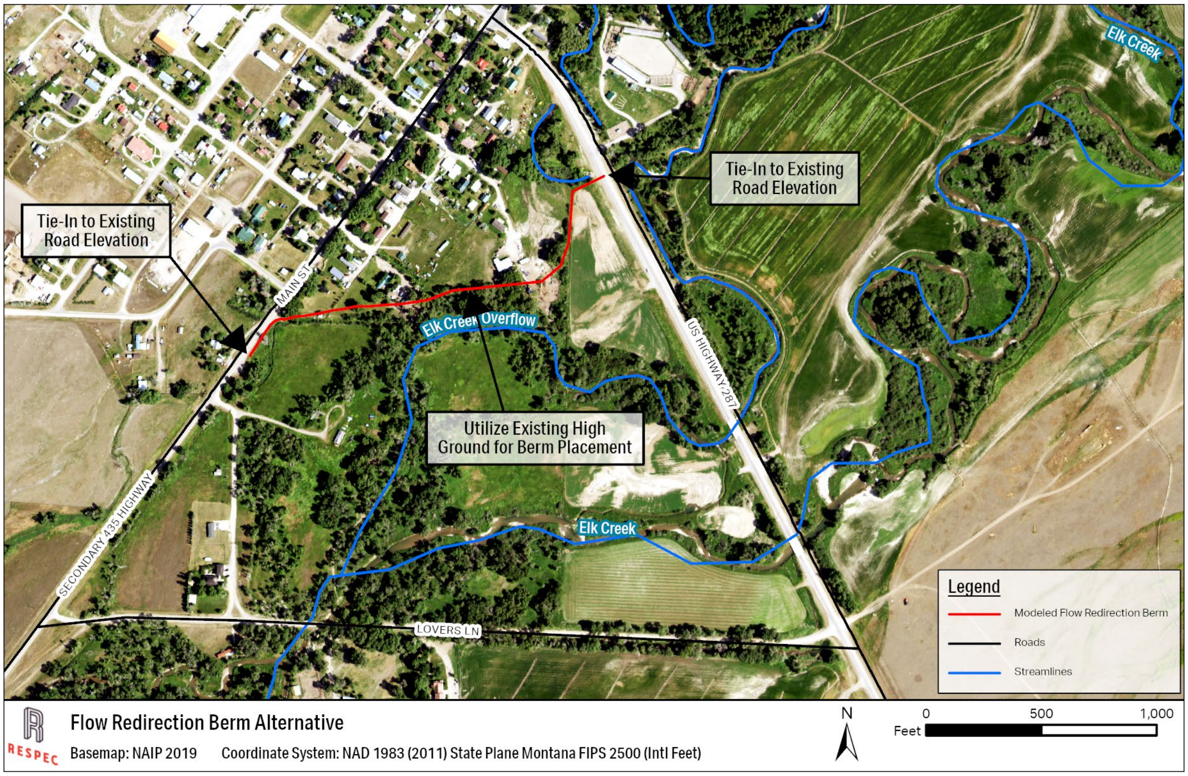


Figure 34. Modeled flow redirection berm alternative.

5.2.10.2. RESULTS

The floodplain footprint decreased behind the flow redirection berm, and along the left overbanks of the Elk Creek Overflow downstream of US 287. The floodplain extents stayed the same through the rest of the model domain. Water surface elevation decreases occurred behind the modeled berm and remained decreased by approximately 0.25 to 0.5′ through the rest of the Elk Creek Overflow channel, larger water surface elevations increases were observed along and upstream of the berm for approximate 450′ upstream. Further upstream than the 450′ experienced slight increases in locations, but generally did not change. Figure 35 illustrates the flood areas removed and added to the floodplain because of the Flow Redirection Berm. Also shown are the changes in water surface elevations where coincident flooding occurs between the 2018 existing conditions and flow redirection berm results. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

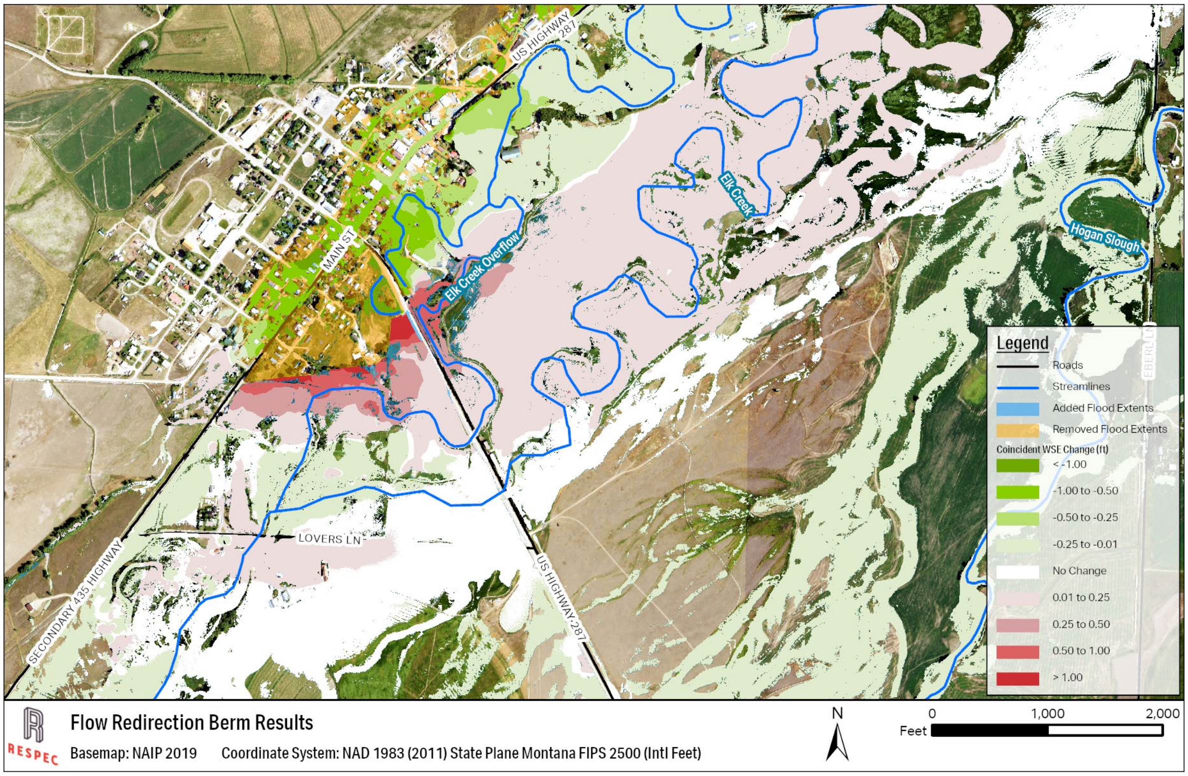


Figure 35. HEC-RAS output WSEL comparison between the flow redirection berm alternative and the 2018 existing conditions.

Small flow reductions were seen along the Elk Creek Overflow flow evaluation line, mainly within the channel itself and its left overbanks. Flow increases were observed along the Elk Creek line, but the Hogan Slough flows remained the same. Flow changes between the 2018 existing conditions and flow redirection berm results are shown in Table 16.

Table 16. Flow comparison between the 2018 existing conditions and the flow redirection berm alternative.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Flow Redirection Berm
Elk Creek Overflow	2,443	2,200
Elk Creek	2,823	3,075
Hogan Slough	1,326	1,325

5.2.11. FLOW REDIRECTION BERM WITH EXTENSION

5.2.11.1. OVERVIEW

The previously presented flow redirection berm was extended to follow the right overbanks of the Elk Creek Overflow channel for approximately 7,000' downstream of US 287. The extension berm maintained the same characteristics of the flow redirection berm, tying in on the upstream side with the elevation of US 287 and with the Elk Creek Overflow top of bank at the downstream extents. Figure 36 shows the modeled flow redirection berm with extension alternative.

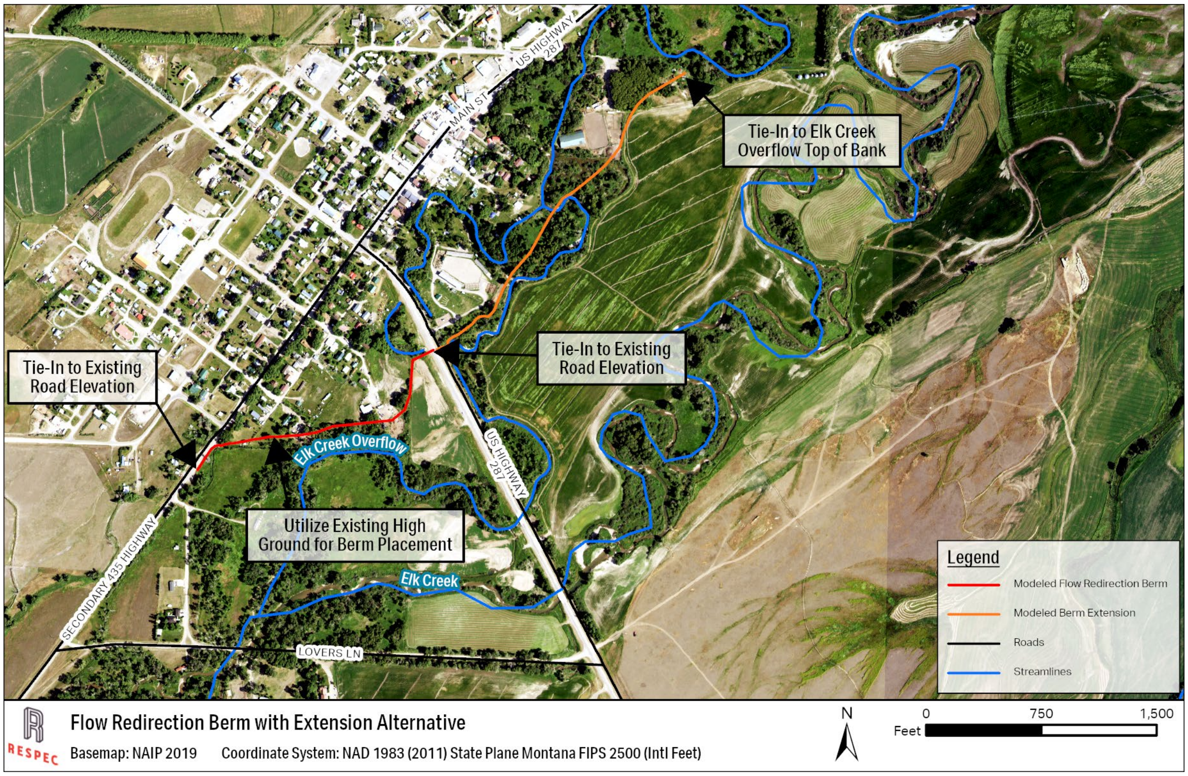


Figure 36. Modeled flow redirection berm with extension alternative.

5.2.11.2. RESULTS

Large floodplain extent removal occurred behind the flow redirection berm with the extension, also within the Elk Creek Overflow channel and its overbanks downstream of US 287 until in joins back up with the Elk Creek just upstream of MT 21. Floodplain extents elsewhere in the model domain remained the same. Water surface elevations largely decreased behind the berm and extension and remained significantly decreased until joining Elk Creek. Significant increases in water surface elevations were observed behind the berm for up to 500′. Figure 37 illustrates the flood areas removed and added to the floodplain because of the Flow Redirection Berm with Extension alternative, as well as the difference in water surface elevations where coincident flooding occurs. Decreases in water surface elevations are shown in green, and increases are shown in red. White or slightly tinted colors represent very small changes in WSEL.

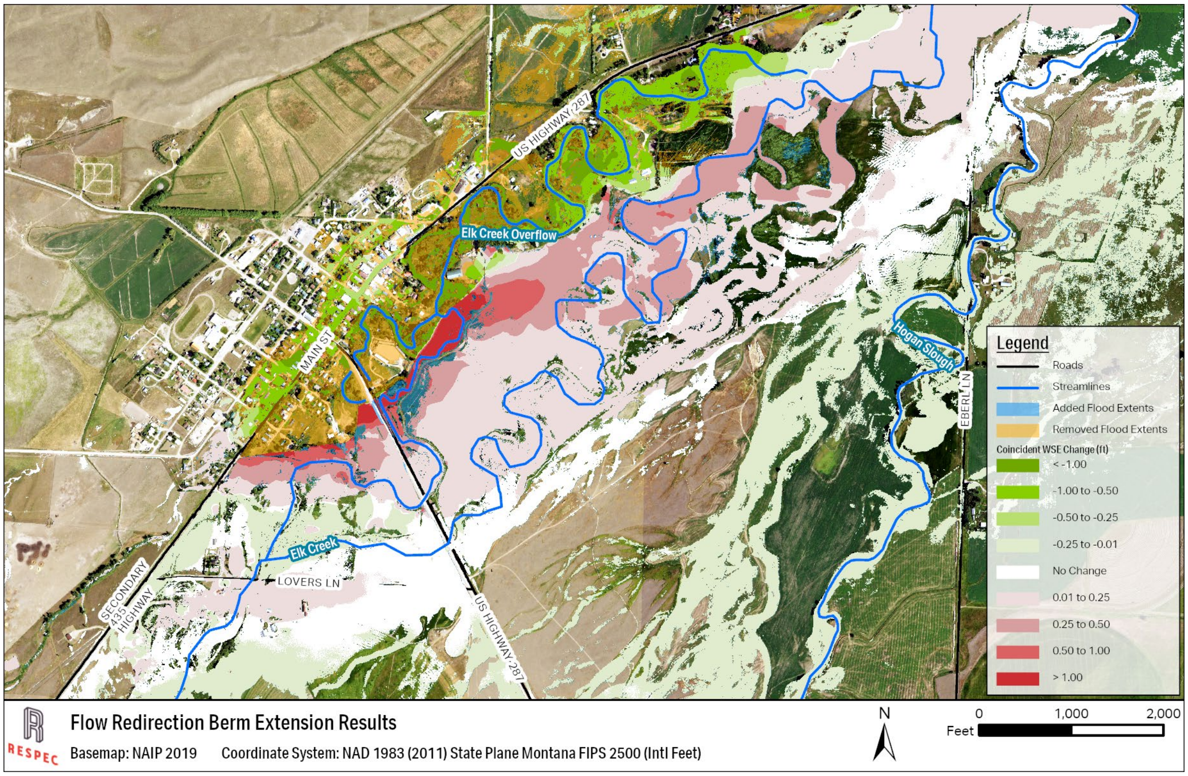


Figure 37. HEC-RAS output WSEL comparison between the flow redirection berm extension alternative and the 2018 existing conditions.

Similar to the flow redirection berm alternative, small flow reductions were seen along the Elk Creek Overflow flow evaluation line, mainly within the channel itself and its left overbanks, as well as behind the extended berm. Flow increases were observed along the Elk Creek line, but the Hogan Slough flows remained the same. Flow changes between the 2018 existing conditions and flow redirection berm results are shown in Table 17.

Table 17. Flow comparison between the 2018 existing conditions and the flow redirection berm with extension alternative.

Flow Evaluation Line	Flow Results (cfs)	
	2018 Existing Conditions	Flow Redirection Berm with Extension
Elk Creek Overflow	2,443	2,142
Elk Creek	2,823	3,131
Hogan Slough	1,326	1,326

6.0 DISCUSSION AND COST COMPARISON

6.1. DISCUSSION AND COST ESTIMATES

In general, the Augusta area of the Elk Creek valley experiences flooding in shallow, expansive footprints because of the wide, floodplain and network of channels throughout the floodplain. The town of Augusta, specifically Main Street and the commercial and residential structures in its vicinity experience flooding because of their similar elevation to the surrounding floodplain. Several factors, such as the existing transportation infrastructure, exacerbate flooding in Augusta due to their embankments, skews to the floodplain, borrow ditches delivering water, and relatively small conveyance structures. Eleven alternatives were evaluated, ranging from small scale and low-cost options to large scale, expensive options. Provided in the following sections are discussions of the presented results and conceptual level cost estimates for each alternative. Approximate quantities and costs for each alternative are included in Appendix C. Costs estimates were guided using MDT average pricing catalogs (Reference 13) and cost estimation procedure guidelines published by MDT (Reference 14) and the National Cooperative Highway Research Program (Reference 15). All alternatives, if chosen to construct, will require detailed design and permitting, and refined cost estimates that will differ from those presented here.

6.1.1. CHANNEL AND FLOODPLAIN DEBRIS REMOVAL

6.1.1.1. DISCUSSION

Results showed small decreases in depths throughout the model domain; however, it is more likely that debris deposition occurs on smaller scales, and should be assessed on a targeted, localized scale in the field. Removal of large debris accumulations will reduce the potential for localized backwater effects, large-scale channel change, and long-lasting effects of debris deposition on fields within the floodplain. Monitoring for debris accumulation prior to spring runoff helps to maintain the stream for flood events in the future, as well as to assess locations within Elk Creek that may experience change in the case of a flood event. The community may choose to formulate a work group to annually identify localized areas for removal. This effort could be done in conjunction with Montana Fish Wildlife, and Parks and the Lewis and Clark Conservation District to streamline those required permits.

6.1.1.2. CONCEPTUAL COST ESTIMATE

Debris removal of Elk Creek and the Elk Creek Overflow could primarily be completed with volunteers, residents, and LCC staff, therefore the overall cost is relatively low. Future monitoring will need to be continued after runoff occurs, especially in years where flood events occur. The cost of removing debris through these channels is estimated to be $25,000 This cost includes permitting costs, contractor costs for large debris removal with equipment, and haul-off costs. It is anticipated this would be the initial cost to remove accumulated debris over many years and that subsequent annual removal costs would be less.

6.1.2. US 287 REMOVAL

6.1.2.1. DISCUSSION

The removal of US 287 decreased the backwater effects caused by the existing road embankment and undersized structures. Instead of backwatering behind the road embankment and flowing towards Augusta and the Elk Creek Overflow, more water stayed within the Elk Creek channel and its floodplain. However, because Augusta itself is of similar elevation to the Elk Creek floodplain, the highway removal did not prevent water from accessing town. The removal of US 287 would be an expensive alternative, with potential to affect the tourism through Augusta the town relies upon. At the public meetings residents had comments, both in favor of removing US 287 to eliminate the backwater effects those residents are experiencing and in opposition because US 287 is the major route to Augusta, and if removed there is concern that tourism traffic will not travel through the downtown area. This alternative was mainly considered to obtain a baseline understanding of US 287 effect on flooding conditions. It was also considered along with the new US 287 alignment alternative.

6.1.2.2. CONCEPTUAL COST ESTIMATE

The removal of US 287 from Camp Walker Road to the access road for the rodeo grounds is estimated to cost $1,370,00. The largest incurred cost of this alternative is hauling off the removed road embankment and structures. The cost estimate includes construction costs and all logistical costs associated with design, permitting, and construction.

6.1.3. US 287 BRIDGE ALTERNATIVES

6.1.3.1. DISCUSSION

Documentation from the recent floods in 2018 and 2019, both from photos and residents' comments, show the existing bridges on US 287 and MT 21 with flooding depths up to the low chords and the roadways overtopping on either side of the bridges. Even though the US 287 bridges were recently replaced, simulated 2018 existing condition model results, photographs, and landowner comments show the replacement bridge spans were insufficiently sized for the flood events that occur in Augusta. Results from both bridge alternatives helped to decrease the backwater water surface elevations within the immediate area, but only by up to 0.25 feet. Results also showed that the alternative to replace the existing bridges provided a negligible benefit over the alternative to widen the channels on the existing bridges.

6.1.3.2. CONCEPTUAL COST ESTIMATE

Widening the existing channels of both the Elk Creek and Elk Creek Overflow bridge sites on US 287 is estimated to cost $151,000. Replacing the existing bridges for bridges with larger spans to cover floodplain-elevation benches is estimated $5,710,000. Costs are heavily influenced by material procurement and further bridge design. Both cost estimates include construction costs and all logistical costs associated with design, permitting, and construction.

6.1.4. US 287 REMOVAL AND RE-ALIGNMENT

6.1.4.1. DISCUSSION

While significant decreases in flow occurred through town and the Elk Creek Overflow, as well as large water surface elevation decreases because of the removal of the existing US 287, backwater effects were moved upstream to behind the new alignment. This alternative relies heavily on property procurement, as flood mitigation is not possible without right of way acquisition for the new road alignment through private properties. The benefits gained by creating a new road alignment for US 287 are small when compared to the overall estimated cost.

6.1.4.2. CONCEPTUAL COST ESTIMATE

Removing the existing US 287 up to the proposed alignment and creating a new road embankment upstream perpendicular to the floodplain and where the floodplain is narrower is estimated to cost approximately $8,300,000. Costs are heavily influenced by material procurement and further bridge design. The cost estimate includes construction costs and all logistical costs associated with design, permitting, and construction.

6.1.5. EXISTING IRRIGATION CANAL DIVERSIONS

6.1.5.1. DISCUSSION

Although results from studying one specific existing irrigation canal did not show meaningful change, there is potential in further studying the effects of using the remaining existing irrigation canals mentioned previously. If all identified canals are viable options, approximately 2,500 cfs could be diverted from Elk Creek and conveyed elsewhere or allowed to infiltrate into the ground. When 2,500 cfs is removed from the model simulation, the mitigation benefits are substantial and widespread. Further investigation must be completed to determine capacities of these channels, as well as to determine the existing flood conditions for each of the canals. More topographic data, detailed soils data, channel condition investigations, and cross-sectional surveys will need to be completed to perform a more detailed analysis of these irrigation channels. Channels would have to be individually investigated with relation to the floodplain to determine flow capacities and potential release of water for ground infiltration. Furthermore, a stakeholder group including ditch landowners, water right holders/users, and irrigation districts should be developed to provide consent and contribute to the planning. An Elk Creek surface water management plan should be developed with the stakeholder group. The plan would address management strategies under various flow conditions, identify roles and responsibilities, and overall serve as a guiding document for this mitigation option before, during, and after the flood event. This alternative has high potential as a low cost option with notable flood reduction to benefit many residents of the Augusta area.

6.1.5.2. CONCEPTUAL COST ESTIMATE

There are many unknowns associated with this alternative to provide a definitive cost. However, for comparison purposes to other alternatives, the estimated cost to divert floodwaters through the six existing irrigation canals is $238,000. This cost includes enhancing diversions/headgates and crossings to accommodate the maximum channel capacity flows, clearing of diversion channels of debris where flood routing is anticipating, engineering and permitting costs, coordination with landowners, and development of the management plan.

6.1.6. ELK CREEK OVERFLOW DIVERSION CHANNEL

6.1.6.1. DISCUSSION

Flood extents did not substantially change because large amounts of floodwaters were still able to access the Elk Creek Overflow from upstream of US 287. These floodwaters are from backwater formed at the road embankment, water overtopping the road close to town, the Highway 435 borrow ditches routing water towards town, and from the existing culverts crossing US 287 still conveying water downstream of the roadway. Those handful of culverts could be removed; however, water will still reach Main Street and the surrounding residential area. This alternative has potential to be more effective if combined with an alternative targeted at upstream flood mitigation, such as the Flow Redirection Berm. This overflow channel relies on a small amount of property easements and relies largely on earthwork and bank stabilization efforts. In general, when diverting water from one channel to another, bank and channel stabilization is anticipated to be implemented on the channel receiving the diverted water. This alternative has high potential for downstream channel changes such as channel widening, erosion, avulsion, and alignment changes.

6.1.6.2. CONCEPTUAL COST ESTIMATE

Plugging the existing Elk Creek Overflow channel and diverting water back to Elk Creek through an artificial channel is estimated to cost $113,000. The cost estimate includes construction costs and logistical costs associated with design, permitting, and construction.

RESPEC

6.1.7. HOGAN SLOUGH DIVERSION

6.1.7.1. DISCUSSION

When reviewing the modeled flow reductions and water surface elevation reductions for Elk Creek and Elk Creek Overflow, this alternative provides effective flood mitigation for the town of Augusta. However, a large volume of water is diverted to Hogan Slough, and it is likely channel alterations and excavation would need to occur for the extent of Hogan Slough. The existing Hogan Slough channel would need to be evaluated for channel geometry, condition, and bank stability, in addition to evaluation of existing irrigation infrastructure. This alternative also relies heavily on property easements and requires substantial amounts of earthwork. Potential variations of this alternative would be channel design for the entire reach of Hogan Slough, resembling the Flood Bypass Channel alternative, or to divert water back to Elk Creek before Hogan Slough crosses Eberl Lane, to avoid extending improvements the entire length and through MT 21. As noted in the Elk Creek Overflow diversion alternative, because a large amount of water will be routed into Hogan Slough, potential downstream changes such as channel widening, erosion, and alignment changes may occur.

6.1.7.2. CONCEPTUAL COST ESTIMATE

Diverting water from Elk Creek to Hogan Slough downstream of Augusta Clemons Road is estimated to cost $1,540,000. Costs are heavily influenced by material procurement and further bridge design. The cost estimate includes construction costs and all logistical costs associated with design, permitting, and construction. This cost alternative does not include potential scenarios such as the need for channel design for the entire length of Hogan Slough downstream of Augusta Clemons Road.

6.1.8. FLOOD BYPASS CHANNEL

6.1.8.1. DISCUSSION

For the 2018 measured flood event, diverting floodwaters into the flood bypass channel showed the largest reduction in flooding of all other alternatives. Modeled extents still showed some floodwaters accessing the floodplains of Elk Creek and Elk Creek Overflow, most likely due to varying channel morphology and backwater from road embankments. The bypass channel dimensions simulated showed high velocities where vegetation lining would not be feasible. A wider channel would need to be created to reduce velocities and allow vegetation to prevail when the channel is active during a flood event. Where the flood bypass channel ties in downstream to Elk Creek, further analyses are necessary to determine channel stabilization measures needed to accommodate the high flows re-entering Elk Creek. This alternative relies heavily on earthwork and property easements to mitigate flooding in Augusta. Potential variations of this alternative would be the creation of a wide, gradually side sloped swale that would be farmable on years without flood events. Factors such as water velocities, scour, and sediment deposition will need to be considered in final design.

6.1.8.2. CONCEPTUAL COST ESTIMATE

As currently designed, the estimated cost of the flood bypass channel is $7,490,000. Costs are heavily influenced by material procurement and placement of road crossings. The cost estimate includes construction costs and all logistical costs associated with design, permitting, and construction.

6.1.9. FLOW CONTAINMENT BERM UPSTREAM OF AUGUSTA CLEMONS ROAD

6.1.9.1. DISCUSSION

The results of the flow containment berm upstream of Augusta Clemons Road showed potential localized benefits and restriction of floodwaters from accessing the Highway 435 borrow ditches; however, the berm confining floodwaters to the Elk Creek channel caused slight increases to the water surface elevations and flows through Elk Creek Overflow and town. This alternative showed that despite restricting floodwaters access to the borrow ditches of Highway 435, floodwaters will continue to flow towards town due to the elevation and backwater created by US 287 road embankment.

6.1.9.2. CONCEPTUAL COST ESTIMATE

The estimated cost of implementing a berm to contain flows spilling out of Elk Creek above Augusta Clemons Road is $106,000. The cost estimate includes construction costs and logistical costs associated with design, permitting, and construction.

6.1.10. FLOW REDIRECTION BERM

6.1.10.1. DISCUSSION

Implementation of a flow redirection berm between Highway 435 and US 287 provided significant flood reduction for residents between US 287, Highway 435, and the berm itself. Because of the existing Elk Creek Overflow, floodwaters were only slightly decreased for residents downstream of US 287. Increased water surface elevations upstream of the berm do not appear to affect any structures, however elevations are increased because of backwater from the berm and US 287. As with all the alternatives but more important with the effectiveness of a berm, the berm will only be sized to a certain event, the 2018 flood in this analysis. Once overtopped, the berm will not be as effective at reducing flooding.

6.1.10.2. CONCEPTUAL COST ESTIMATE

The total estimated cost for construction of the flow redirection berm is $516,000. Although costs are largely earthwork, the cost estimate is influenced by property easements. The cost estimate includes construction costs and logistical costs associated with design, permitting, and construction.

6.1.11. FLOW REDIRECTION BERM WITH EXTENSION

6.1.11.1. DISCUSSION

The extension of the flow redirection berm downstream of US 287 had similar effects to that of the berm without the extension, but with propagated effects for residents along the length of Main Street until Elk Creek Overflow rejoins Elk Creek just upstream of Main Street. Modeled results show residual flooding along Main Street that is entering through the highway borrow ditches and overtopping of the berm where its upstream end meets Highway 435. The berm placement and resulting water surface elevations upstream and behind the berm do not appear to affect any visible structures. Adjacent fields to the berm extension experience increase floodwaters surface elevations because of the backwater created by the berm. Despite the increased water surface elevations, no flood extent increases were observed. The US 287 bridges remain undersized, however the modeled floodwaters for this alternative overtop the highway in the same locations the existing conditions model overtops.

6.1.11.2. CONCEPTUAL COST ESTIMATE

Implementation of the flow redirection berm with the downstream extension is estimated to cost $864,000. The estimated cost included a total of ten expected property easements, an increase of six easements from the previous alternative. The cost estimate includes construction costs and all logistical costs associated with design, permitting, and construction.

6.2. COST-BENEFIT REVIEW

6.2.1. QUALITATIVE COST-BENEFIT REVIEW

Based on the model results, public meeting comments, and preliminary cost estimates, a qualitative cost-benefit analysis graph was created to help visualize the cost and benefit relationship between each of the alternatives. Positive feedback from public meetings was received from displaying the information in this way. Figure 38 shows the qualitative cost-benefit analysis for each of the alternatives.

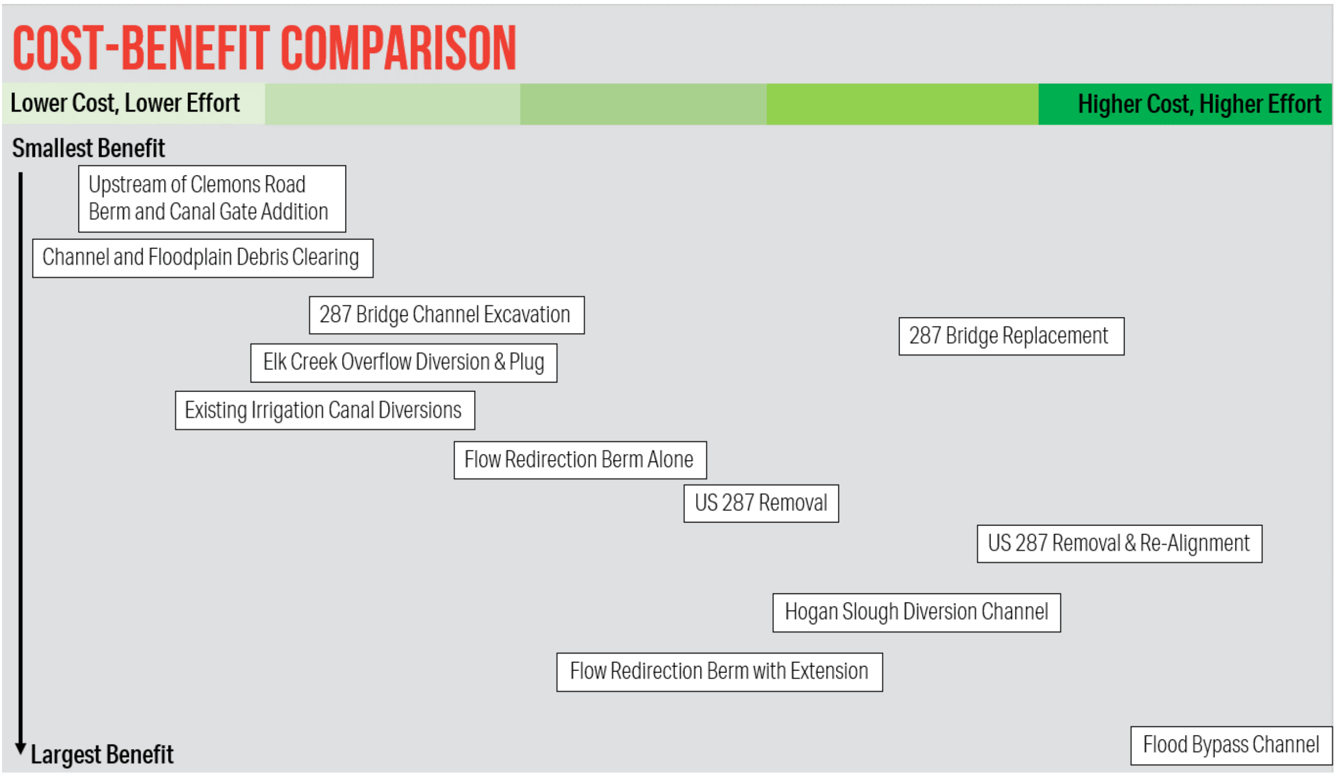


Figure 38. Qualitative cost-benefit analysis for all evaluated alternatives.

7.0 RECOMMENDATIONS

This study aims to present a suite of feasible flood mitigation alternatives that vary in scope, scale, cost, and effectiveness. Since funding for flood mitigation is likely to be sourced in state and federal grants, the study was structured such that a variety of mitigation options could be pursued based on any specific one, or combination of alternatives and their eligibility under different grant programs. However, based on the simulated hydraulic results and flood reduction benefits, combined with conceptual cost estimates and qualitative cost-benefit comparisons, engineering recommendations are provided.

Recommendations were made for baseline improvements, a singular alternative, and a combination of alternatives. The recommendations are provided in the following sections:

7.1.1. BASELINE IMPROVEMENTS RECOMMENDATIONS

7.1.1.1. CHANNEL AND FLOODPLAIN DEBRIS REMOVAL

Debris removal is a low cost option to improve flood conveyance in localized areas. With appropriate authorizations from the Lewis and Clark Conservation District, Montana Fish, Wildlife, and Parks, US Army Corps of Engineers, and/or Lewis and Clark County Floodplain, removal of large debris accumulations and monitoring of debris accumulation prior to spring runoff is recommended.

7.1.1.2. REGULAR CULVERT MAINTENANCE

Based off field investigations conducted by RESPEC, it was observed that many of the culverts within the Augusta area have accumulated sediment and/or woody debris. Removal of debris and sediment will improve conveyance through the existing culverts and reduce backwater and localized flooding. It is recommended that culverts be inspected for debris removal prior to spring runoff.

7.1.1.3. CULVERT BACKWATER PREVENTION

Based on model results, aerial flood imagery, and resident recollection of flood events, backwater is one of the significant issues the town of Augusta experiences during these flood events. For the culverts along MT 21 and the culverts closer to town than the US 287 bridges, a potential backwater prevention technique is the addition of backwater flaps to prevent backwater from downstream to propagate up the culvert. This may be a beneficial option for the culverts along US 287 where Elk Creek Overflow parallels the highway, for culverts along MT 21, and for certain culverts on Highway 435 where floodwaters from Elk Creek are accessing the highway borrow ditches on the opposite side of the roadway through the existing culverts.

7.1.2. SINGULAR ALTERNATIVE RECOMMENDATION

Based on the model results, feasibility, public comment, and the benefits compared to the cost of designing, permitting, and constructing an alternative, it is recommended that baseline improvements be implemented alongside the Flow Redirection Berm with Extension alternative. Although the Flood Bypass Channel with the option of a farmable swale provides the greatest flood mitigation alternative, the alternative may not be cost effective. For mitigation planning and funding purposes it is recommended the most feasible, beneficial for the greatest amount of people, and cost effective alternative be pursued.

7.1.3. ALTERNATIVE COMBINATION RECOMMENDATIONS

Depending on grant funding availability and successful grant acquisition, it is recommended the baseline improvements be implemented alongside the Flow Redirection Berm and the Existing Irrigation Canal Diversions. This combination of alternatives would help prevent US 287 backwater from accessing town from the upstream side, as well as decrease the total volume of floodwaters within the Elk Creek floodplain near Augusta.

8.0 FUNDING

Funding for final design, permitting, and construction of flood mitigation alternatives should be pursued through state and federal grants. The following list are a summary of potential state and federal funding opportunities, that if successful, will support flood mitigation improvements for Elk Creek in Augusta.

- FEMA Flood Mitigation Assistance (FMA) Grant
- FEMA Building Resilient Infrastructure Communities (BRIC)
- FEMA Hazard Mitigation Grant Program (HMGP)
- Montana Department of Natural Resources and Conservation (DNRC) Renewable Resources Grant and Loan Program (RRGL)
- MT Governor's Budget, Lobbying during Legislative Session
- U.S. Infrastructure Investment and Jobs Act

The funding opportunities listed above may provide funds for flood mitigation projects.

9.0 CONCLUSION

The overall goal of this phase of the Augusta Flood Mitigation Engineering project, was to develop a hydraulic study and provide flood mitigation recommendations to Lewis and Clark County and the community of Augusta. The following steps were completed to satisfy this goal:

- Collection of background data relevant to the 2018 and 2019 flooding of Elk Creek through Augusta;
- Complete an existing field conditions site visit and field survey to help process existing topographic data and incorporate hydraulic structures into the hydraulic model;
- Create a hydraulic model for existing flood conditions for the 2018 and 2019 events;
- Develop flood mitigation alternatives for analysis and recommendation;
- Engage public officials and residents of Augusta; and
- Communicate recommendations and next steps for the project.

Upon completion of the Augusta flood mitigation report, the next steps are to seek and pursue funding opportunities to develop detailed designs, permits, and implementation for the recommended flood mitigation alternatives.

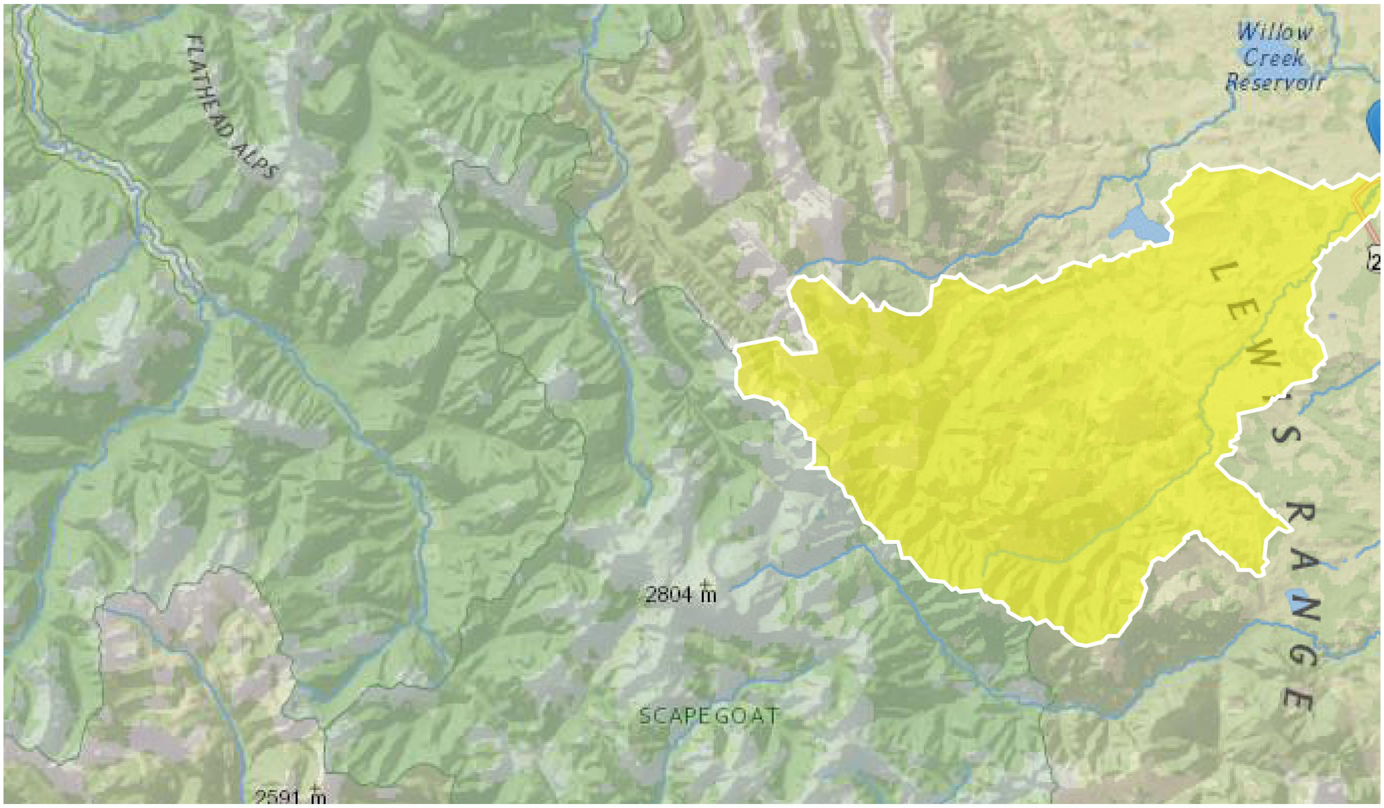
10.0 REFERENCES

1. **Federal Emergency Management Agency, 2012.** "Flood Insurance Study, Lewis and Clark County, Montana and Incorporated Areas, 30049CV000A".
2. **Great West Engineering and Watershed Consulting, 2012**. "Elk Creek (South Fork Sun River) Phase 1 Stream Assessment".
3. **Confluence Consulting and Applied Geomorphology, 2020**. "Post Flooding Hydrologic Assessment of Elk, Ford and Smith Creeks".
4. **DOWL, 2020**. "Elk Creek Hydrology Memo Update".
5. **United States Geologic Survey (USGS), 2016.** "Peak-Flow Frequency Analyses and Results Based on Data through Water Year 2011 for Selected Streamflow-Gaging Stations in or near Montana," Scientific Investigation Report 2015-5019.
6. **United States Geologic Survey (USGS), 2018.** "Methods for Peak-Flow Frequency Analysis and Reporting for Streamgages in or near Montana, Based on Data through Water Year 2015," *Scientific Investigations Report 2018-5046*.
7. **United States Geologic Survey (USGS), 2019.** "Peak-flow frequency analyses for selected streamgages in and near Teton County, Montana, based on data through water year 2019," *Scientific Investigations Report 2018-5046.*
8. **Hydrologic Engineering Center, 2021.** "HEC-RAS 6.1 Hydraulic Modeling Software." *United States Army Corps of Engineers.*
9. **Hydrologic Engineering Center, 2022.** "HEC-RAS 6.2 Hydraulic Modeling Software." *United States Army Corps of Engineers.*
10. **Hydrologic Engineering Center, 2021.** "HEC-RAS River Analysis System Hydraulic 2D Modeling User's Manual Version 6.0." *United States Army Corps of Engineers.*
11. **Environmental Systems Research Institute (ESRI), 2021.** "ArcGIS Pro: Version 2.8.0".
12. **Chow, Ven Te, 1959.** "Open Channel Hydraulics", *McGraw-Hill Book Company, Inc. New York*.
13. **Montana Department of Transportation, 2021.** "Average Prices Catalog".
14. **Montana Department of Transportation, 2016.** "Cost Estimation Procedure for Highway Design Projects".
15. **National Cooperative Highway Research Program, 2007.** "Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction".
16. **Hydrologic Engineering Center, 2021.** "HEC-RAS River Analysis System User's Manual Version 6.0." *United States Army Corps of Engineers.*

APPENDIX A
STREAMSTATS RESULTS

Elk Creek at MT 21 StreamStats

Region ID: MT
Workspace ID: MT20220608172133592000
Clicked Point (Latitude, Longitude): 47.50219, -112.36683
Time: 2022-06-08 11:21:56 -0600



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CHANWD_RS	Channel width determined from remotely sensed data sources, including aerial imagery	0	feet
CONTDA	Area that contributes flow to a point on a stream	167.1	square miles
EL6000	Percent of area above 6000 ft	21.1	percent
FOREST	Percentage of area covered by forest	27.3	percent
PRECIP	Mean Annual Precipitation	21.85	inches

Parameter Code	Parameter Description	Value	Unit
WACTCH	Width of active channel	0	feet
WBANKFULL	Width of channel at bankfull	0	feet

Peak-Flow Statistics

Peak-Flow Statistics Parameters [NW Region BasinC 2015 5019F]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	167.1	square miles	2.43	1560

Peak-Flow Statistics Parameters [NW Region Active Channel SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
WACTCH	Width Of Active Channel	0	feet	9.5	234.5

Peak-Flow Statistics Parameters [NW Region Bankfull SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
WBANKFULL	Width Of Bankfull Channel	0	feet	11.5	273.5

Peak-Flow Statistics Parameters [NW Region Aerial Photo SIR 2020 5142]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CHANWD_RS	Channel_Width_remotely_sensed	0	feet	8.9	257.2

Peak-Flow Statistics Flow Report [NW Region BasinC 2015 5019F]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
66.7-percent AEP flood	1610	ft^3/s	342	7570	115
50-percent AEP flood	1970	ft^3/s	548	7080	88.9
42.9-percent AEP flood	2130	ft^3/s	653	6950	80.4

Statistic	Value	Unit	PII	PIu	ASEp
20-percent AEP flood	3130	ft^3/s	1370	7170	52.8
10-percent AEP flood	4370	ft^3/s	2510	7620	34.4
4-percent AEP flood	6830	ft^3/s	6130	7610	9.1
2-percent AEP flood	9450	ft^3/s	8260	10800	11.3
1-percent AEP flood	13000	ft^3/s	11100	15300	13.6
0.5-percent AEP flood	17900	ft^3/s	14800	21700	16
0.2-percent AEP flood	27100	ft^3/s	21600	34100	19.3

Peak-Flow Statistics Disclaimers [NW Region Active Channel SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [NW Region Active Channel SIR 2020 5142]

Statistic	Value	Unit
Active chan width 66.7 percent AEP flood	0	ft^3/s
Active Channel Width 50-percent AEP flood	0	ft^3/s
Active chan width 42.9 percent AEP flood	0	ft^3/s
Active Channel Width 20-percent AEP flood	0	ft^3/s
Active Channel Width 10-percent AEP flood	0	ft^3/s
Active Channel Width 4-percent AEP flood	0	ft^3/s
Active Channel Width 2-percent AEP flood	0	ft^3/s
Active Channel Width 1-percent AEP flood	0	ft^3/s
Active Channel Width 0.5-percent AEP flood	0	ft^3/s
Active Channel Width 0.2-percent AEP flood	0	ft^3/s

Peak-Flow Statistics Disclaimers [NW Region Bankfull SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [NW Region Bankfull SIR 2020 5142]

Statistic	Value	Unit

Statistic	Value	Unit
Bankfull width 66.7 percent AEP flood	0	ft^3/s
Bankfull Width 50-percent AEP flood	0	ft^3/s
Bankfull width 42.9 percent AEP flood	0	ft^3/s
Bankfull Width 20-percent AEP flood	0	ft^3/s
Bankfull Width 10-percent AEP flood	0	ft^3/s
Bankfull Width 4-percent AEP flood	0	ft^3/s
Bankfull Width 2-percent AEP flood	0	ft^3/s
Bankfull Width 1-percent AEP flood	0	ft^3/s
Bankfull Width 0.5-percent AEP flood	0	ft^3/s
Bankfull Width 0.2-percent AEP flood	0	ft^3/s

Peak-Flow Statistics Disclaimers [NW Region Aerial Photo SIR 2020 5142]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [NW Region Aerial Photo SIR 2020 5142]

Statistic	Value	Unit
Rem sens chan width 66.7 percent AEP fld	0	ft^3/s
Rem_sens_chan_width_50_percent_AEP_flood	0	ft^3/s
Rem sens chan width 42.9 percent AEP fld	0	ft^3/s
Rem_sens_chan_width_20_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_10_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_4_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_2_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_1_percent_AEP_flood	0	ft^3/s
Rem_sens_chan_width_0_5_pct_AEP_flood	0	ft^3/s
Rem_sens_chan_width_0_2_pct_AEP_flood	0	ft^3/s

Peak-Flow Statistics Flow Report [Area-Averaged]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	ASEp
66.7-percent AEP flood	1610	ft^3/s	342	7570	115
50-percent AEP flood	1970	ft^3/s	548	7080	88.9
42.9-percent AEP flood	2130	ft^3/s	653	6950	80.4
20-percent AEP flood	3130	ft^3/s	1370	7170	52.8
10-percent AEP flood	4370	ft^3/s	2510	7620	34.4
4-percent AEP flood	6830	ft^3/s	6130	7610	9.1
2-percent AEP flood	9450	ft^3/s	8260	10800	11.3
1-percent AEP flood	13000	ft^3/s	11100	15300	13.6
0.5-percent AEP flood	17900	ft^3/s	14800	21700	16
0.2-percent AEP flood	27100	ft^3/s	21600	34100	19.3
Active chan width 66.7 percent AEP flood	0	ft^3/s			
Active Channel Width 50-percent AEP flood	0	ft^3/s			
Active chan width 42.9 percent AEP flood	0	ft^3/s			
Active Channel Width 20-percent AEP flood	0	ft^3/s			
Active Channel Width 10-percent AEP flood	0	ft^3/s			
Active Channel Width 4-percent AEP flood	0	ft^3/s			
Active Channel Width 2-percent AEP flood	0	ft^3/s			
Active Channel Width 1-percent AEP flood	0	ft^3/s			
Active Channel Width 0.5-percent AEP flood	0	ft^3/s			
Active Channel Width 0.2-percent AEP flood	0	ft^3/s			
Bankfull width 66.7 percent AEP flood	0	ft^3/s			
Bankfull Width 50-percent AEP flood	0	ft^3/s			
Bankfull width 42.9 percent AEP flood	0	ft^3/s			
Bankfull Width 20-percent AEP flood	0	ft^3/s			
Bankfull Width 10-percent AEP flood	0	ft^3/s			
Bankfull Width 4-percent AEP flood	0	ft^3/s			
Bankfull Width 2-percent AEP flood	0	ft^3/s			
Bankfull Width 1-percent AEP flood	0	ft^3/s			
Bankfull Width 0.5-percent AEP flood	0	ft^3/s			
Bankfull Width 0.2-percent AEP flood	0	ft^3/s			

Statistic	Value	Unit	PII	PIu	ASEp
Rem sens chan width 66.7 percent AEP fld	0	ft^3/s			
Rem_sens_chan_width_50_percent_AEP_flood	0	ft^3/s			
Rem sens chan width 42.9 percent AEP fld	0	ft^3/s			
Rem_sens_chan_width_20_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_10_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_4_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_2_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_1_percent_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_0_5_pct_AEP_flood	0	ft^3/s			
Rem_sens_chan_width_0_2_pct_AEP_flood	0	ft^3/s			

Peak-Flow Statistics Citations

Sando, Roy, Sando, S.K., McCarthy, P.M., and Dutton, D.M.,2016, Methods for estimating peak-flow frequencies at ungaged sites in Montana based on data through water year 2011: U.S. Geological Survey Scientific Investigations Report 2015–5019–F, 30 p. (https://doi.org/10.3133/sir20155019)

Chase, K.J., Sando, R., Armstrong, D.W., and McCarthy, P., 2021, Regional regression equations based on channel-width characteristics to estimate peak-flow frequencies at ungaged sites in Montana using peak-flow frequency data through water year 2011 (ver. 1.1, September 2021): U.S. Geological Survey Scientific Investigations Report 2020–5142, 49 p. (https://doi.org/10.3133/sir20205142)

Channel-width Methods Weighting

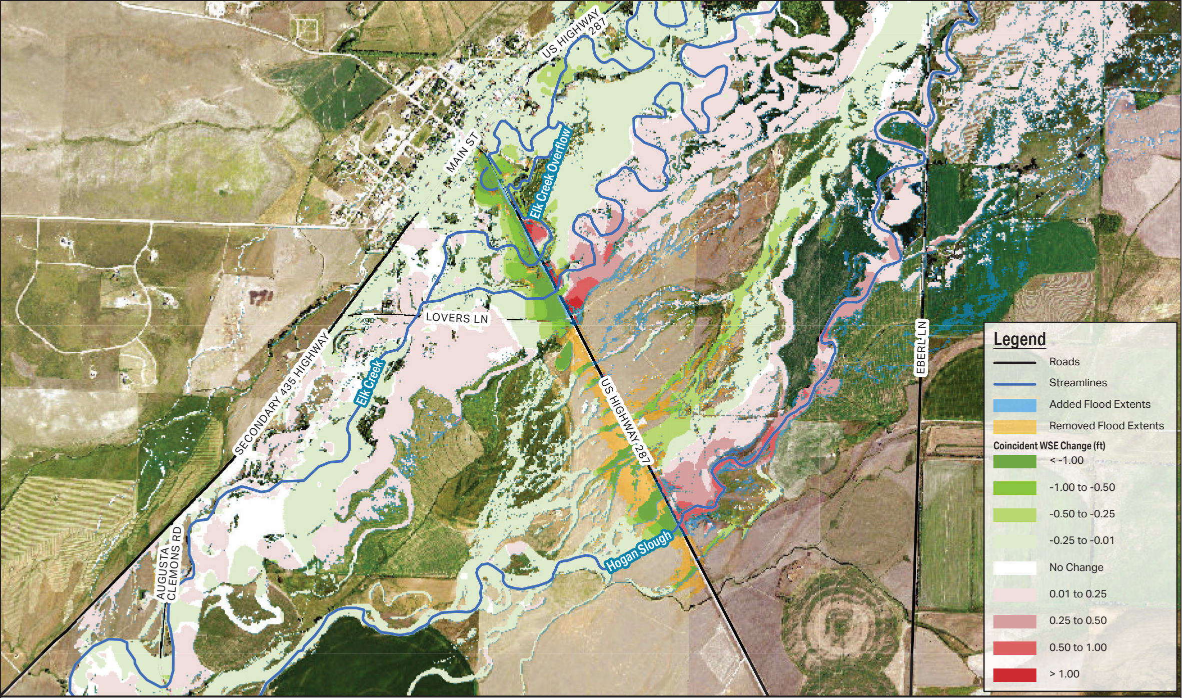
No method weighting results returned.

functionality of the software and related material nor shall the fact of release constitute any such warranty. Furthermore, the software is released on condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use.

USGS Product Names Disclaimer: Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

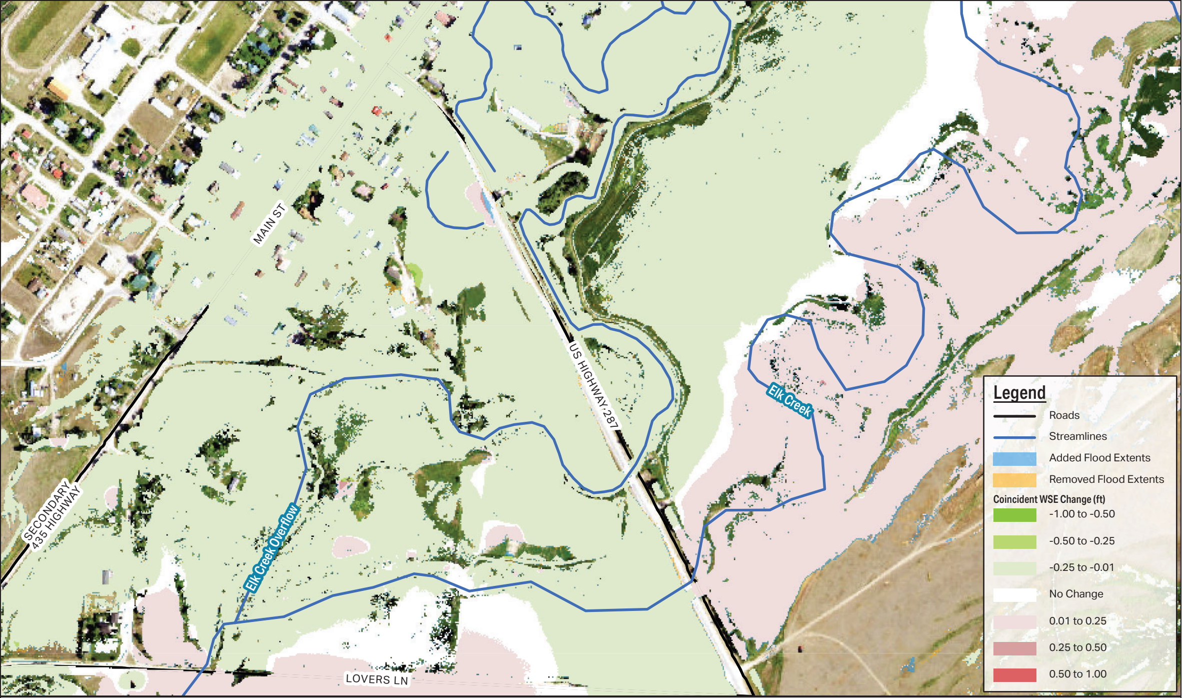
Application Version: 4.9.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.0

APPENDIX B
MODEL RESULTS MAPS



US 287 Removal Results

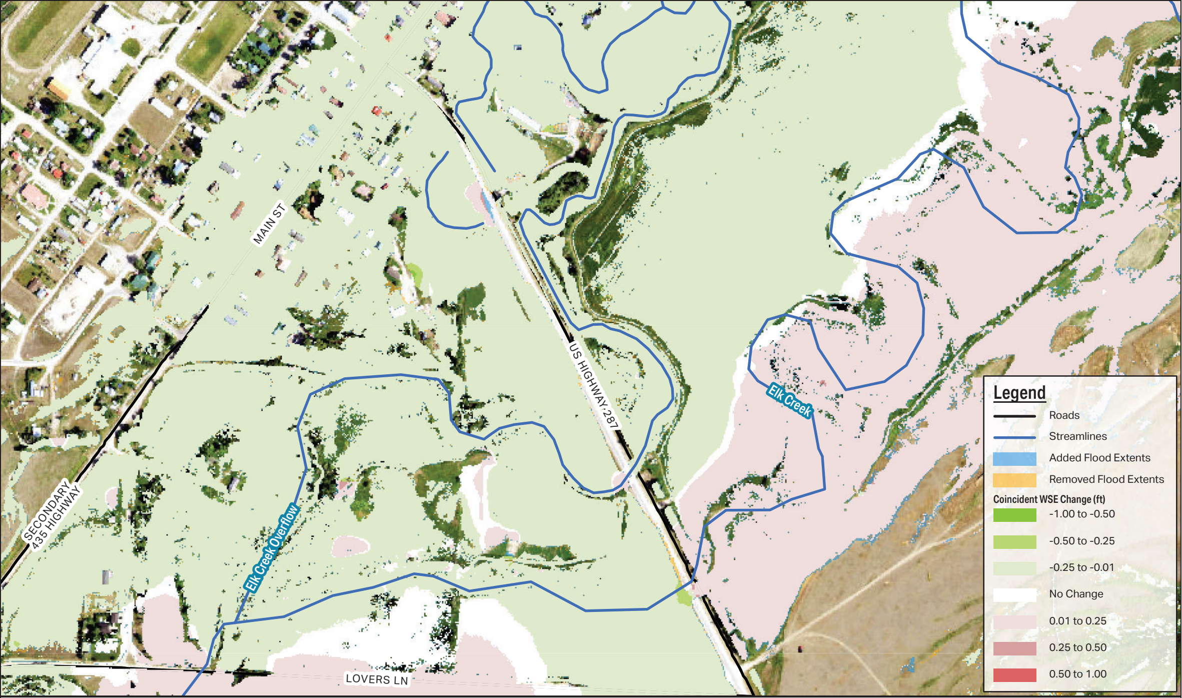
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

US 287 Bridge Channel Widening Results

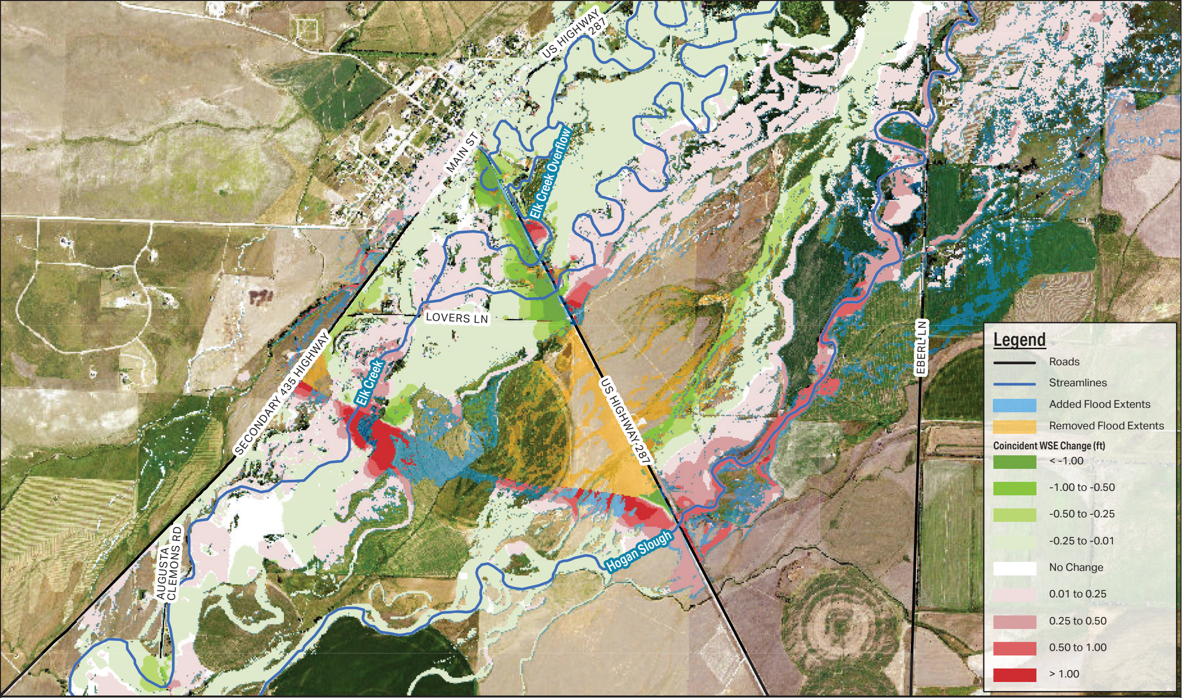
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

US 287 Bridge Replacement Results

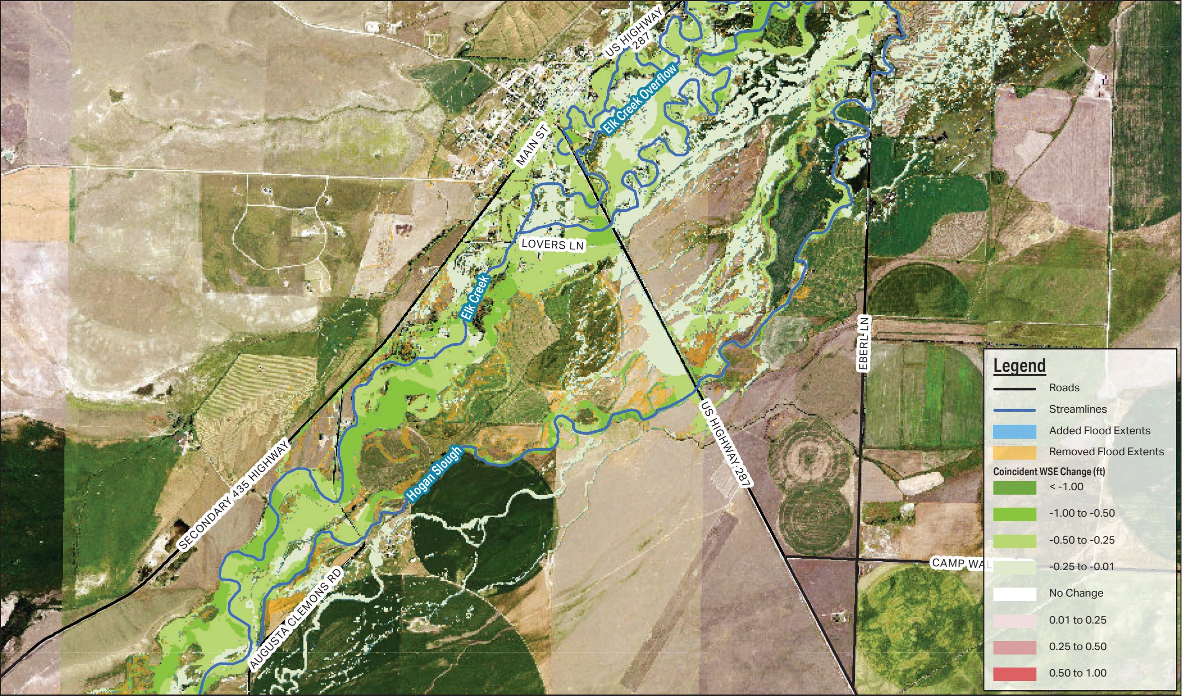
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

US 287 Removal and Re-Alignment Results

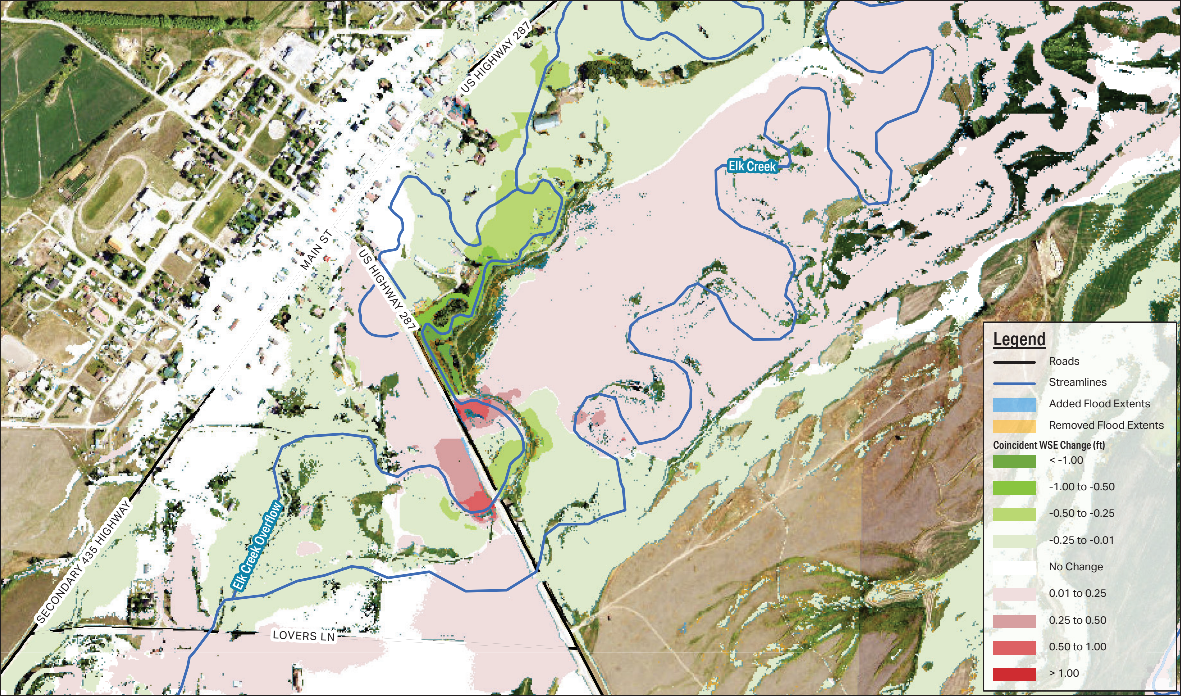
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

Existing Irrigation Canals Results

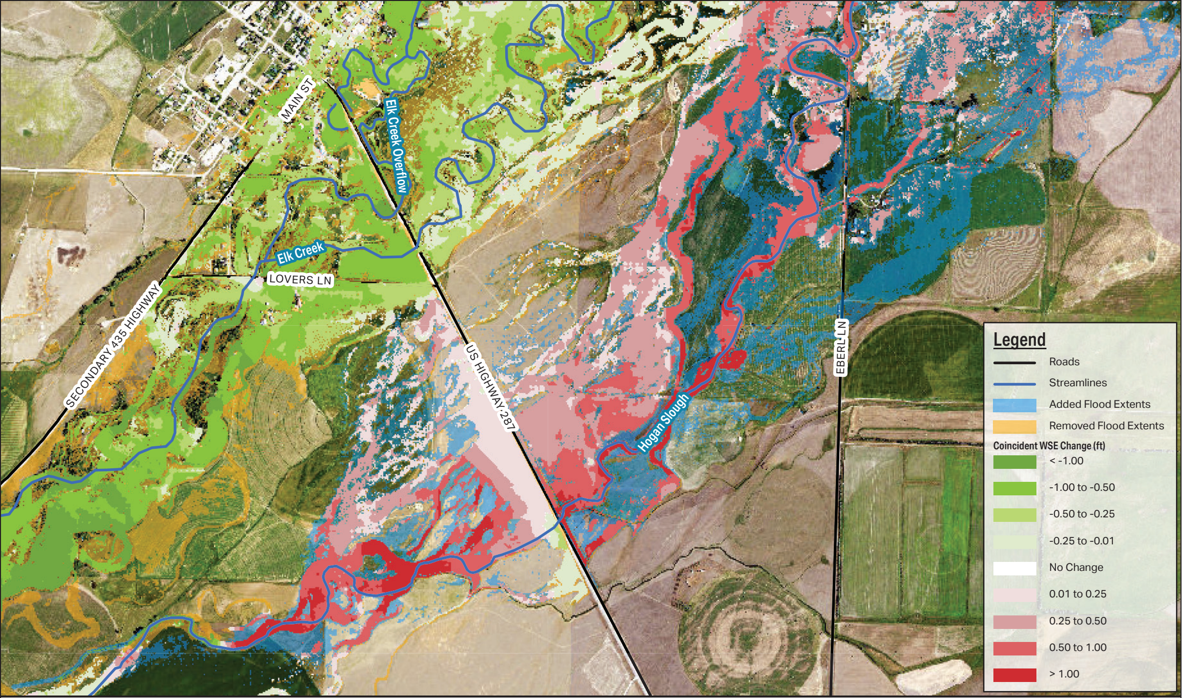
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

Elk Creek Overflow Diversion Results

Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

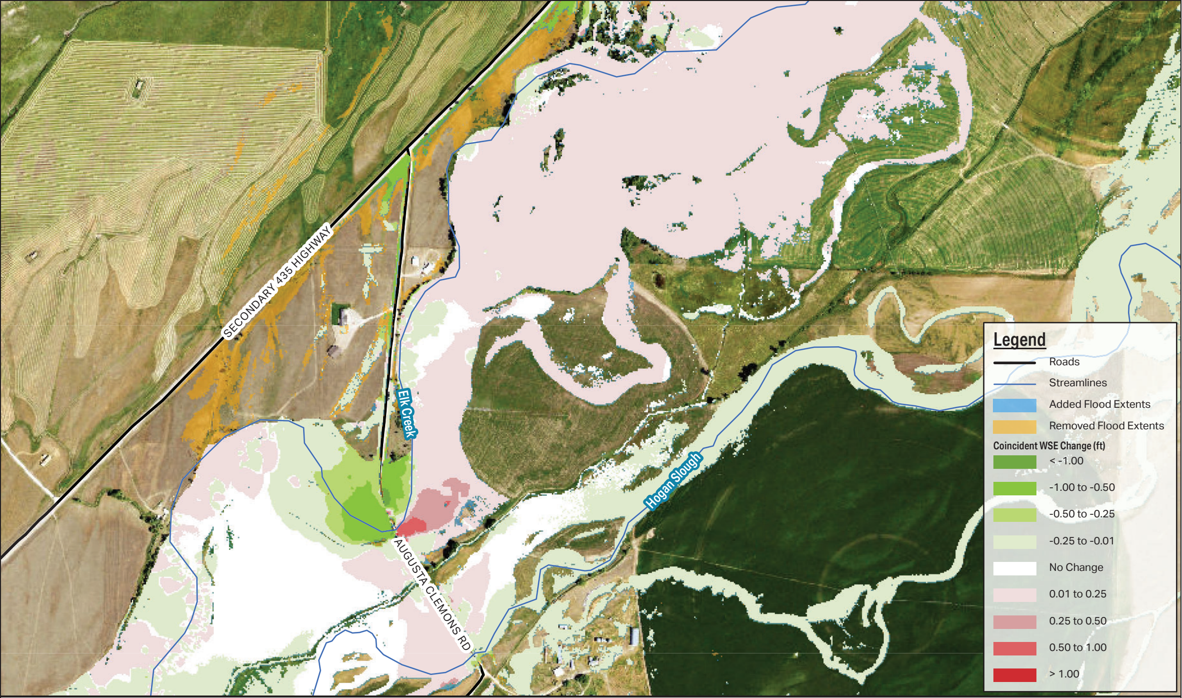
Hogan Slough Diversion Results

Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)

RESPEC

Flood Bypass Channel Results

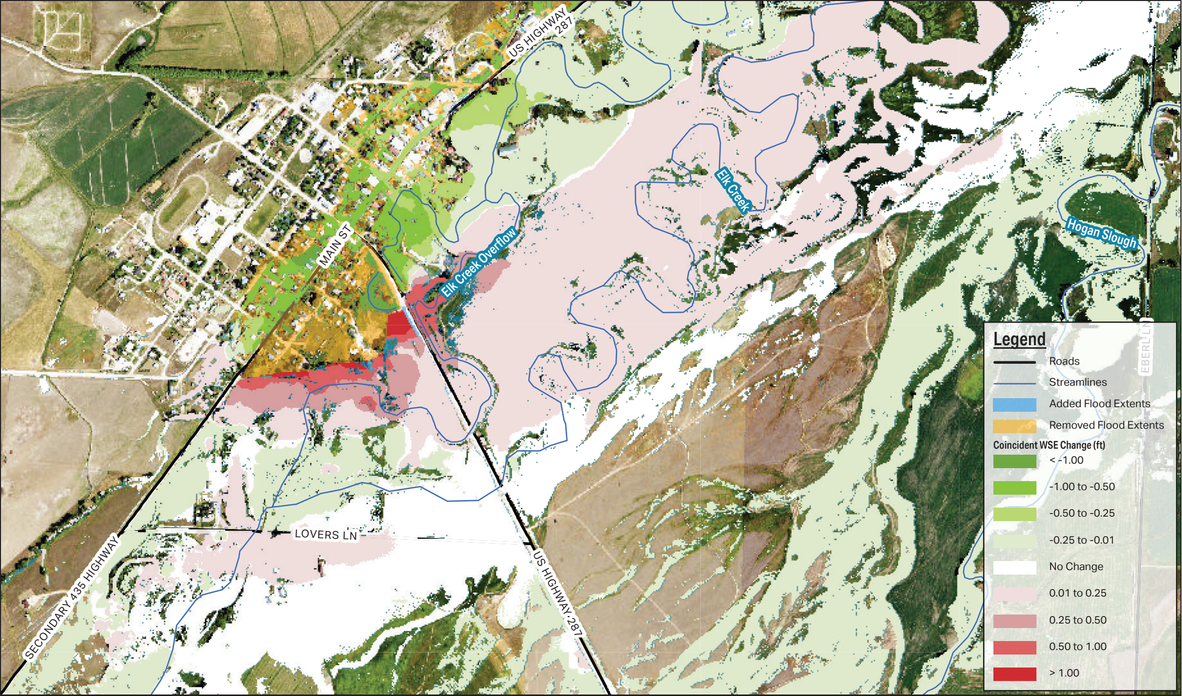
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

Flow Containment Berm Upstream of Augusta Clemons Road Results

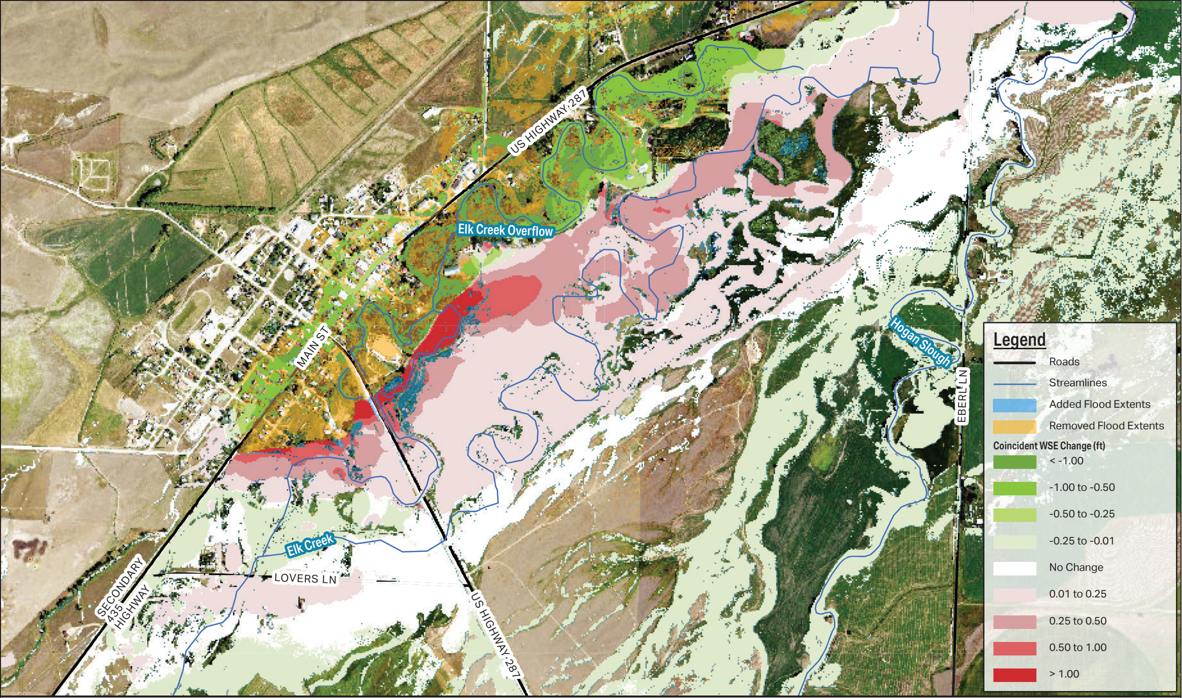
Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

Flow Redirection Berm Results

Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)



RESPEC

Flow Redirection Berm Extension Results

Basemap: NAIP 2019 Coordinate System: NAD 1983 (2011) State Plane Montana FIPS 2500 (Intl Feet)

N

0 1,000 2,000
Feet

APPENDIX C
ALTERNATIVES COST ANALYSIS

SUMMARY OF CONCEPTUAL COSTS
ESTIMATED BY: MAX HALLER
REVIEWED BY: MATTHEW JOHNSON
DATE: 06/10/2022

US 287 Removal				
ITEM	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL COST**
BRIDGE REMOVAL	2	EA	$75,000	$150,000
CULVERT REMOVAL	4	EA	$1,500	$6,000
EXCAVATION - TYPE 1	57489	CY	$2	$114,980
EXCAVATION - TYPE 2B	383	CY	$12	$4,600
HAUL OFF	57489	CY	$10	$574,890
CONCEPTUAL CONSTRUCTION COST:				**$850,470**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$170,094
EROSION CONTROL	NA	%	5%	$42,524
TRAFFIC CONTROL	NA	%	5%	$42,524
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$85,047
CONTINGENCY	NA	%	20%	$170,094
COCEPTUAL PROJECT COST:				**$1,360,752**

US 287 Existing Bridges Channel Widening				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
EXCAVATION - TYPE 3	1201	CY	$15	$18,020
RIPRAP	585	CY	$110	$64,340
HAUL OFF	1201	CY	$10	$12,010
CONCEPTUAL CONSTRUCTION COST:				**$94,370**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$18,874
EROSION CONTROL	NA	%	5%	$4,719
TRAFFIC CONTROL	NA	%	5%	$4,719
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$9,437
CONTINGENCY	NA	%	20%	$18,874
COCEPTUAL PROJECT COST:				**$150,992**

US 287 Bridge Replacement				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
BRIDGE REMOVAL	2	EA	$75,000	$150,000
BRIDGE REPLACEMENT	12866	SF	$250	$3,216,480
EXCAVATION - TYPE 3	1100	CY	$15	$16,500
RIPRAP	585	CY	$110	$64,340
HAUL OFF	1100	CY	$10	$11,000
CONCEPTUAL CONSTRUCTION COST:				**$3,458,320**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$691,664
EROSION CONTROL	NA	%	5%	$172,916
TRAFFIC CONTROL	NA	%	10%	$345,832
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$345,832
CONTINGENCY	NA	%	20%	$691,664
COCEPTUAL PROJECT COST:				**$5,706,228**

US 287 Removal & Re-Alignment				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
BRIDGE REMOVAL	2	EA	$75,000	$150,000
CULVERT REMOVAL	4	EA	$1,500	$6,000
ROAD REPLACEMENT	6261	LF	$480	$3,005,280
BRIDGE REPLACEMENT	5125	SF	$250	$1,281,250
EXCAVATION - TYPE 1	35562	CY	$2	$71,120
CMP CULVERT - 3'	85	LF	$175	$14,880
RIPRAP	500	CY	$110	$55,000
PROPERTY ACQUISITION	3	EA	$30,000	$90,000
HAUL OFF	35562	CY	$10	$355,620
CONCEPTUAL CONSTRUCTION COST:				**$5,029,150**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$1,005,830
EROSION CONTROL	NA	%	5%	$251,458
TRAFFIC CONTROL	NA	%	10%	$502,915
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$502,915
CONTINGENCY	NA	%	20%	$1,005,830
COCEPTUAL PROJECT COST:				**$8,298,098**

Existing Irrigation Canal Diversions				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
DIVERSION ENHANCEMENTS	6	EA	$12,000	$72,000
CROSSING ENHANCEMENTS	16	EA	$1,000	$16,000
DEBRIS AND CHANNEL CLEARING	1	LS	$25,000	$25,000
CONCEPTUAL CONSTRUCTION COST:				**$113,000**
LANDOWNER COORDINATION/PLANNING	NA	%	90%	$101,700
CONTINGENCY	NA	%	20%	$22,600
COCEPTUAL PROJECT COST:				$237,300

Elk Creek Overflow Diversion				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
EXCAVATION - TYPE 2B	2500	CY	$12	$30,000
STRUCTURAL FILL	193	CY	$15	$2,890
HEADGATE	1	LS	$10,000	$10,000
PROPERTY EASEMENT - MAJOR	1	EA	$30,000	$30,000
CONCEPTUAL CONSTRUCTION COST:				**$72,890**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$14,578
EROSION CONTROL	NA	%	5%	$3,645
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$7,289
CONTINGENCY	NA	%	20%	$14,578
COCEPTUAL PROJECT COST:				$112,980

Hogan Slough Diversion				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
CULVERT REMOVAL	1	EA	$1,500	$1,500

BRIDGE REPLACEMENT	1920	SF	$250	$480,000
RCB CULVERT (14'X7')	36	LF	$2,800	$100,800
IRRIGATION/CHANNEL IMPROVEMENTS	23874	LF	$2	$47,750
EXCAVATION - TYPE 2A	27180	CY	$8	$217,440
RIPRAP	273	CY	$110	$30,070
HEADGATE	1	LS	$10,000	$10,000
PROPERTY EASEMENT - MINOR	3	EA	$15,000	$45,000
CONCEPTUAL CONSTRUCTION COST:				**$932,560**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$186,512
EROSION CONTROL	NA	%	5%	$46,628
TRAFFIC CONTROL	NA	%	10%	$93,256
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$93,256
CONTINGENCY	NA	%	20%	$186,512
COCEPTUAL PROJECT COST:				**$1,538,724**

Flood Bypass Channel

	QUANTITY	UNIT	UNIT COST	TOTAL COST
BRIDGE REPLACEMENT	5625	SF	$250	$1,406,250
EXCAVATION - TYPE 2A	330924	CY	$8	$2,647,390
RIPRAP	750	CY	$110	$82,500
HEADGATE	1	LS	$10,000	$10,000
PROPERTY EASEMENT - MAJOR	13	EA	$30,000	$390,000
CONCEPTUAL CONSTRUCTION COST:				**$4,536,140**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$907,228
EROSION CONTROL	NA	%	5%	$226,807
TRAFFIC CONTROL	NA	%	10%	$453,614
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$453,614
CONTINGENCY	NA	%	20%	$907,228
COCEPTUAL PROJECT COST:				**$7,484,631**

FLOW CONTAINMENT BERM UPSTREAM OF AUGUSTA CLEMONS ROAD

	QUANTITY	UNIT	UNIT COST	TOTAL COST
STRUCTURAL FILL	761	CY	$15	$11,420
HEADGATE	2	LS	$10,000	$20,000
REVEGETATION	1520	SY	$3	$4,560
PROPERTY EASEMENT - MINOR	2	EA	$15,000	$30,000
CONCEPTUAL CONSTRUCTION COST:				**$65,980**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$13,196
EROSION CONTROL	NA	%	5%	$3,299
TRAFFIC CONTROL	NA	%	5%	$3,299
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$6,598
CONTINGENCY	NA	%	20%	$13,196
COCEPTUAL PROJECT COST:				**$105,568**

Flow Redirection Berm

	QUANTITY	UNIT	UNIT COST	TOTAL COST

STRUCTURAL FILL	14030	CY	$15	$210,440
REVEGETATION	17163	SY	$3	$51,490
PROPERTY EASEMENT - MINOR	4	EA	$15,000	$60,000
CONCEPTUAL CONSTRUCTION COST:				**$321,930**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$64,386
EROSION CONTROL	NA	%	5%	$16,097
TRAFFIC CONTROL	NA	%	5%	$16,097
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$32,193
CONTINGENCY	NA	%	20%	$64,386
COCEPTUAL PROJECT COST:				**$515,088**

Flow Redirection Berm Extension				
	QUANTITY	UNIT	UNIT COST	TOTAL COST
STRUCTURAL FILL	20873	CY	$15	$313,100
REVEGETATION	25536	SY	$3	$76,610
PROPERTY EASEMENT - MINOR	10	EA	$15,000	$150,000
CONCEPTUAL CONSTRUCTION COST:				**$539,710**
ENGINEERING, PERMITTING, DESIGN, CM	NA	%	20%	$107,942
EROSION CONTROL	NA	%	5%	$26,986
TRAFFIC CONTROL	NA	%	5%	$26,986
MOBILIZATION, INSURANCE, BONDING	NA	%	10%	$53,971
CONTINGENCY	NA	%	20%	$107,942
COCEPTUAL PROJECT COST:				**$863,536**

APPENDIX D
PUBLIC MEETING 1 SLIDES

ELK CREEK – AUGUSTA FLOOD MITIGATION

LEWIS AND CLARK COUNTY

FEBRUARY 18, 2022

Aerial photo of 2018 flooding at Augusta and Highway 287, courtesy of Montana Department of Transportation.

RESPEC

2018 FLOODING

Photograph courtesy of Carol Fletcher

Photograph courtesy of USGS

2018 FLOODING

Photograph by Mark Taylor via Great Falls Tribune


2018 FLOODING
Photograph by Mark Taylor via Great Falls Tribune

2018 FLOODING

Drone footage by Into the Little Belts

2018 FLOODING MT HIGHWAY 287

Photographs courtesy of the Montana Department of Transportation.

MT HIGHWAY 21 FLOODING

Photographs courtesy of the Montana Department of Transportation.

1964 AERIAL FLOOD PHOTOGRAPHS

AUGUSTA FLOOD

June 8 in Augusta was a wet day as the rain-swollen South Fork of the Sun River poured water into the town. The rodeo arena is at left under water. DeMier photo.

MT-21 aerial photograph of the 1964 flood.

Photographs courtesy of the Great Falls Tribune

1964 FLOOD AT GIBSON RESERVOIR

Photograph by USGS

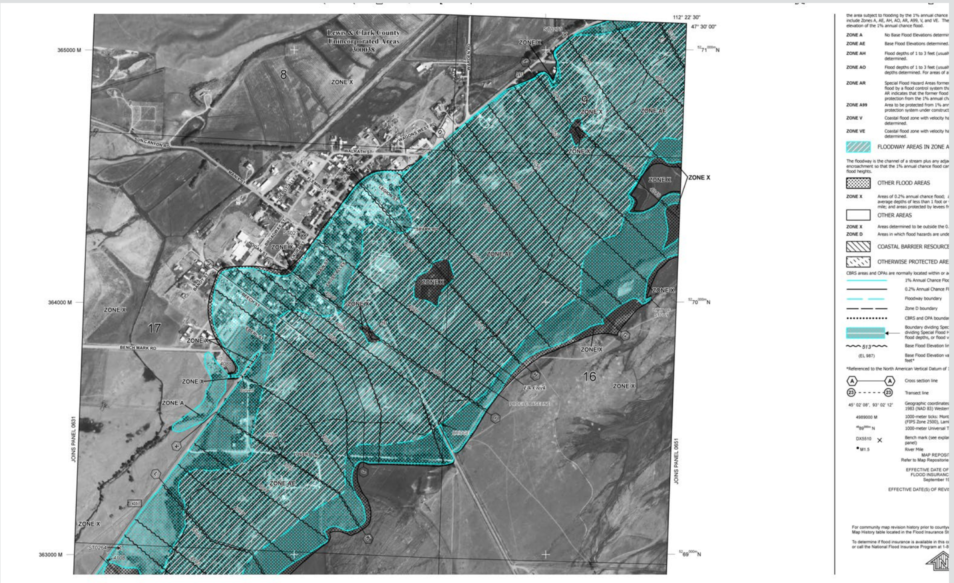
AUGUSTA FLOOD MITIGATION PROJECT

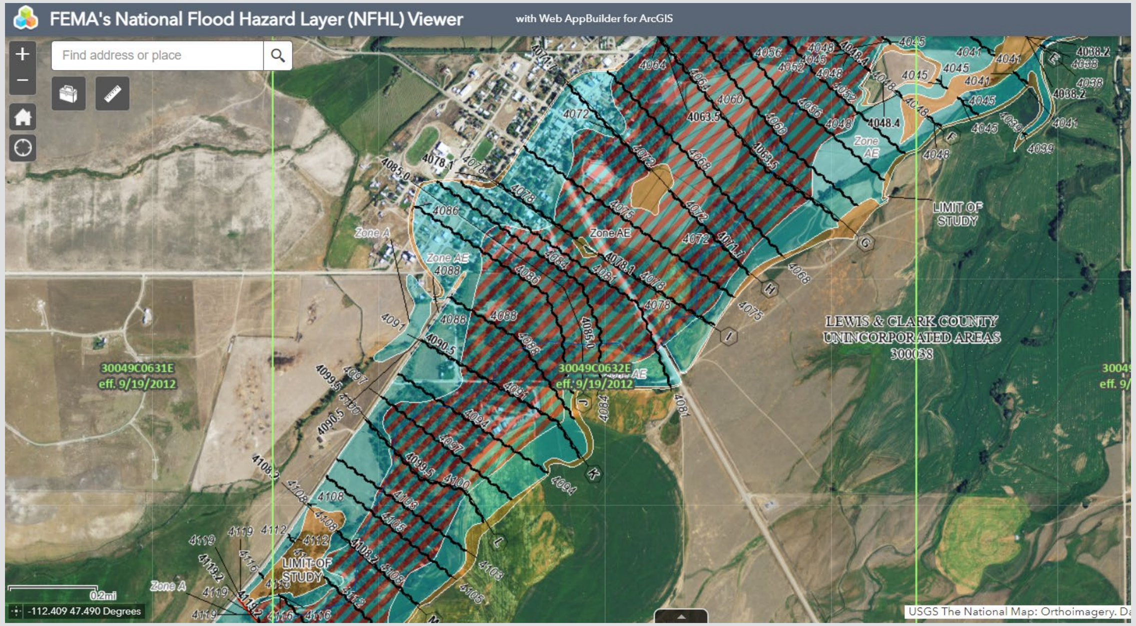
- **DEVELOP FLOOD STUDY**
  - Quantify existing conditions, evaluate effectiveness of alternatives
  - Leverage existing data and work to-date
    - Lewis and Clark Conservation District
    - Montana Department of Transportation
- **PUBLIC ENGAGEMENT**
  - Two Public Meetings to gather local insights and feedback
- **DEVELOP FLOOD MITIGATION ENGINEERING RECOMMENDATIONS REPORT**
  - Used to leverage grant funding opportunities
  - Used to guide community

HISTORIC SUMMARY

- **LARGE FLOODS IN:**
  - 1948
  - 1953
  - 1964
  - 1975
  - 2011
  - 2018
  - 2019

- **PAST STUDIES:**
  - 1980 FEMA FIS
  - 2019-2020 (CONFLUENCE AND APPLIED GEOMORPHOLOGY)
  - 2020 MDT/DOWL HYDROLOGY AT MT-21





HYDROLOGIC ASSESSMENT SUMMARY

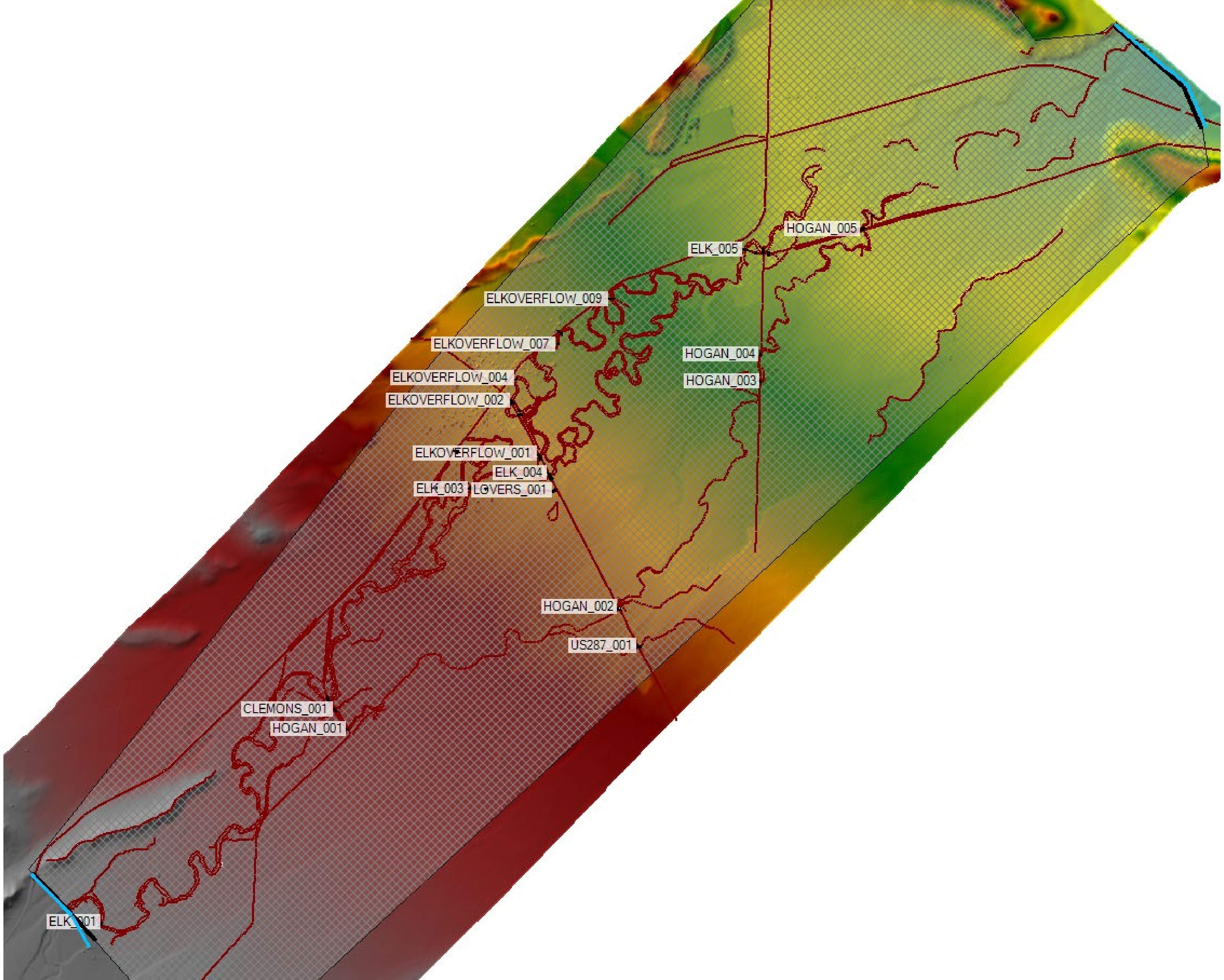
- FLOODING MOST PRONOUNCED AROUND AUGUSTA DUE TO THE FLAT, WIDE FLOODPLAIN
- WATER IS ROUTED BY IRRIGATION DITCHES, BORROW DITCHES, AND STREAM CHANNELS
- ROADS AND LARGE DEBRIS JAMS CREATE BACKWATER
- CHANGING CHANNEL MORPHOLOGY DUE TO SEDIMENT TRANSPORT DURING FLOODS

WHY IS A FLOOD STUDY NECESSARY?

- UNDERSTAND HOW THE NETWORK OF DITCHES AND STREAM CHANNELS ROUTE WATER
- EXTENT OF BACKWATERING FROM ROAD NETWORKS AND CROSSINGS
- ASSESS POTENTIAL MITIGATION SOLUTIONS
- FLOOD STUDY IS NECESSARY FOR FLOODPLAIN PERMITTING
- FEDERAL GRANT ELIGIBILITY
  - Project included in PDM Plan
  - Develop benefit cost analysis (FEMA grants)

HYDRAULICS

- **ELK CREEK, ELK CREEK OVERFLOW, HOGAN SLOUGH**
  - Utilized measured flows at USGS gage
    - USGS 06084500 Elk Creek at Augusta MT
  - All flooding sources modeled in one 2D area
  - Bridges and Culverts based on RPA survey and field measured elevations
  - Study area:
    - Upstream Extent: 0.5 mi NE of Smith and Elk Creek confluence
    - Downstream Extent: 0.25 mi NE of abandoned railroad berm east of Augusta
  - Simulated the Existing Conditions (EX) – 1964, 1975, 2018 floods



HOGAN_005
ELK_005
ELKOVERFLOW_009
ELKOVERFLOW_007
HOGAN_004
ELKOVERFLOW_004
HOGAN_003
ELKOVERFLOW_002
ELKOVERFLOW_001
ELK_004
ELK_003
LOVERS_001
HOGAN_002
US287_001
CLEMONS_001
HOGAN_001
ELK_001

SIMULATION ANIMATION - EX

- FLOODS OF INTEREST:
  - 2018 flood event – 6,580 cfs (10-25 year)
  - 1975 flood event – 8,500 cfs (25-50 year)
  - 1964 flood event – 12,000 cfs (50-100 year)

HYDRAULIC RESULTS SUMMARY

- ELK CREEK MAIN CHANNEL AND FLOODPLAIN
- ELK CREEK OVERFLOW CHANNEL AND FLOODPLAIN
- HOGAN'S SLOUGH CHANNEL AND FLOODPLAIN

	% of Total Flow - 2018		% of Total Flow - 1975		% of Total Flow - 1964	
	US Highway 287	MT Highway 21	US Highway 287	MT Highway 21	US Highway 287	MT Highway 21
Elk Creek Main	37%	86%	35%	81%	33%	75%
Elk Creek Overflow	44%		43%		42%	
Hogan's Slough	19%	14%	22%	19%	25%	25%

FLOOD MITIGATION TOPICS

- COLLECT ADDITIONAL INSIGHT AND FEEDBACK FROM COMMUNITY
- EVALUATE FEASIBILITY AND EFFECTIVENESS OF ALTERNATIVES IN HYDROLOGIC ASSESSMENT:
  - Divert to East Canal and Infiltrate
  - Prevent floodwater capture by 435 ditches at Clemons Rd
  - Highway 287
- DEVELOP A MATRIX OF OPTIONS RANGING IN EASE, COST, AND PERMITTING

POTENTIAL MITIGATION ALTERNATIVES

- CHANNEL AND FLOODPLAIN DEBRIS REMOVAL, CULVERT MAINTENANCE
- STRUCTURE ASSESSMENT AND UPSIZING
- ROUTE FLOODWATERS AWAY FROM HIGH-RISK AREAS (SUCH AS TOWN)
  - Expand existing infrastructure to route excess flood waters
- REALIGN HIGHWAY 287

CHANNEL, FLOODPLAIN, CULVERT DEBRIS REMOVAL

- GENERALLY LOW COST
- ANNUAL MONITORING, MAINTENANCE
- PERMITTING MAY BE REQUIRED
- COORDINATED EFFORT WITH CD AND FWP FOR ANY CHANNEL ACTIVITY

LIMITING BORROW DITCH ABILITY TO FUNNEL FLOOD WATERS

Figure from the Post-Flooding Hydrological Assessment by Confluence and Applied Geomorphology (2020).

- EX. : HIGHWAY 435 BORROW DITCHES
- LOWER COST OPTION
- SHORTER TIMEFRAME

STRUCTURE ASSESSMENT AND UPSIZING

- US HIGHWAY 287 STRUCTURES
- ELK CREEK OVERFLOW STRUCTURES
- MT 21 STRUCTURES
  - MDT Project Ongoing

ROUTE FLOODWATERS AWAY FROM HIGH-RISK AREAS

- UTILIZE EXISTING INFRASTRUCTURE:
  - Irrigation ditches such as Hogan's Slough
- HIGH COST, LONG-TERM
- IMPACT TO IRRIGATION AND AG OPERATION

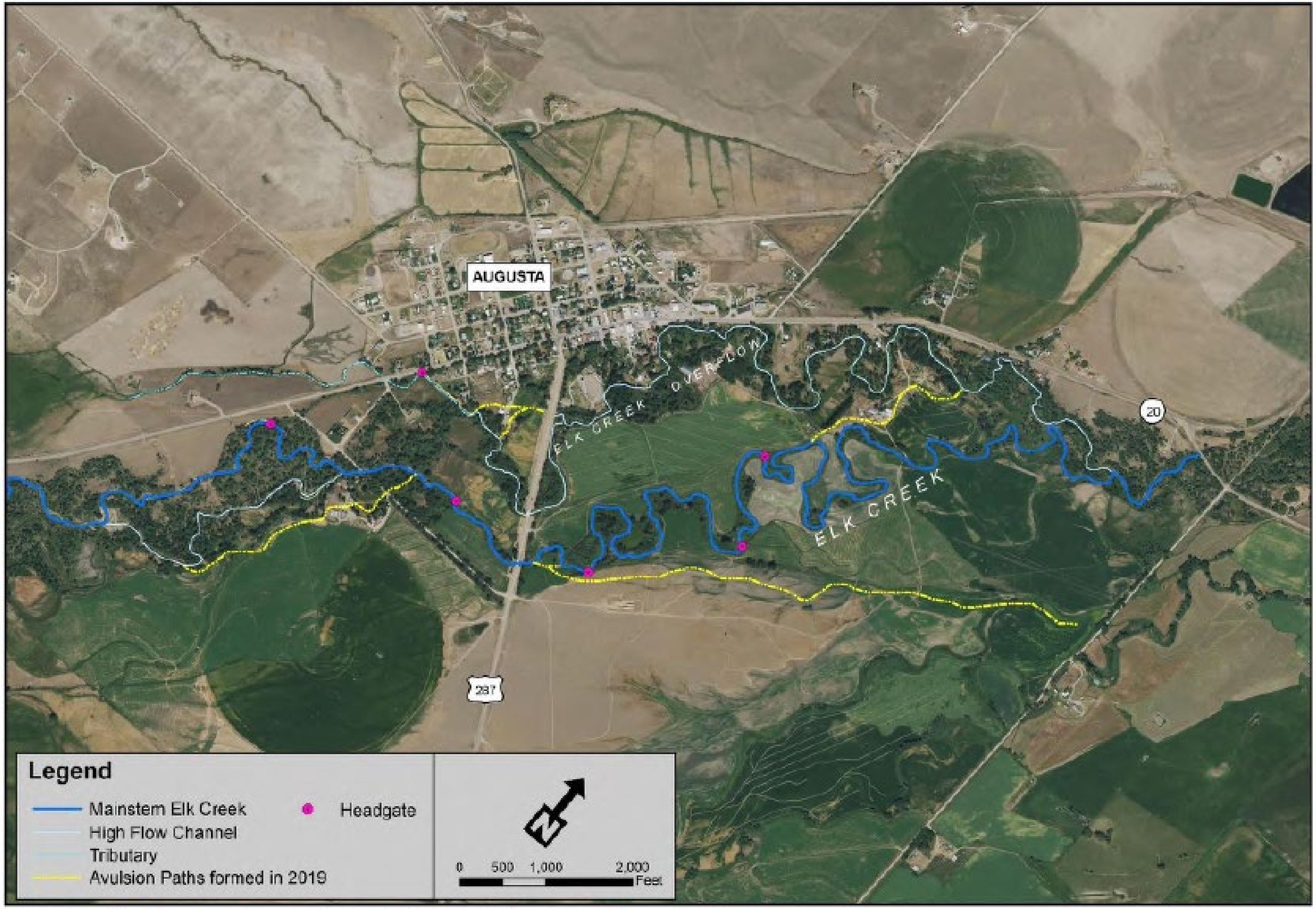


Figure 102. Avulsion paths formed during 2019 flood in the vicinity of Augusta.


Secondary 435 Hwy
Secondary 435 Hwy
Augusta
287
Gilman
21

REALIGN US HIGHWAY 287

- US HIGHWAY 287 IS A LARGE BOTTLENECK
- HIGH COST, LONG TERM
- EVALUATE EFFECTIVENESS IN MODEL
- COLLABORATE WITH MDT

View south across US Highway 287 showing damming of flood waters, flow from right to left.

Figure from the Post-Flooding Hydrological Assessment by Confluence and Applied Geomorphology (2020).

PERMITTING

- 310 PERMIT – LEWIS AND CLARK CONSERVATION DISTRICT
  - Work on bed or bank of perennial stream
- 404 – US ARMY CORPS OF ENGINEERS
  - Placing fill or dredging in Waters of US
- FLOODPLAIN PERMIT
  - Work within the FEMA 100-year floodplain
  - Issued by Lewis and Clark County

ONLINE SURVEY FOR COMMENTS

- HTTPS://WWW.SURVEYMONKEY.COM/R/JMY3GFJ
- COMMENT ON ANY FLOODING RELATED TOPIC
  - Emphasis on observations and mitigation ideas
- OPEN UNTIL 3/18

NEXT STEPS

- COLLECT COMMENTS AND FEEDBACK FROM THIS MEETING
- SIMULATE FEASIBLE ALTERNATIVES TO EVALUATE EFFECTIVENESS (MARCH ‘22)
- HOLD MEETING 2 (APRIL ‘22) TO PRESENT RESULTS AND RECOMMENDATIONS
- COLLECT COMMENTS AND FEEDBACK
- FINAL REPORT – JUNE ‘22

AUGUSTA FLOOD MITIGATION – FEBRUARY 2022 MEETING

QUESTIONS AND DISCUSSION

Photo by Mark Taylor

Photo by Lewis and Clark County

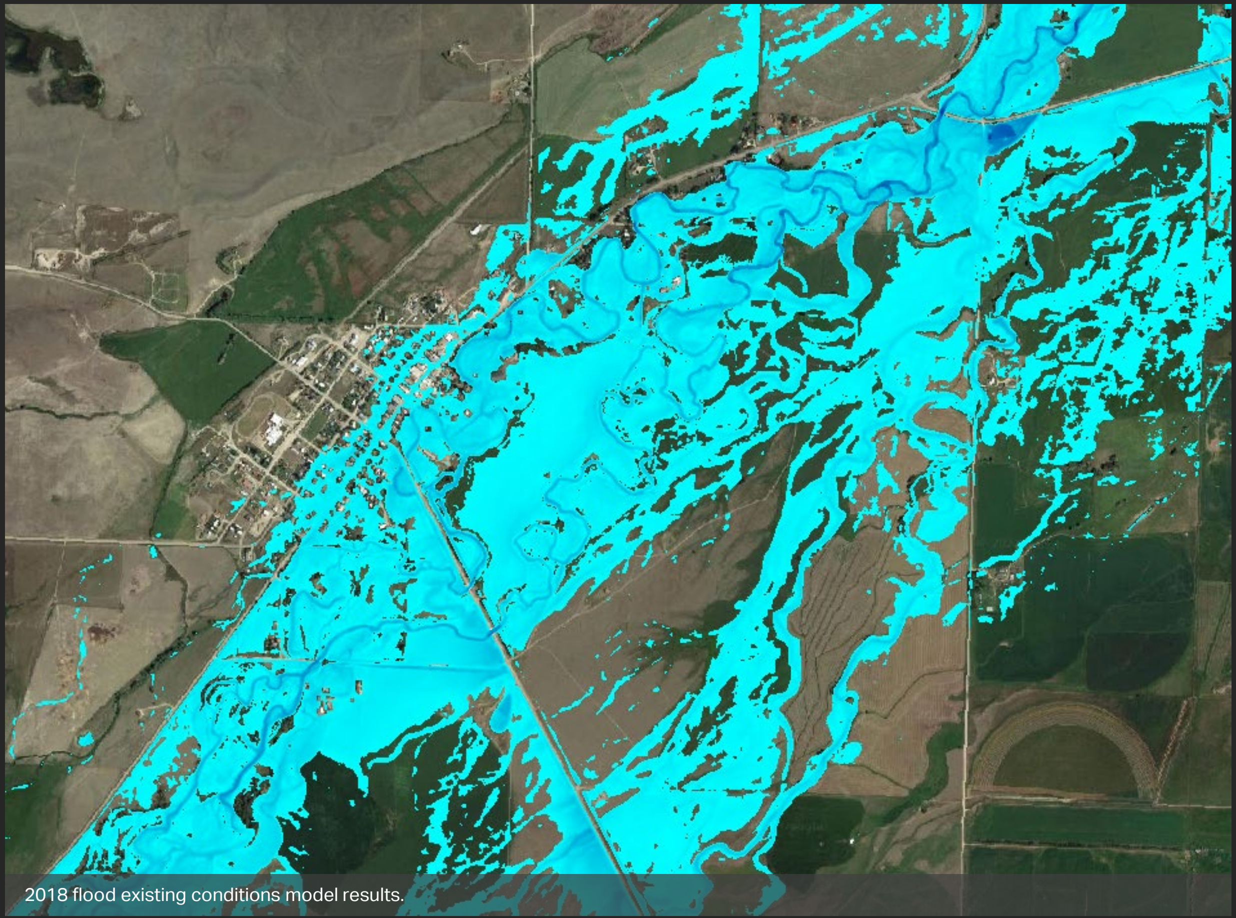
APPENDIX E
PUBLIC MEETING 1 ONLINE SURVEY RESPONSES

Q1 Please provide comment in the box below. Thank you.

Answered: 6 Skipped: 0

#	RESPONSES	DATE
1	I didn't get to attend the presentation but I did find the materials online. On the presentation materials, I found the following suggested mitigation: Route floodwaters away from high-risk areas › Utilize existing infrastructure: ⁄ IrrigationditchessuchasHogan'sSlough My property borders Hogan's Slough and according to FEMA and Lewis and Clark Couny Planning, it is OUT OF THE FLOOD PLAIN. If you divert water into Hogan's Slough, you are now putting my property in danger of flooding according to the accompanying map, which shows my property in blue. If you change the character and flood danger of my property, I will have no choice but to sue the county.	3/8/2022 5:14 AM
2	While the outlined strategies listed above may help mitigate most flooding, the best method will include developing an Elk Creek reservoir that could be used to hold back water at a critical time when flooding is occurring. The side benefit would include additional irrigation, recreation, and wildlife habitat. This method, albeit a huge undertaking is the best mitigation approach.	3/5/2022 3:27 AM
3	At the meeting in Augusta Russell Alt gave you good info Have Russell, Ben Arps , others that have lived there all there lives (over 60) to help you	3/4/2022 9:38 AM
4	One of the problems contributing to flooding is the loss of the streams access to the floodplain. While it is very evident that 287 is acting as a back up and one of the biggest contributors to flooding in town, it should also be evaluated where upstream the stream and floodplain can be restored to provide a more natural functioning floodplain that can help contribute to reducing flood peaks and duration downstream. Similar to Roundup where they need to address upstream to help reduce their flood hazards. The county/state should look at means to work with local landowners to incentivize this work for the benefit of the community as a whole. Not a revolutionary idea, health floodplains help reduce downstream flooding. The county should also look at the increase in SRF funding and the possibility to use their programs to secure funding to accomplish this.	3/4/2022 7:47 AM
5	I was not at the public meeting but I have been involved with Elk Creek issues for over 30 years. I realize this is not very long compared to the local residents that have lived there their entire life BUT I have an objective view because helping with actual on-the-ground projects with private landowners, irrigators, MDT, LCCD, and others. With the projects there was one common, easily identifiable issue - humans wanting to control water under all conditions. Floods like 53, 64 and 75 are just too much to attempt to stop ALL water from reaching the town of Augusta. BUT, if you want to accomplish projects that will matter, then incorporate some that have been brought up including: 1) eliminating ALL in-stream and bypass channel culverts immediately below, in and immediately above Augusta so there is significantly less chance of plugging and backing up water; 2) increase size of bridges so there is almost no chance for them to plug OR back up water like highways 287 and 21 does - this is because MDT feels ok to back up some water; 3) remove all fences that cross the creek that cause blockage; 4) modify irrigation diversions so they do not cause problems with debris or slowing water; and 5) make it VERY clear that some flooding cannot be stopped and if the locals really want flooding to stop then the whole town must be relocated like some were in the midwest. Hope this helps.	3/4/2022 7:34 AM
6	We live at . We had to sand bag our house and yard both years. Our flood insurance is very expensive and any type of mitigation would be appreciated. Thank you	3/4/2022 7:06 AM

APPENDIX F
PUBLIC MEETING 2 SLIDES



2018 flood existing conditions model results.

Aerial photo of 2018 flooding at Augusta and Highway 287, courtesy of Montana Department of Transportation.

RESPEC

ELK CREEK FLOOD MITIGATION ALTERNATIVES

AUGUSTA, MONTANA

LEWIS AND CLARK COUNTY

MAY 6, 2022

PRESENTATION OUTLINE

- Recap from Meeting 1 and Public Comment Summary
- Mitigation Alternatives
- Cost Comparison
- Considerations
- Recommended Alternatives and Phasing
- Permitting
- Next Steps
- Discussion

RECAP FROM MEETING 1 AND PUBLIC COMMENTS

- Existing Conditions Hydraulic Analysis
  - Utilized measured flows at USGS gage
    - USGS 06084500 Elk Creek at Augusta MT
  - All flooding sources modeled in one 2D area
  - Bridges and Culverts based on RPA survey and field measured elevations
  - Study area:
    - Upstream Extent: 0.5 mi NE of Smith and Elk Creek confluence
    - Downstream Extent: 0.25 mi NE of abandoned railroad berm east of Augusta
  - Simulated the Existing Conditions (EX) – 1964, 1975, 2018 floods
    - Focused mitigation on 2018 flood

RECAP FROM MEETING 1 AND PUBLIC COMMENTS

- Public Comments Summary
  - Concern for diverting flow to Hogan Slough and implications to flood risk and FEMA FIRM
  - Elk Creek Reservoir
  - Floodplain restoration, SRF opportunity?
  - Reduce blockages, debris, and backwater. Relocate the town?

CONSIDERATIONS

- ALTERNATIVES ARE NOT FINAL DESIGN
- NEED DESIGN AND PERMITTING TO IMPLEMENT

MITIGATION ALTERNATIVES

1. Backwater Improvement Concepts
2. Diversion Concepts
3. Berm Implementation Concepts

BACKWATER IMPROVEMENT CONCEPTS

1. Channel and floodplain debris cleaning
2. US 287 removal
3. US 287 bridge opening size increase
4. US 287 re-alignment

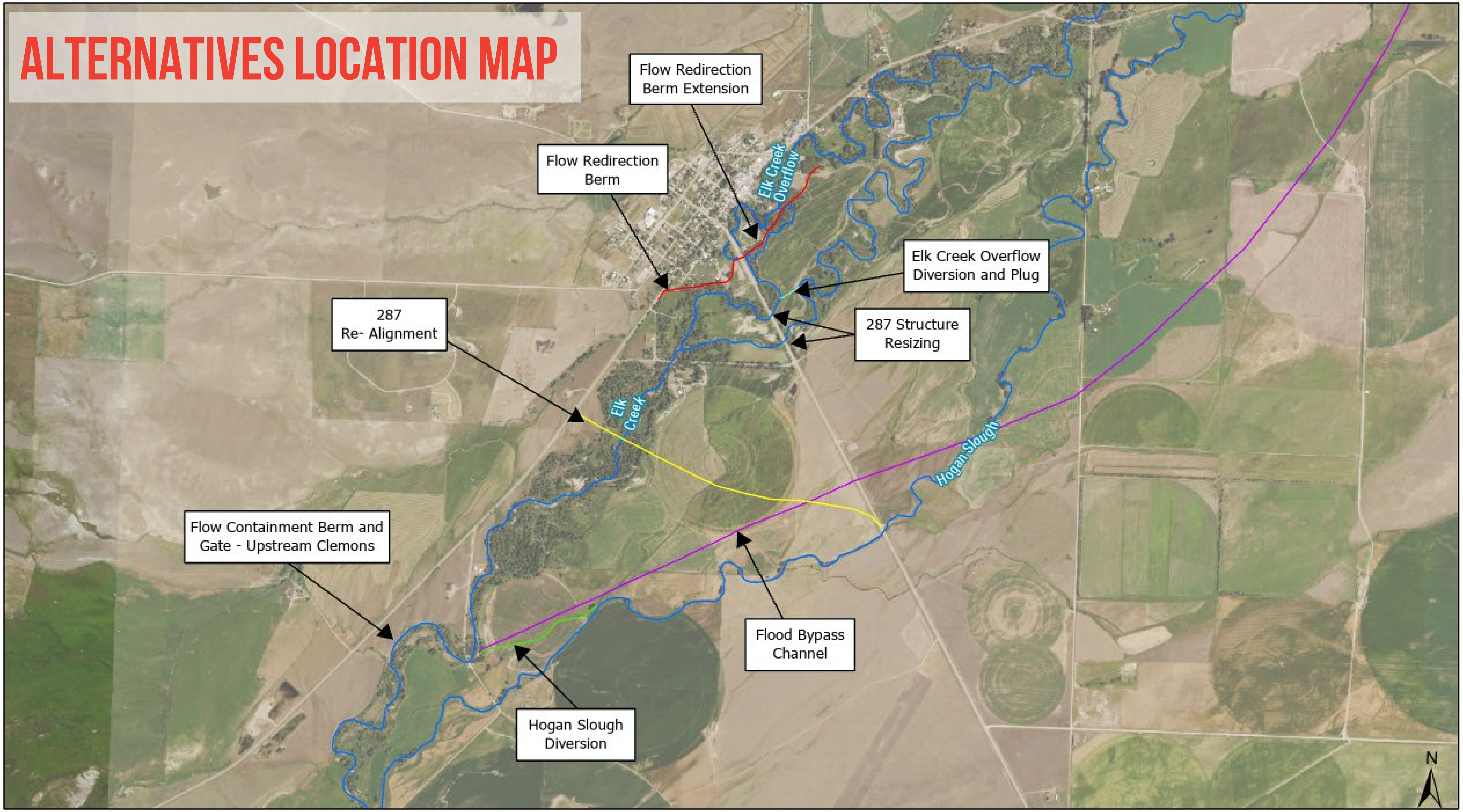
DIVERSION CONCEPTS

1. Florence Canal diversion
2. Flow diversion from Elk Creek Overflow to Elk Creek
3. Hogan Slough diversion
4. Flood bypass channel

BERM IMPLEMENTATION CONCEPTS

1. Flow containment berm and gate upstream of Augusta Clemons Rd
2. Flow redirection berm
3. Flow redirection berm with extension

ALTERNATIVES LOCATION MAP



CHANNEL AND FLOODPLAIN CLEARING

- CHANNEL AND FLOODPLAIN CLEARING
  - Will help to lower flooding depths in debris build-up locations
  - Overall small depth reductions throughout model
  - Low cost
  - Coordinated effort with the CD and FWP
  - Annual monitoring and maintenance

Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

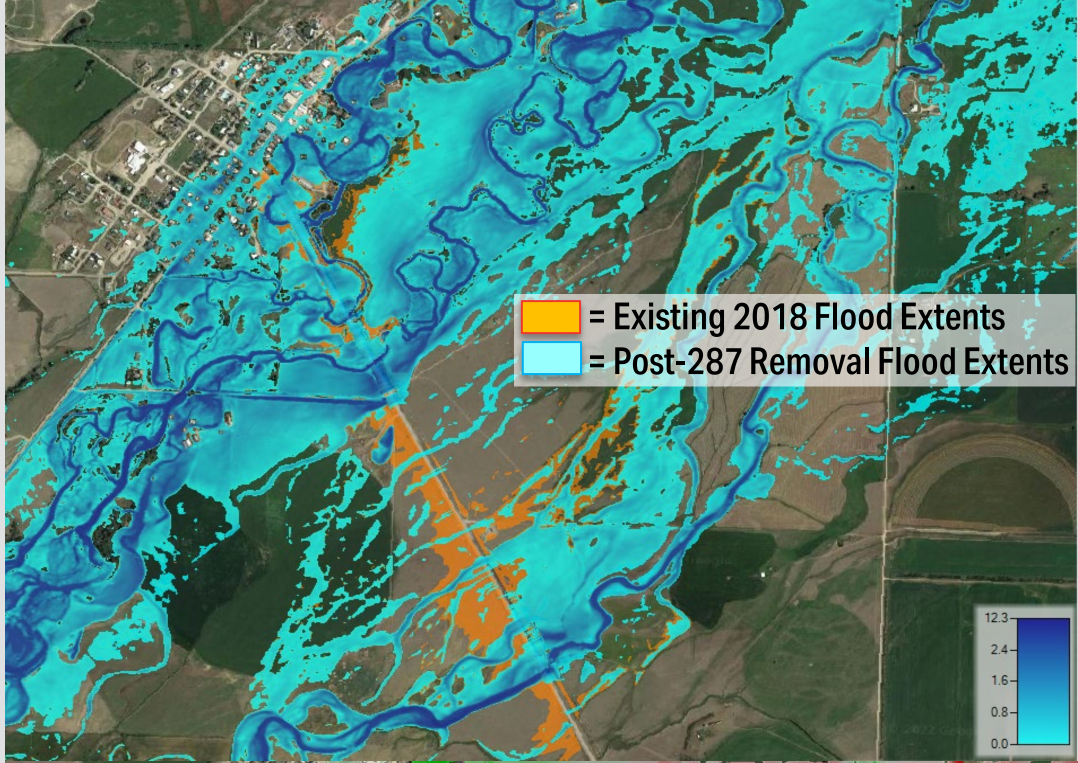
Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37%	43%	20%
Channel and Floodplain Debris Clearing	38%	43%	19%

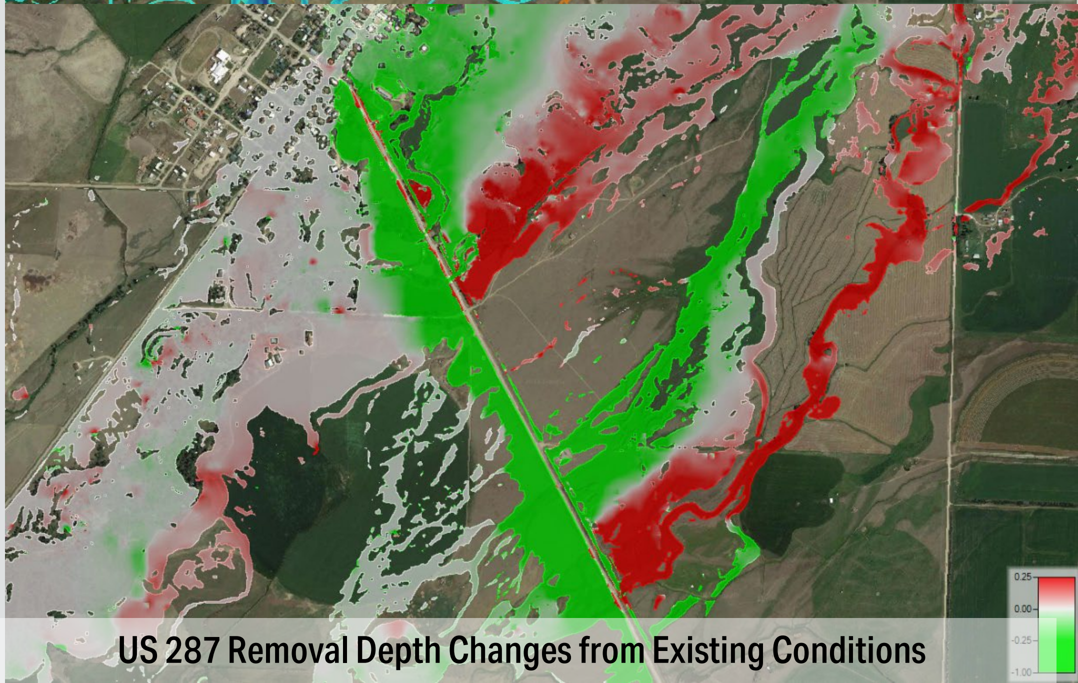
US 287 REMOVAL

- REMOVE HIGHWAY 287 AND STRUCTURES TO LIMIT BACKWATER FROM ROADWAY EMBANKMENT
- HIGH COST, SMALL FLOW REDUCTION THROUGH TOWN AND THE ELK CREEK OVERFLOW CHANNEL (~550 CFS)

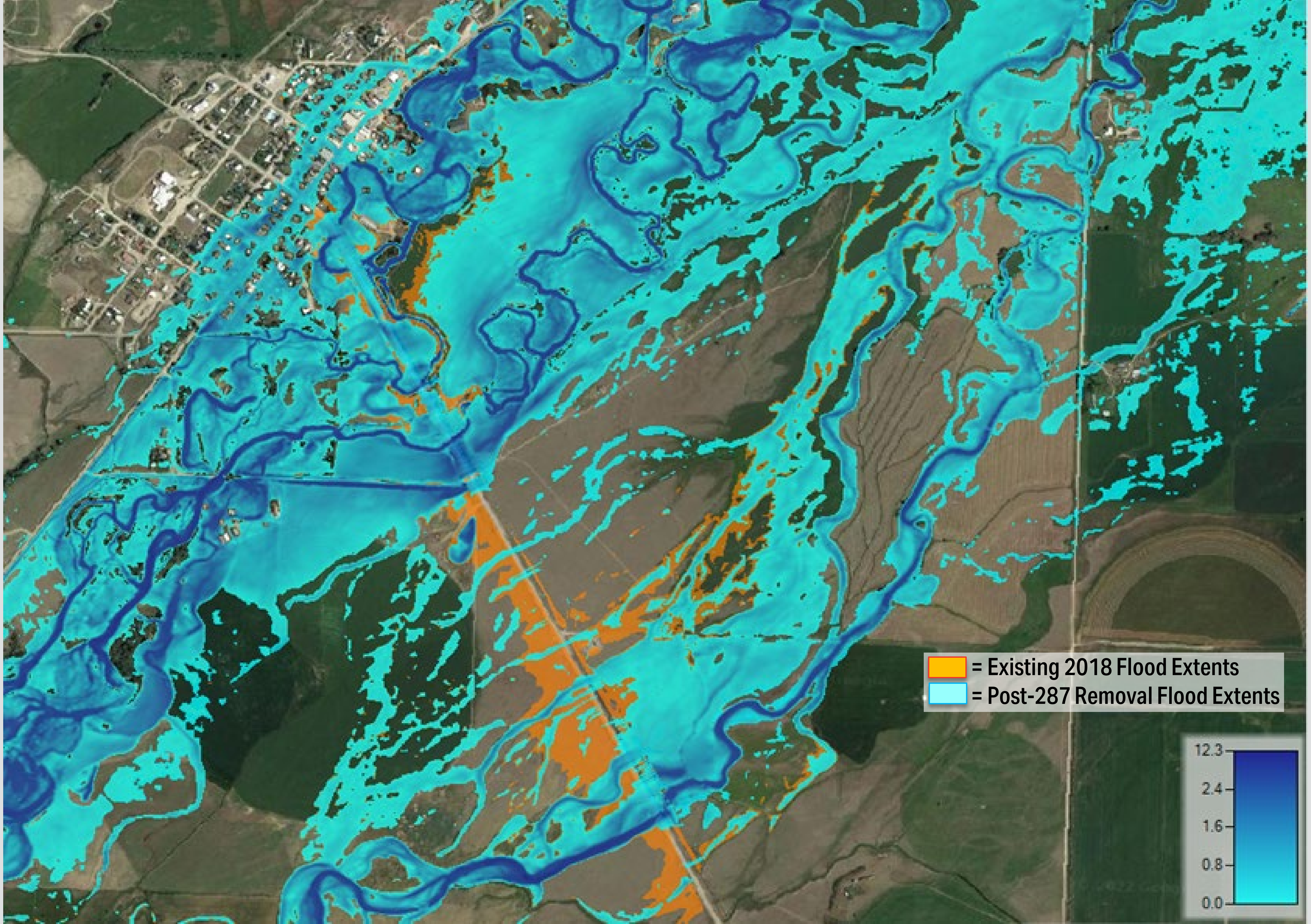
Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

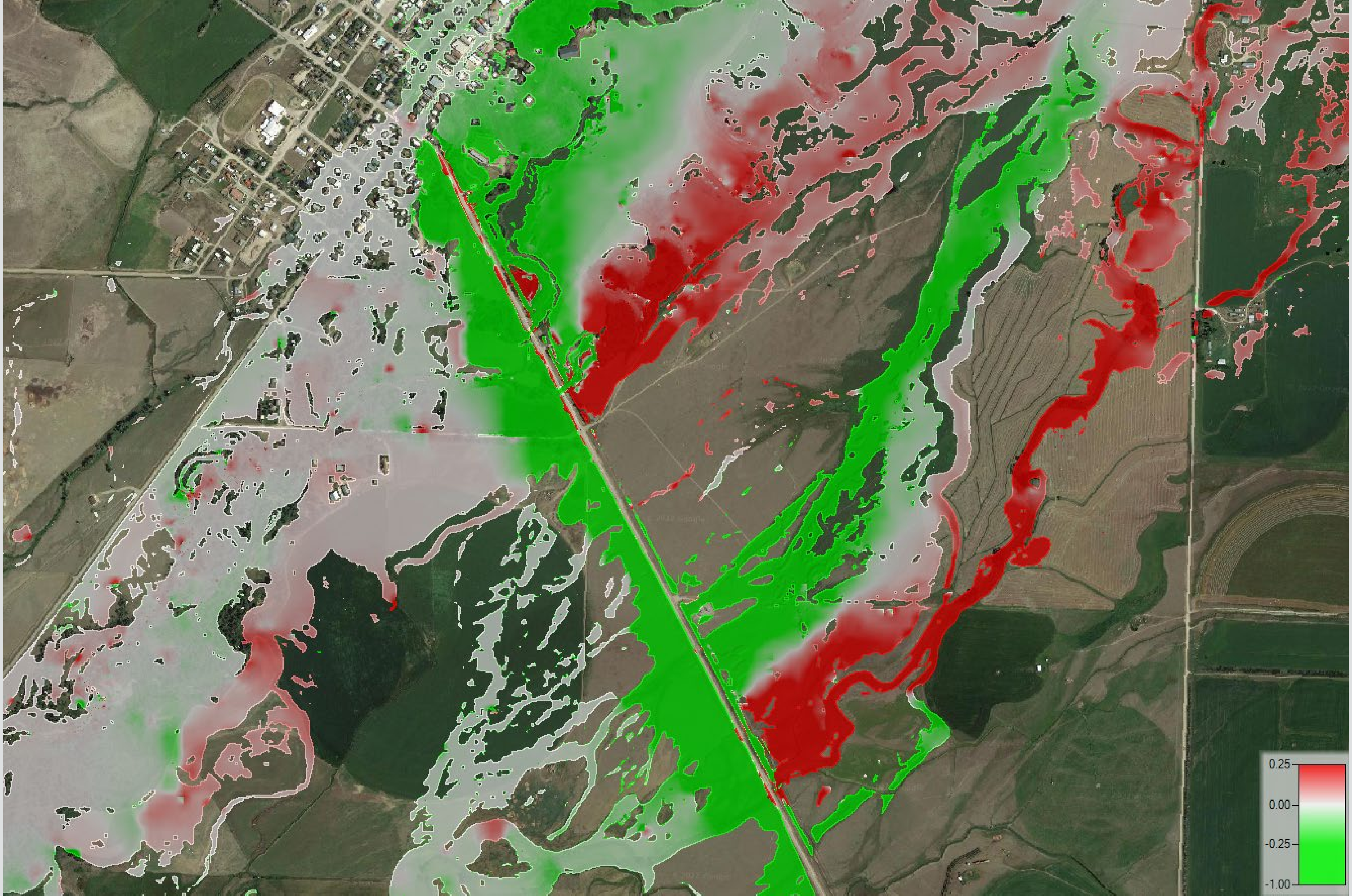
Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20.0%
US 287 Removal	28.7%	49.9%	21.4%





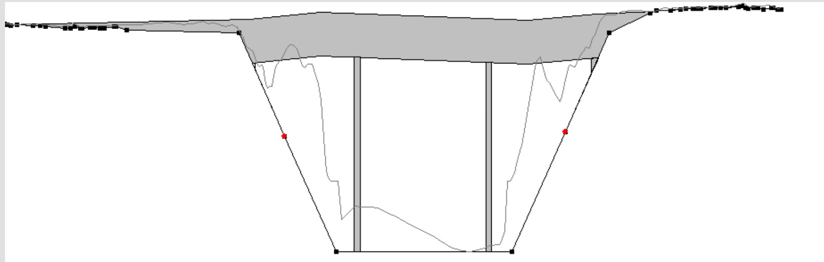
US 287 Removal Depth Changes from Existing Conditions


= Existing 2018 Flood Extents
= Post-287 Removal Flood Extents
12.3
2.4
1.6
0.8
0.0

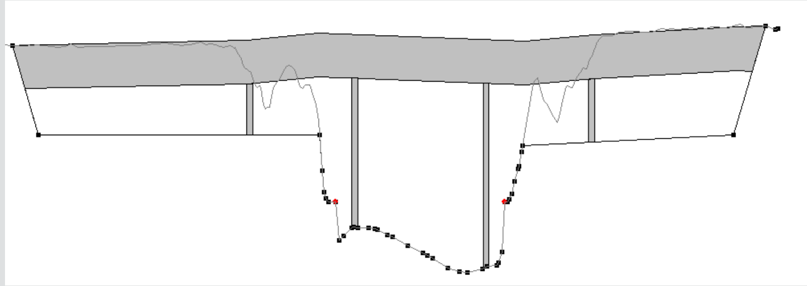

0.25
0.00
-0.25
-1.00

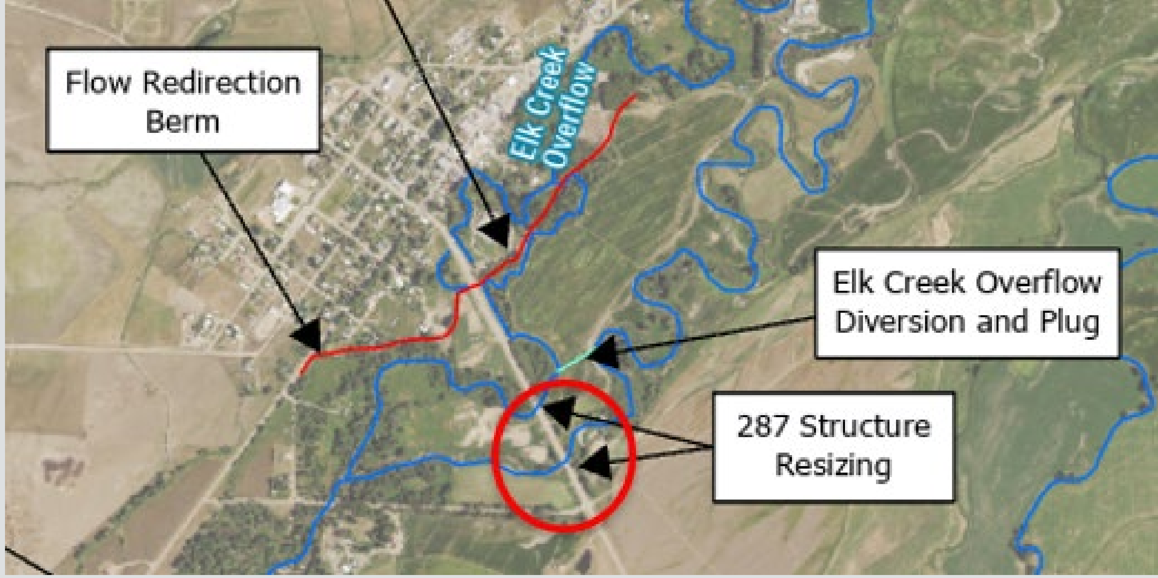
287 STRUCTURE RESIZING

a. Channel widening

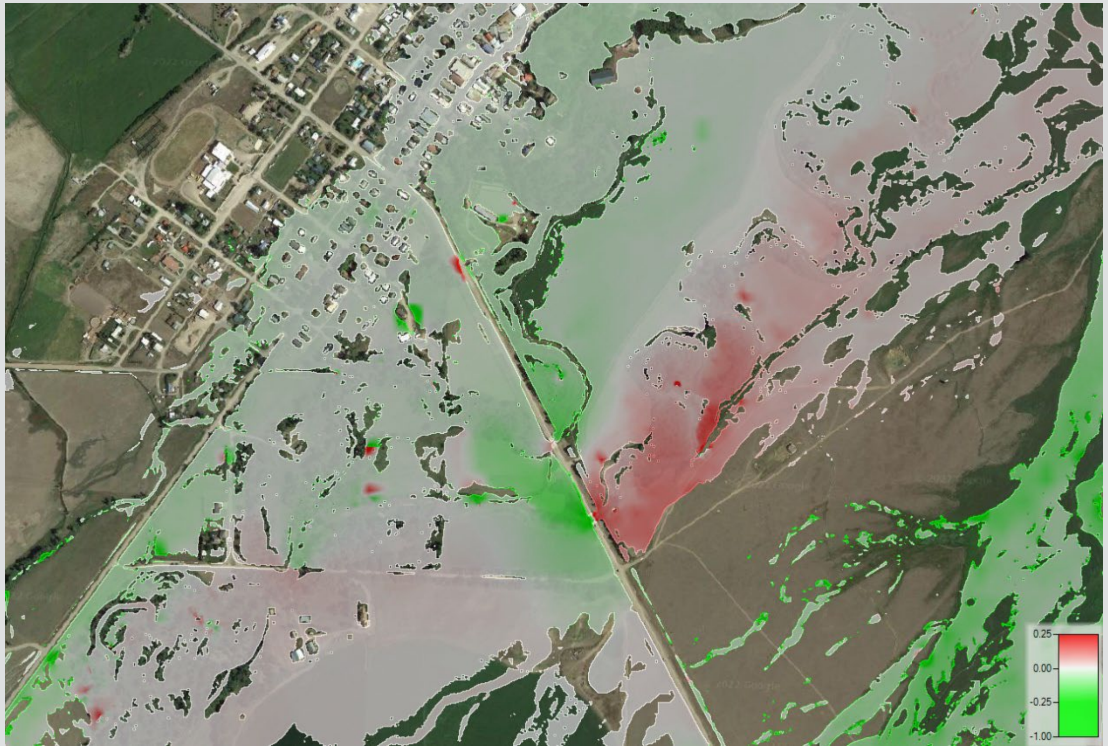


b. Addition of floodplain elevation level benches



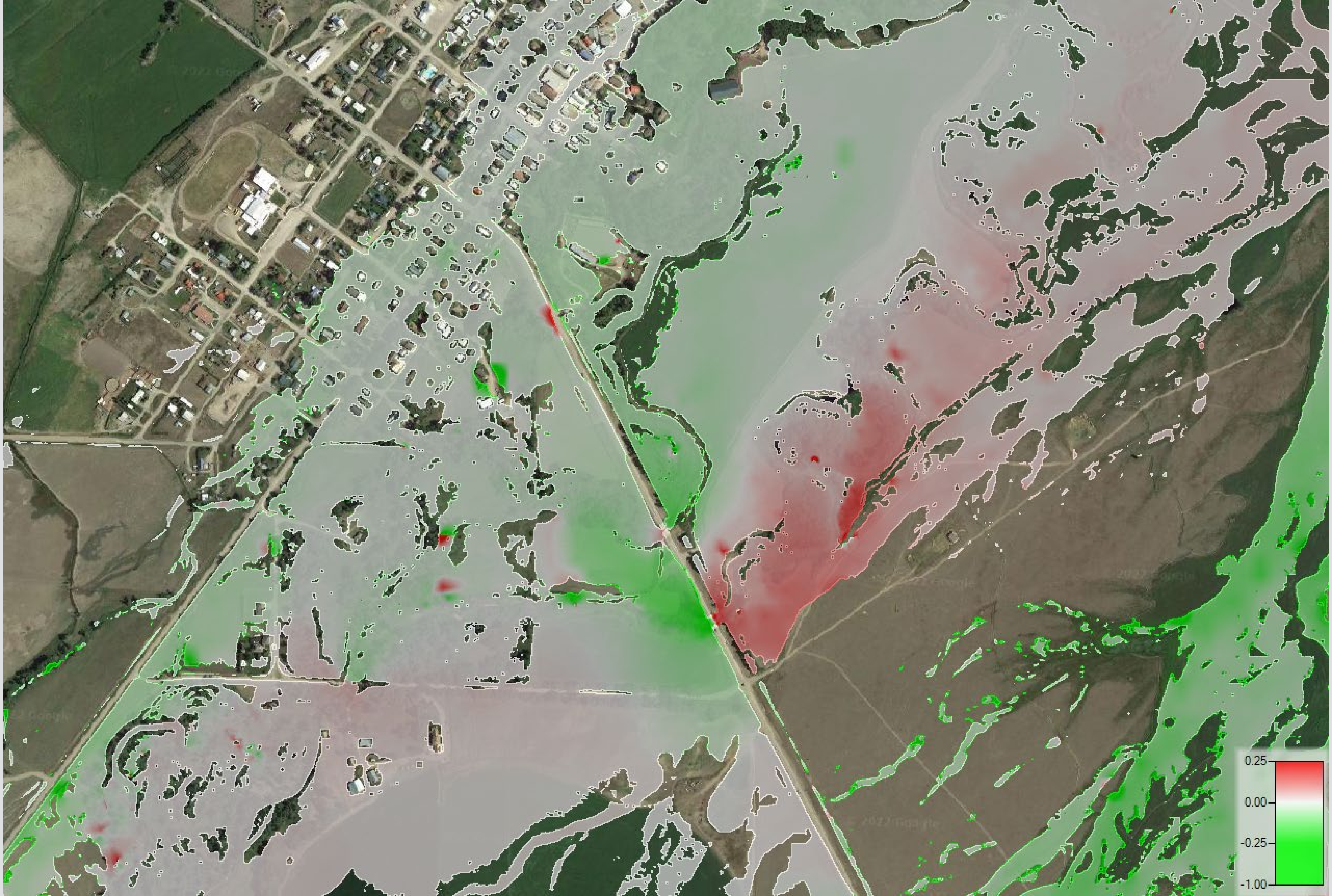


Structure Resizing Depth Changes from Existing Conditions



Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20%
Channel Widening	35.9%	44.1%	20.0%
Floodplain Level Benches	35.7%	44.4%	19.9%

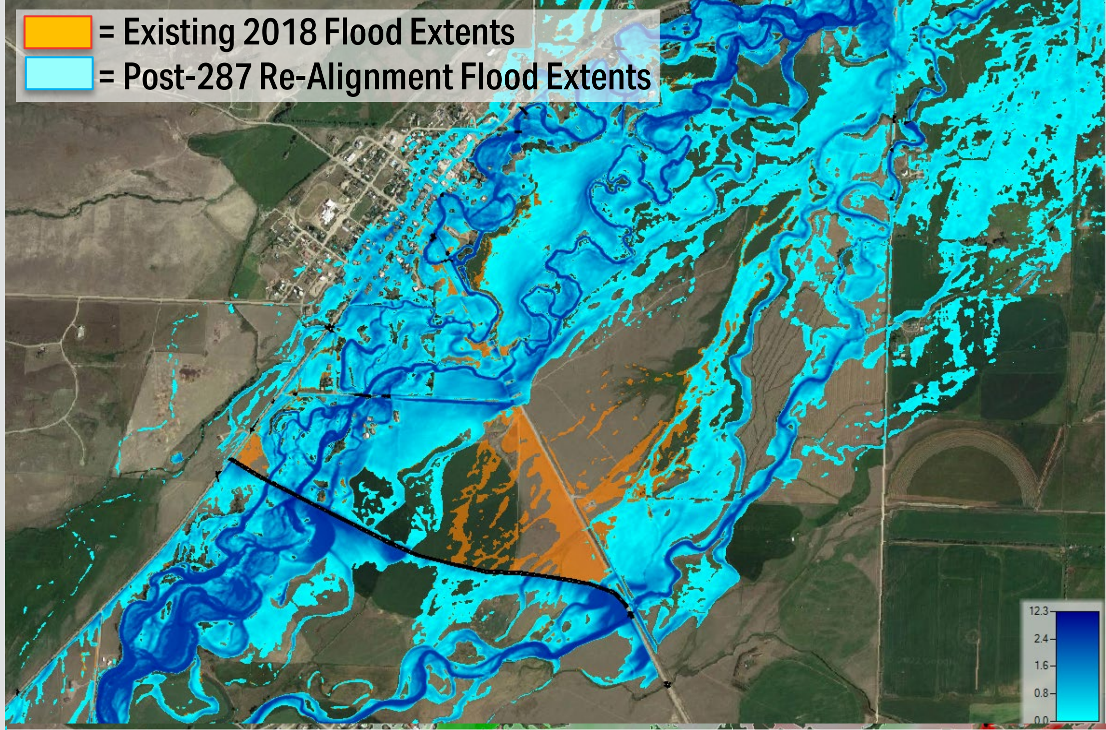

0.25
0.00
-0.25
-1.00

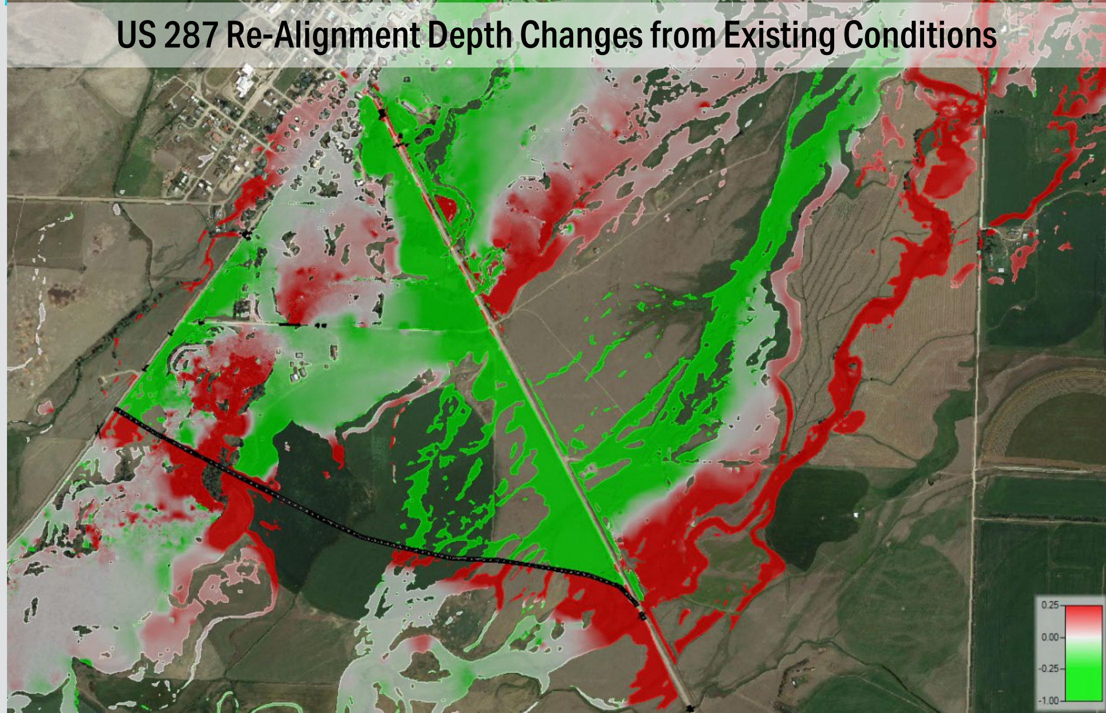
US 287 REMOVAL AND RE-ALIGNMENT

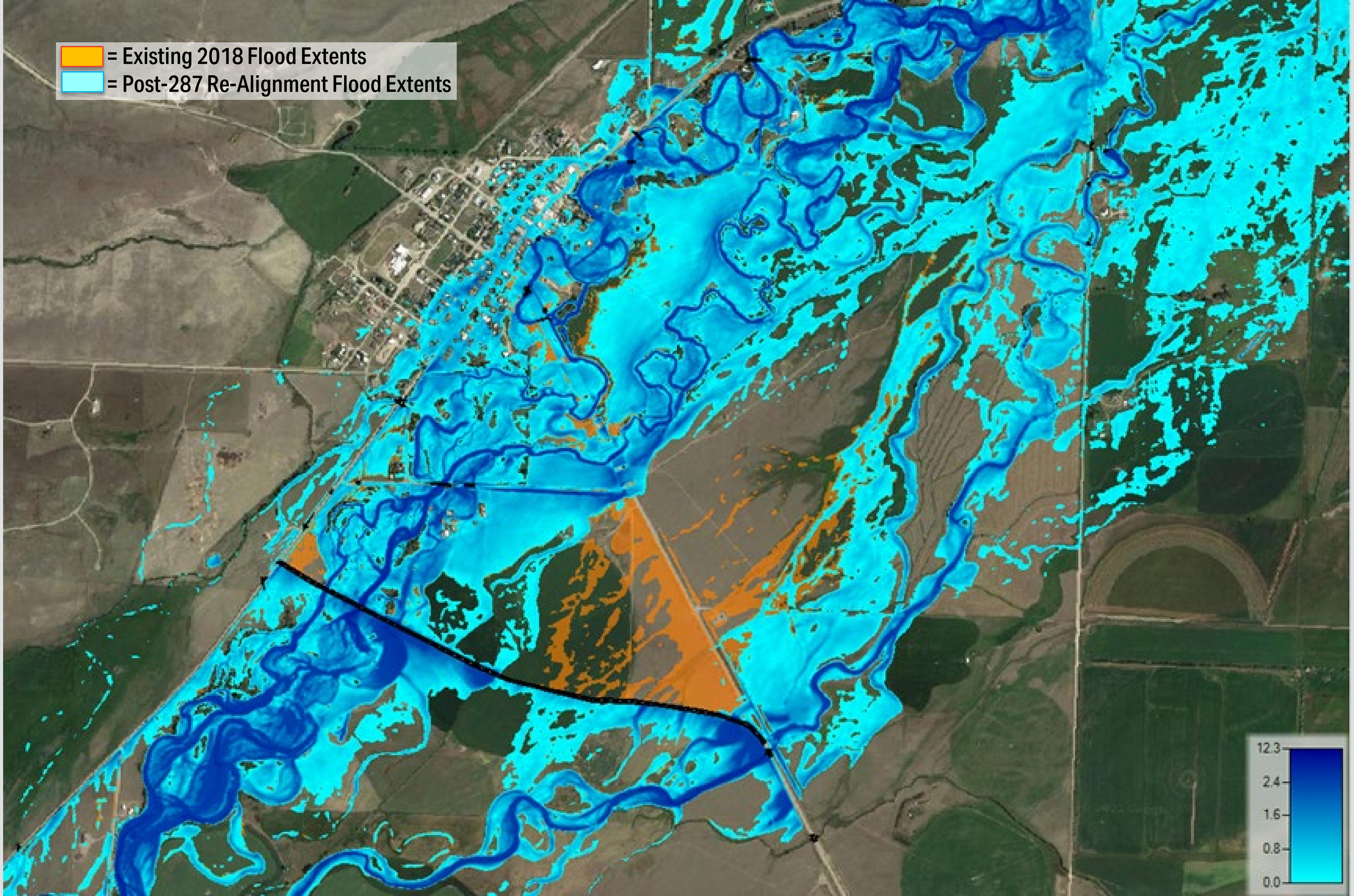
- RE-ALIGN 287 TO BE MORE PERPENDICULAR TO FLOODPLAIN
- HIGH COST, SMALL FLOW REDUCTION THROUGH TOWN AND THE ELK CREEK OVERFLOW CHANNEL (~450 CFS)

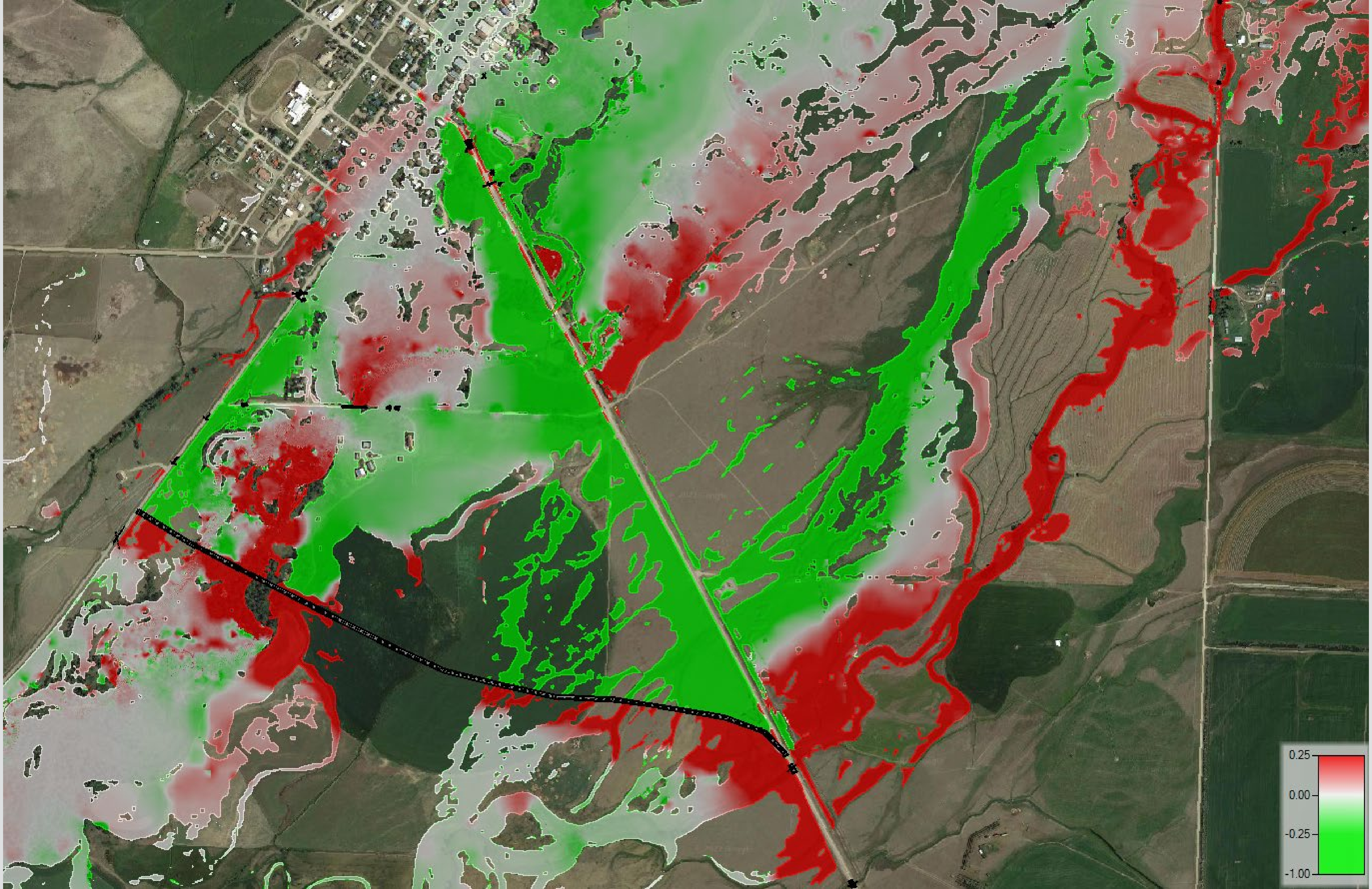
Model Results Percentage of Total Flow In Each Region Just Downstream of the existing US 287

Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20%
US 287 Re-Alignment	30.3%	44.8%	24.9%



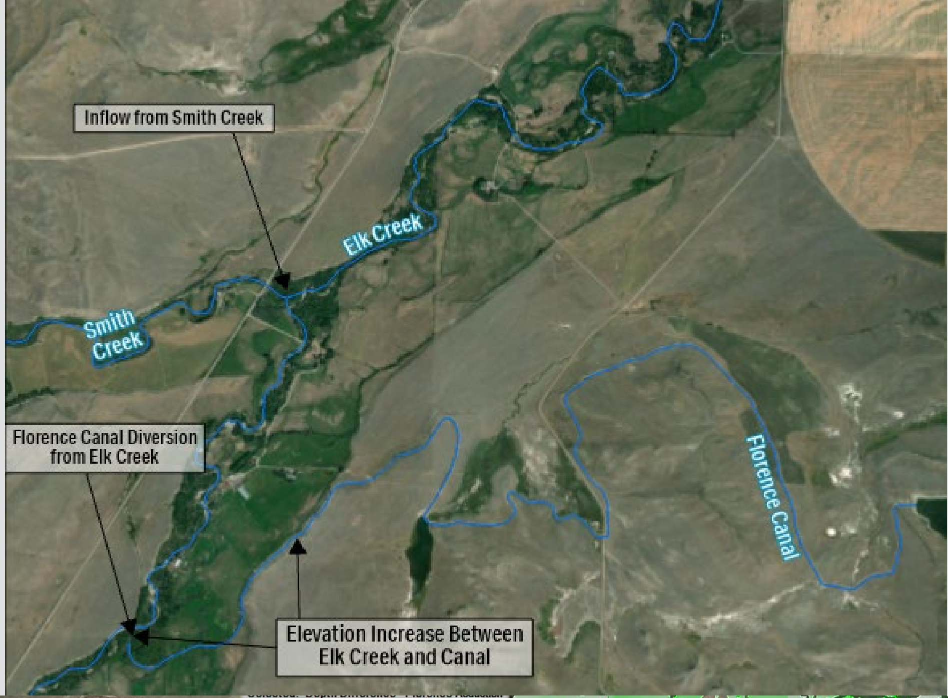



= Existing 2018 Flood Extents
= Post-287 Re-Alignment Flood Extents
12.3
2.4
1.6
0.8
0.0


0.25
0.00
-0.25
-1.00

FLORENCE CANAL DIVERSION

- LOW-CAPACITY CANAL (~500 CFS)
- PERCHED CANAL ABOVE FLOODPLAIN
- APPROXIMATELY A 0.05' DECREASE OF DEPTH IN ELK CREEK OVERFLOW JUST DOWNSTREAM OF US 287
- SMALL DEPTH DECREASES




0.25
0.00
-0.25
-1.00

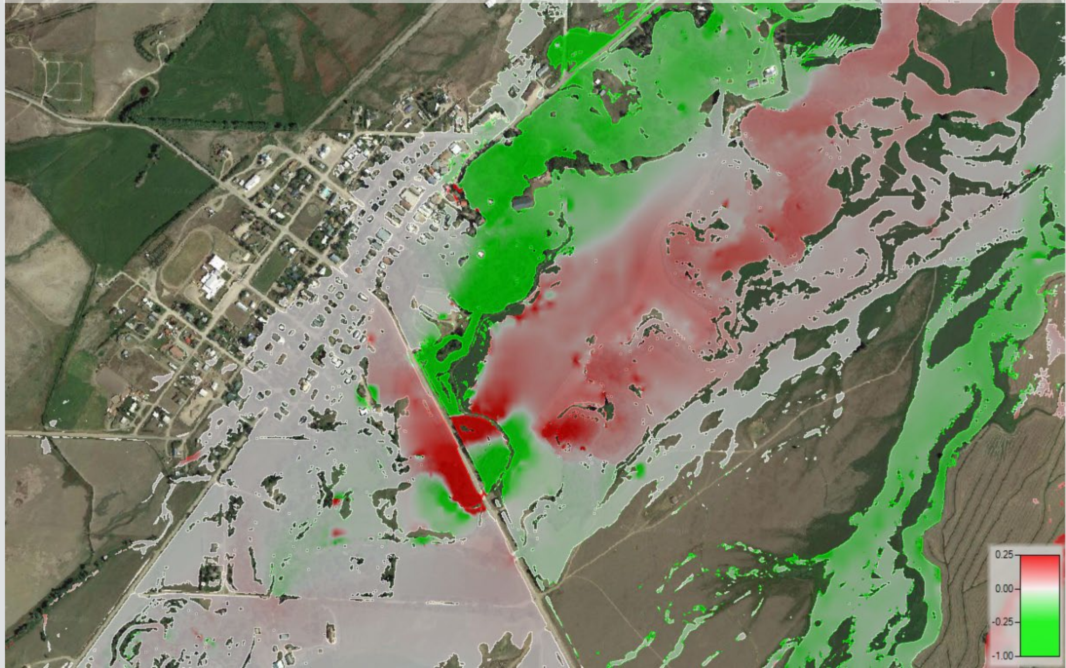
ELK CREEK OVERFLOW DIVERSION

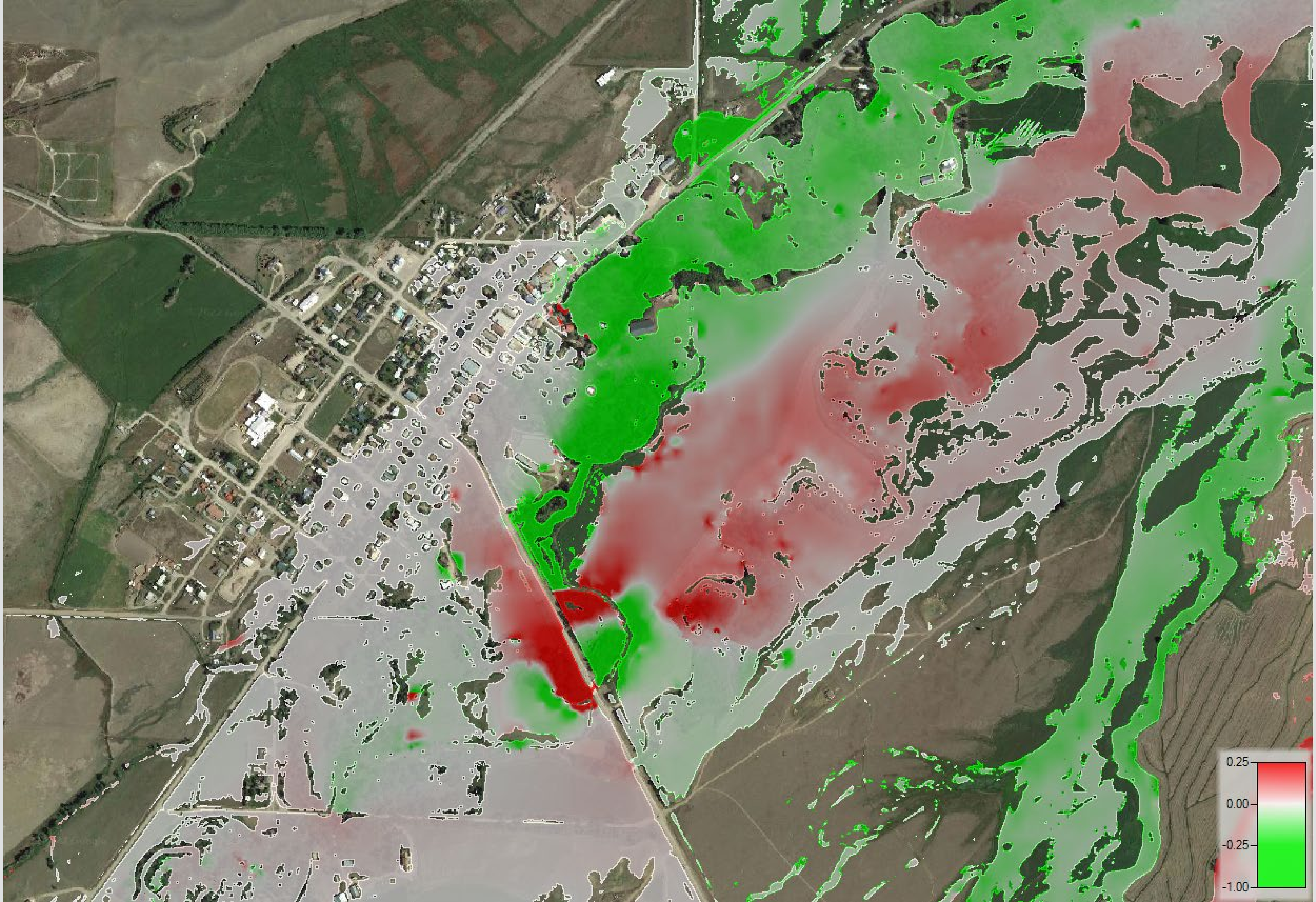
- **DIVERT FLOW BACK INTO ELK CREEK MAIN AT FLOOD STAGES**
  - Small channel creation connecting Elk Creek Overflow and Elk Creek Main
  - Plug Elk Creek Overflow
  - Downstream bank stabilization efforts
  - Consider prevention of backwater into culverts to support

Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20%
Elk Creek Overflow Diversion	31.4%	48.7%	19.9%

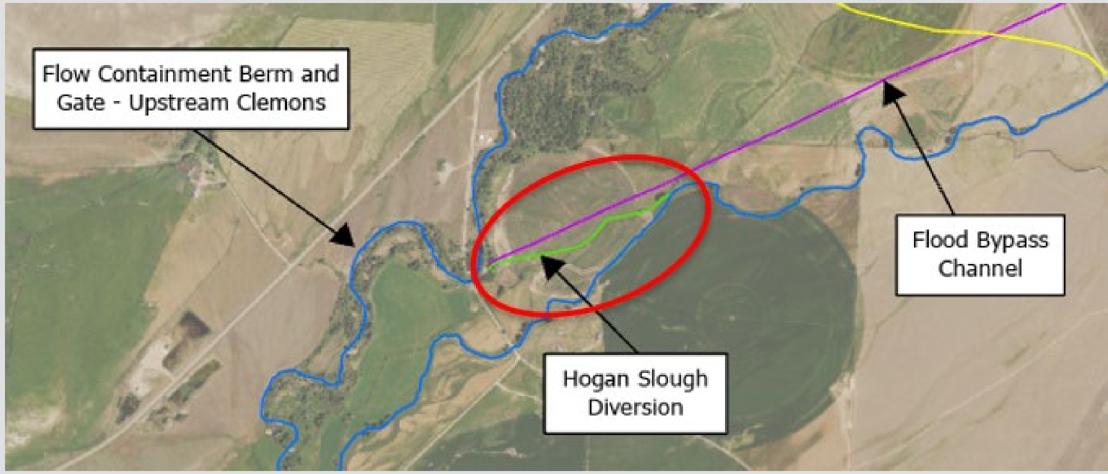
Elk Creek Overflow Diversion Depth Changes from Existing Conditions



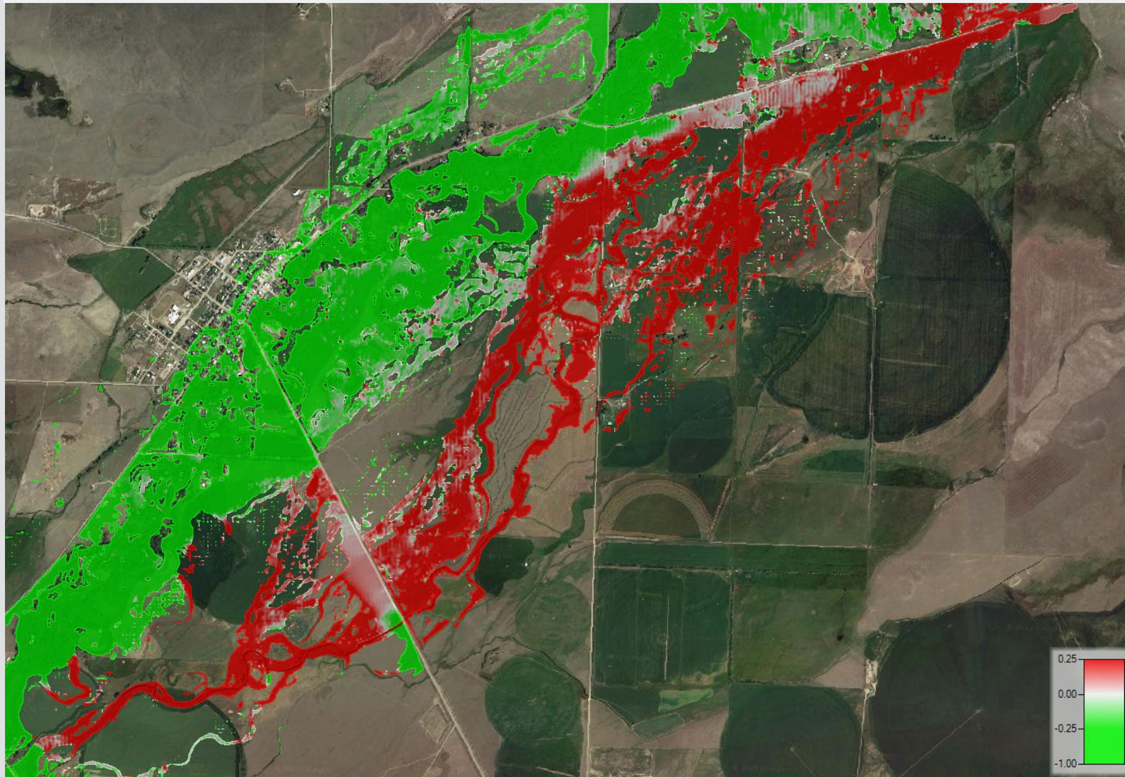

0.25
0.00
-0.25
-1.00

HOGAN SLOUGH DIVERSION

- **DIVERT FLOW INTO HOGAN SLOUGH AT FLOOD STAGES**
  - Small channel creation connecting Elk Creek and Hogan Slough
  - As currently modeled, diverts ~3000 cfs at flood stages
  - Extents
  - Includes resizing of US 287 crossing
    - Larger culvert
    - Bridge

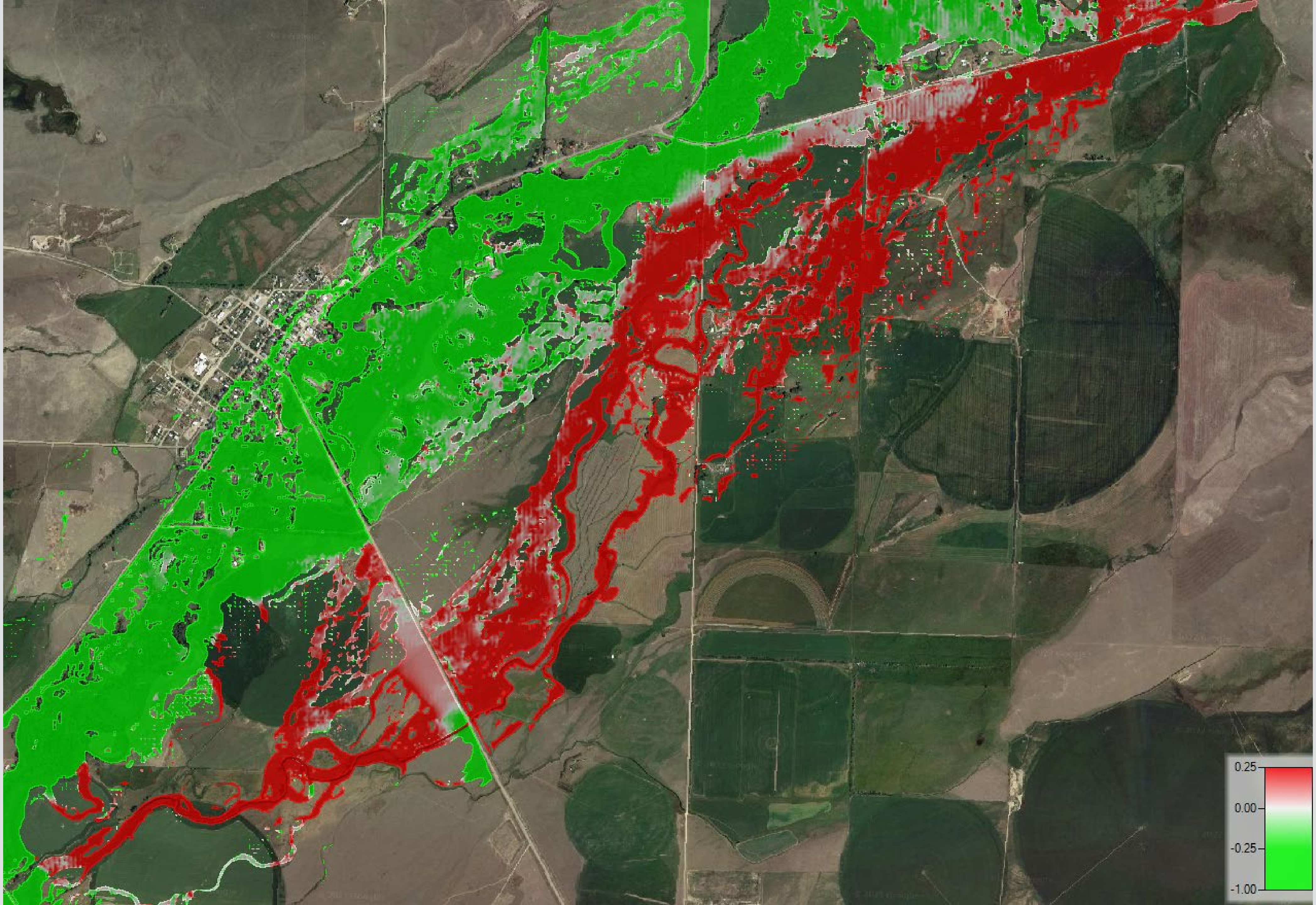


Hogan Slough Diversion Depth Changes from Existing Conditions



Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20.0%
Hogan Slough Diversion	17.3%	25.0%	57.7%

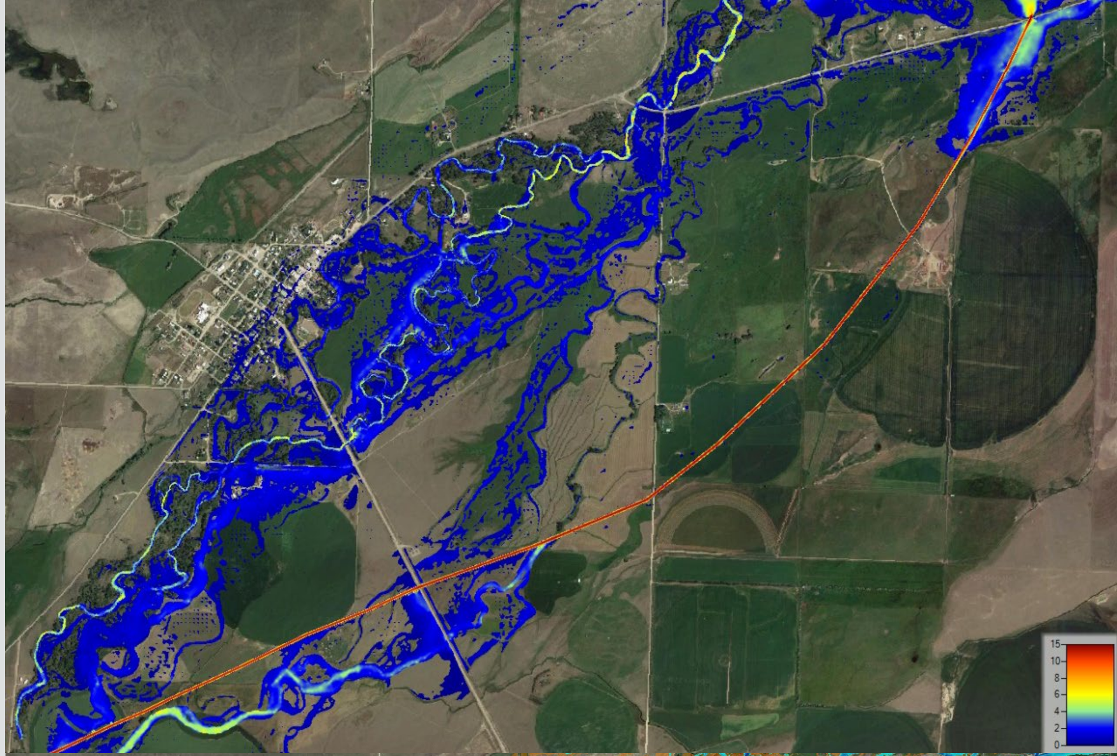

0.25
0.00
-0.25
-1.00

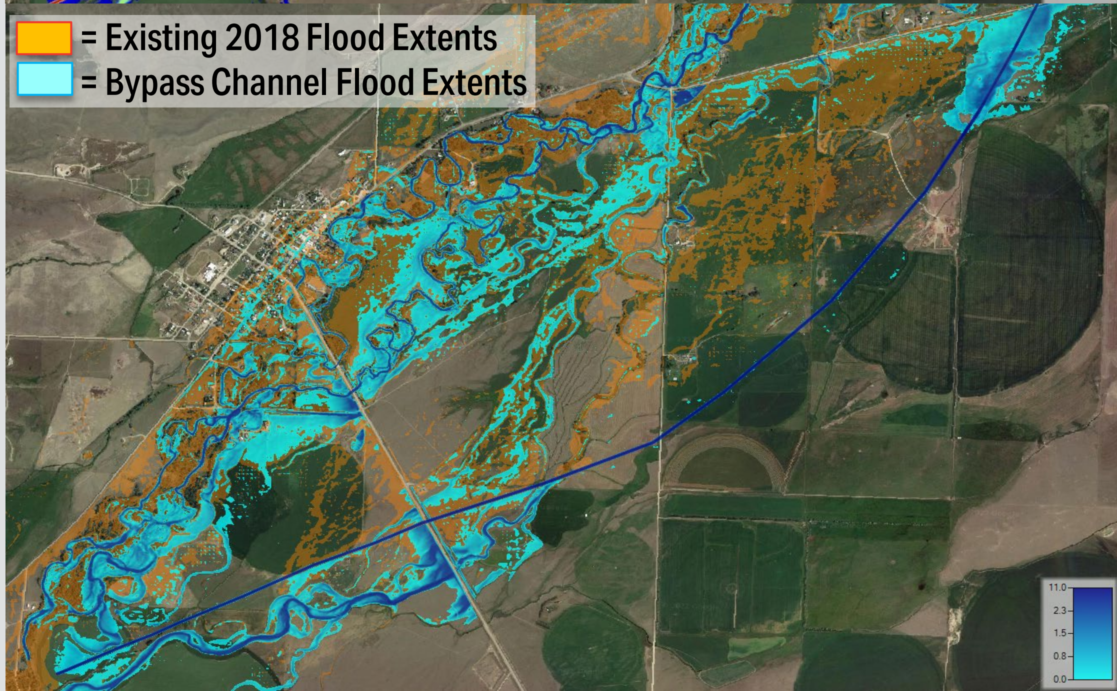
FLOOD BYPASS CHANNEL

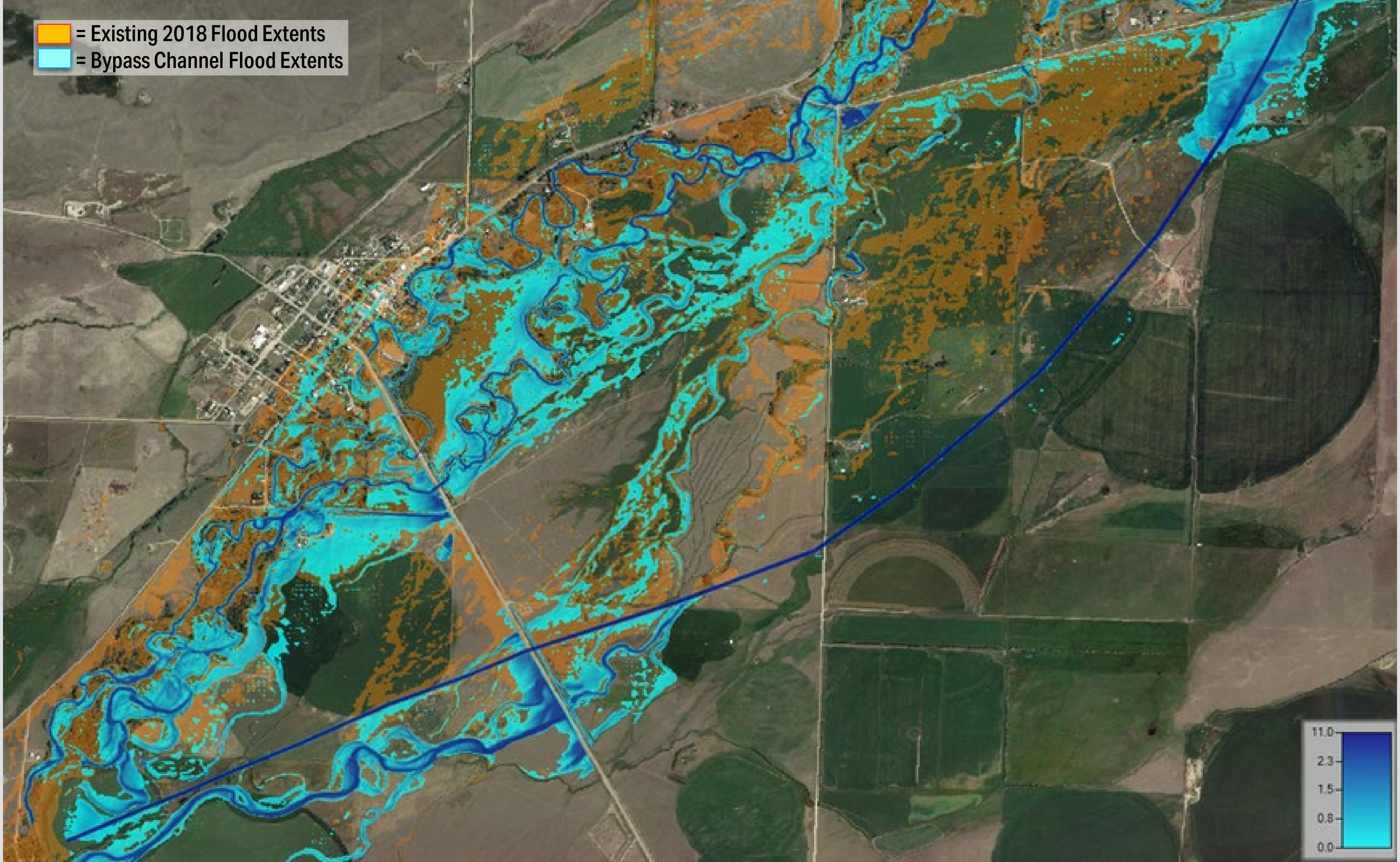
- EXAMPLE OF A FLOOD BYPASS CHANNEL
- CURRENT DESIGN CAPACITY OF 7000 CFS
- DIVERT MOST OF FLOWS INTO CHANNEL, MAINTAIN ~500 CFS IN ELK CREEK MAIN AT FLOOD STAGES
- HIGH VELOCITIES WITHIN CHANNEL (~12 FT/S IN THIS MODEL)
- OTHER ALTERNATIVES CAN STEM FROM THIS
  - Balance/optimize velocities, sediment transport, and cultivability
  - Example: Farmable swale

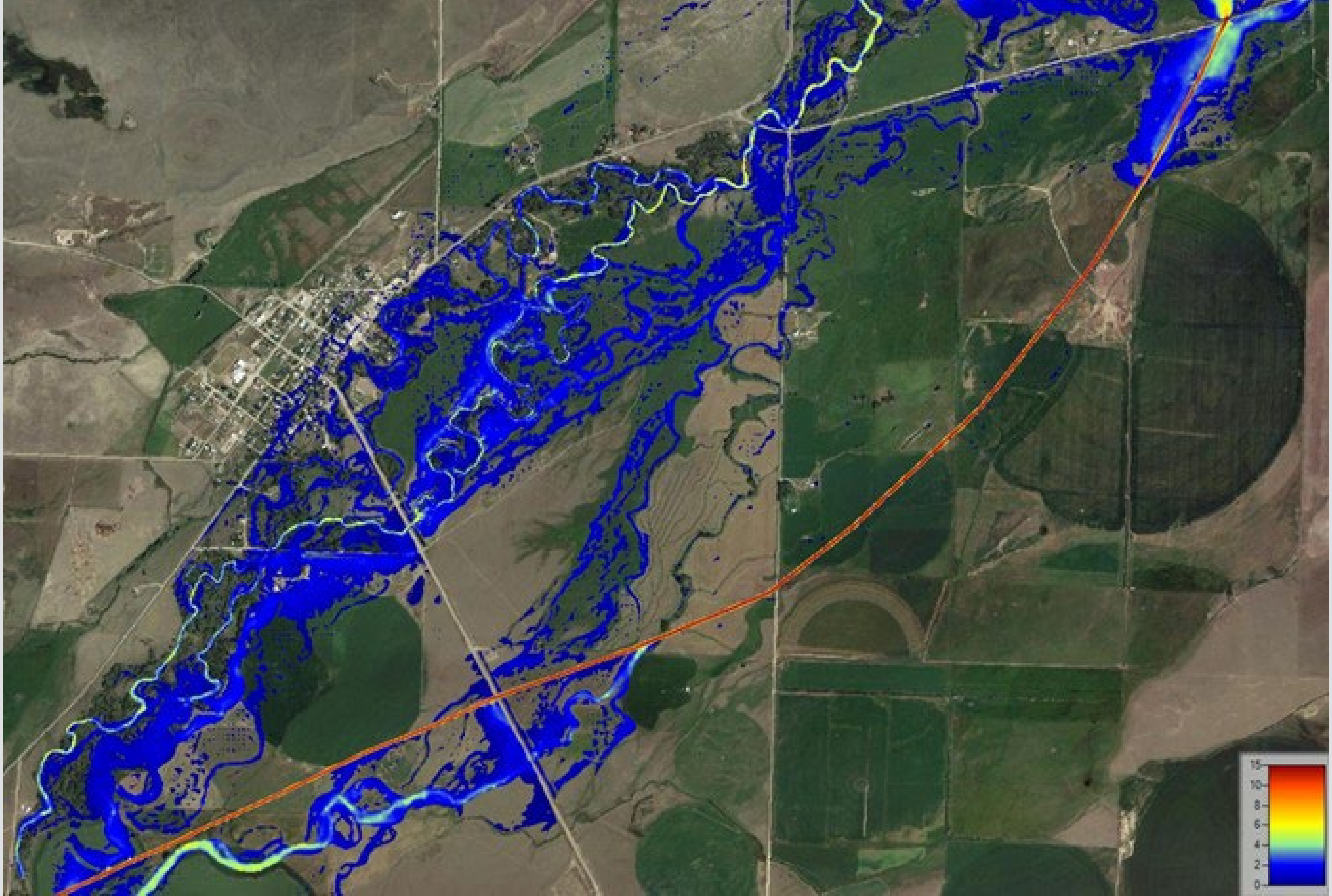
Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20%
Flow Redirection Berm Extension	4.4%	14.4%	81.2%



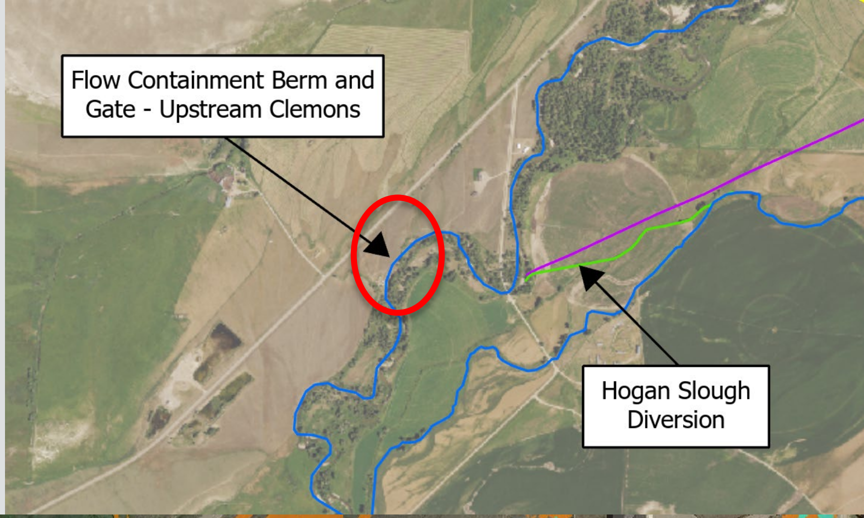


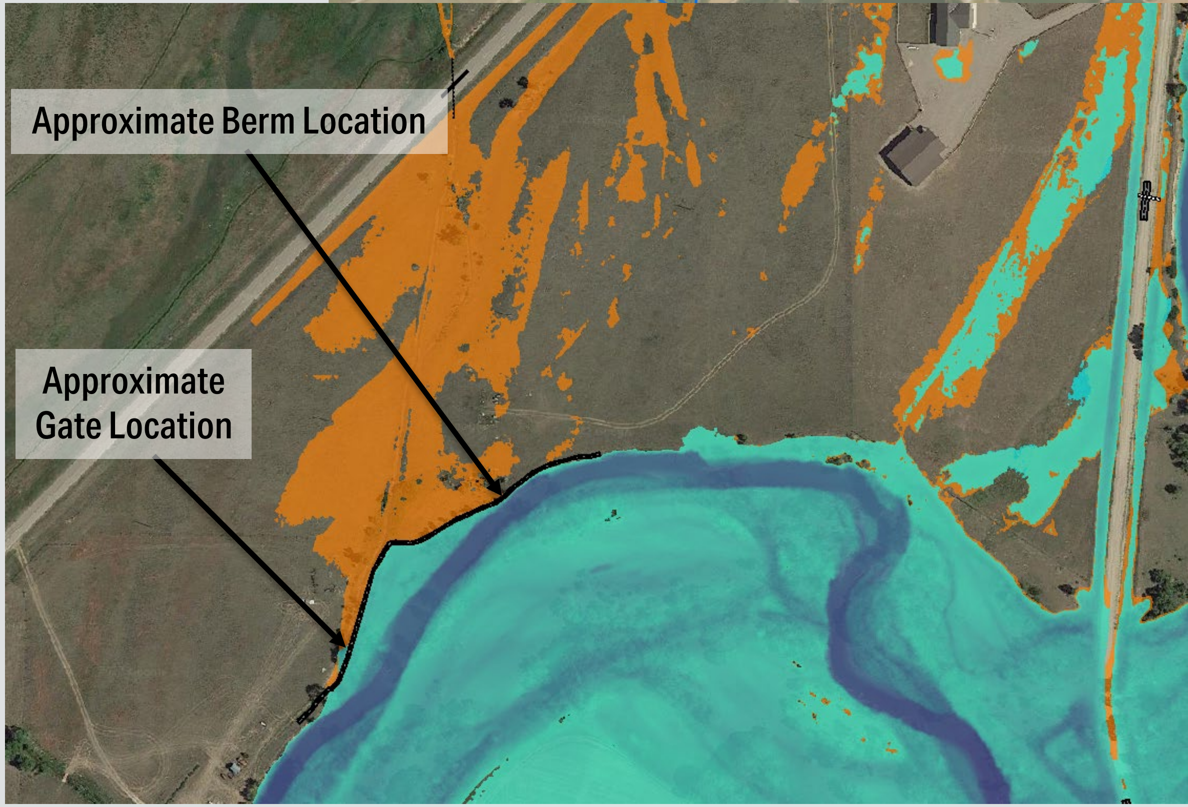

= Existing 2018 Flood Extents
= Bypass Channel Flood Extents
11.0
2.3
1.5
0.8
0.0


15
10
8
6
4
2
0

FLOW CONTAINMENT BERM AND GATE UPSTREAM OF AUGUSTA CLEMONS ROAD

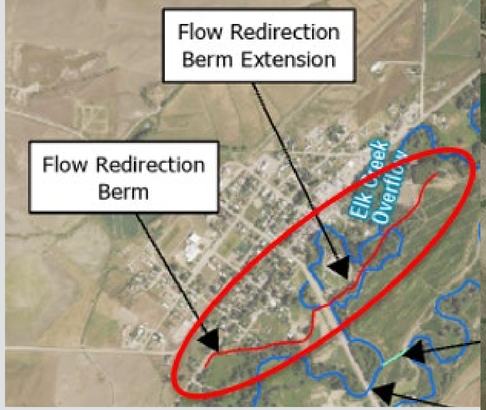
- **BLOCK DIVERSION DITCH AT HIGH FLOOD STAGES**
  - Add berm to help with redirection into Elk Creek
  - Gate incorporated to allow flow at all other stages
  - Prevents water from entering highway ditches that deliver water to town
  - Decreases flood extents in select locations
  - Small flow reduction in Elk Creek Overflow Channel
  - Can be used as a low effort combination with other alternatives



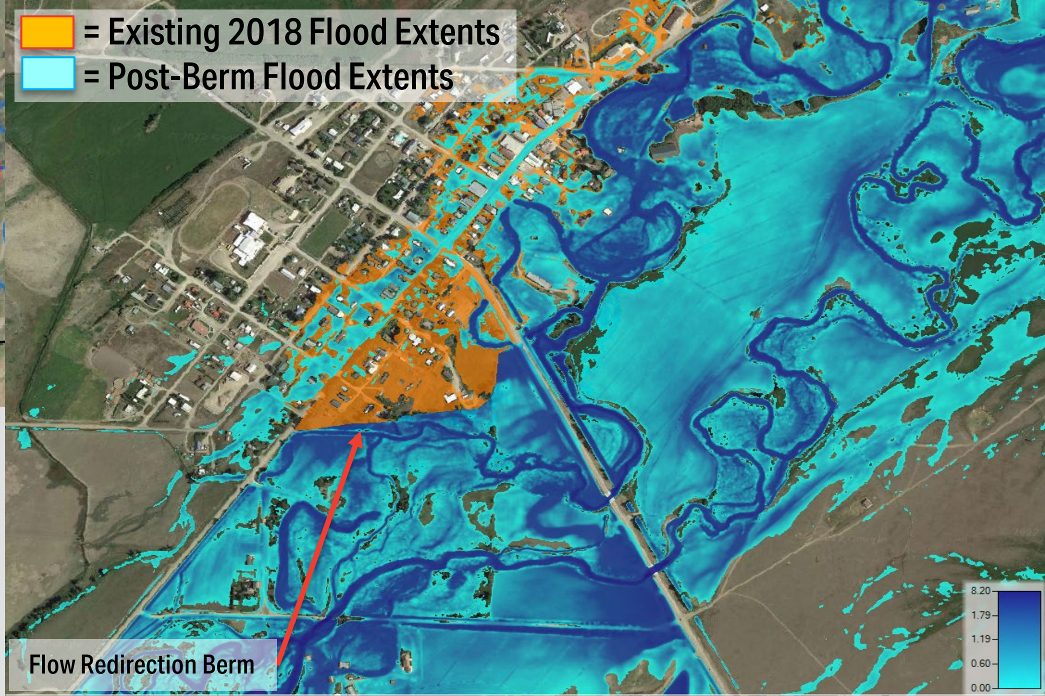


= Existing 2018 Flood Extents
= Post-Berm Flood Extents

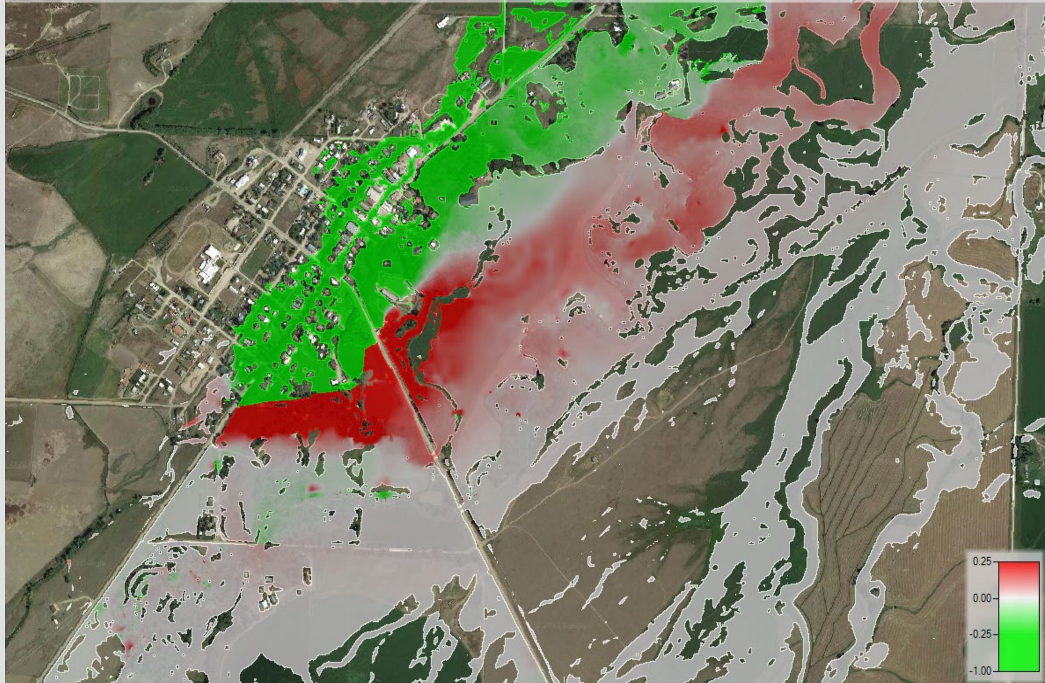
FLOW REDIRECTION BERM

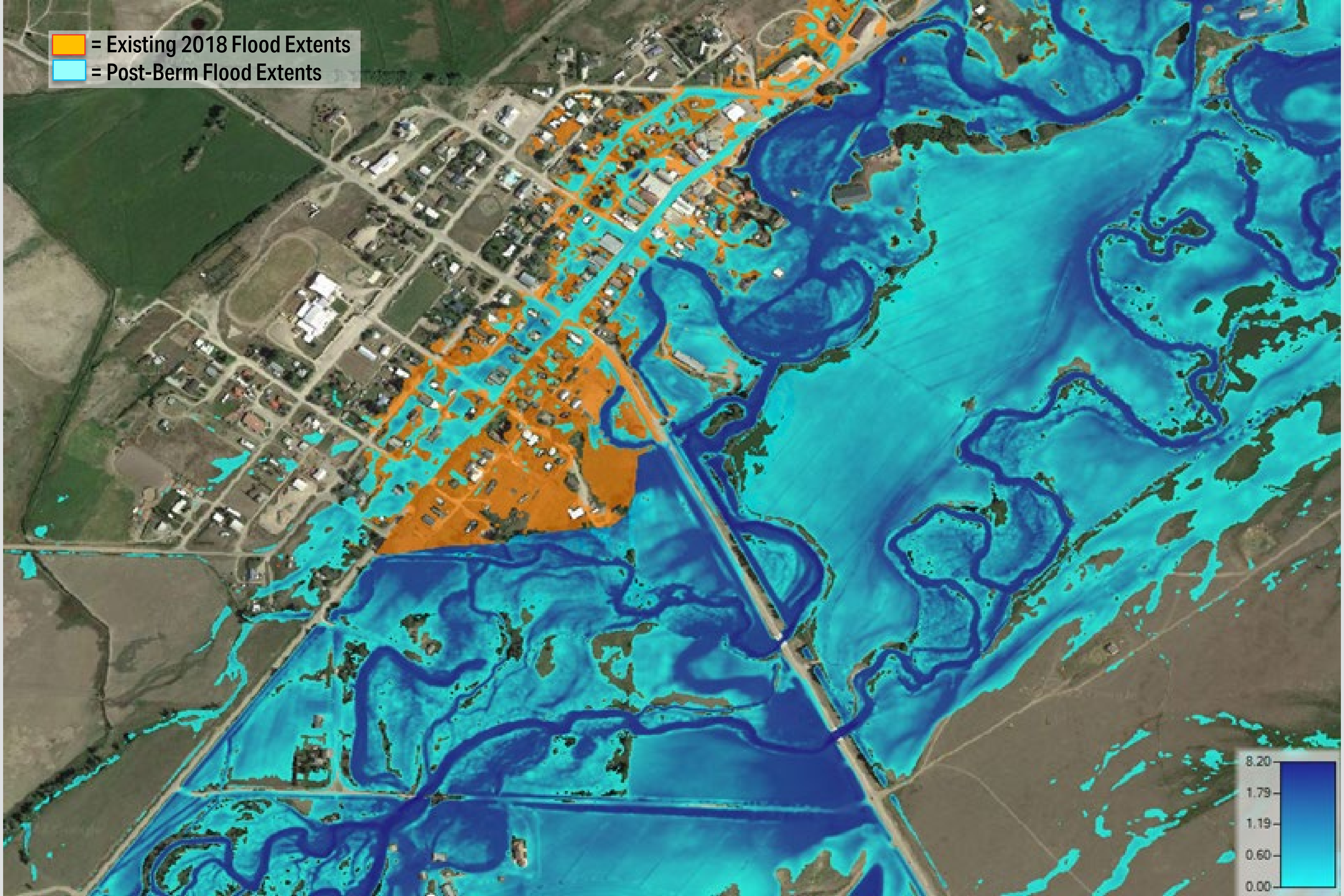


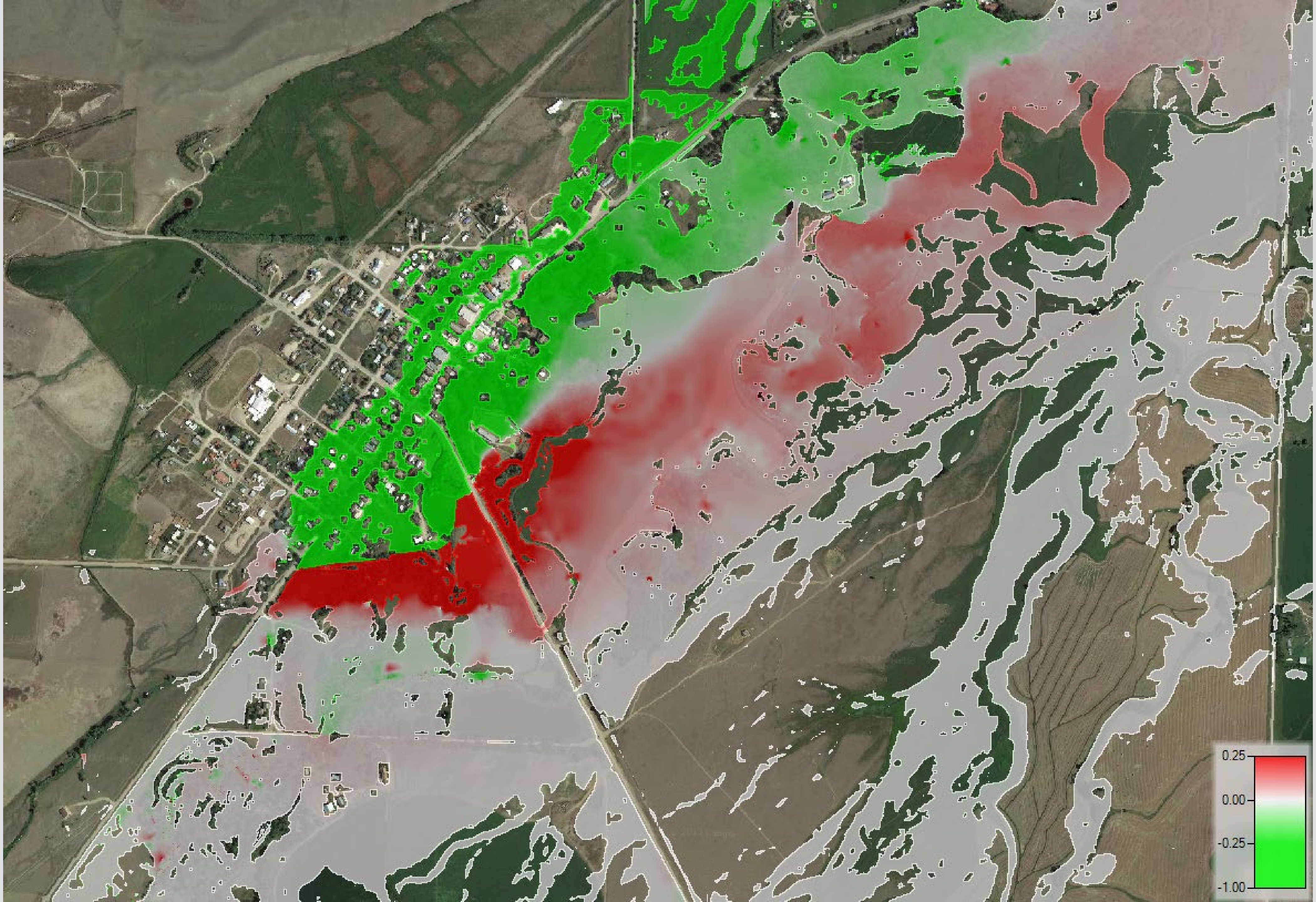
- NORTH OF LOVER'S LANE
- BERM TO BLOCK FLOOD WATERS FROM ENTERING TOWN
- DEPTH INCREASES ALONG BERM ARE 0.2-2 FEET
- DEPTHS ALONG BERM ARE 0.5 – 3 FEET
- CAN BE COMBINED WITH STRUCTURE RESIZING OR ELK CREEK OVERFLOW CHANNEL DIVERSION
- CONSIDER PREVENTION OF BACKWATER INTO CULVERTS TO SUPPORT



Flow Direction Berm Depth Changes from Existing Conditions




= Existing 2018 Flood Extents
= Post-Berm Flood Extents
8.20
1.79
1.19
0.60
0.00

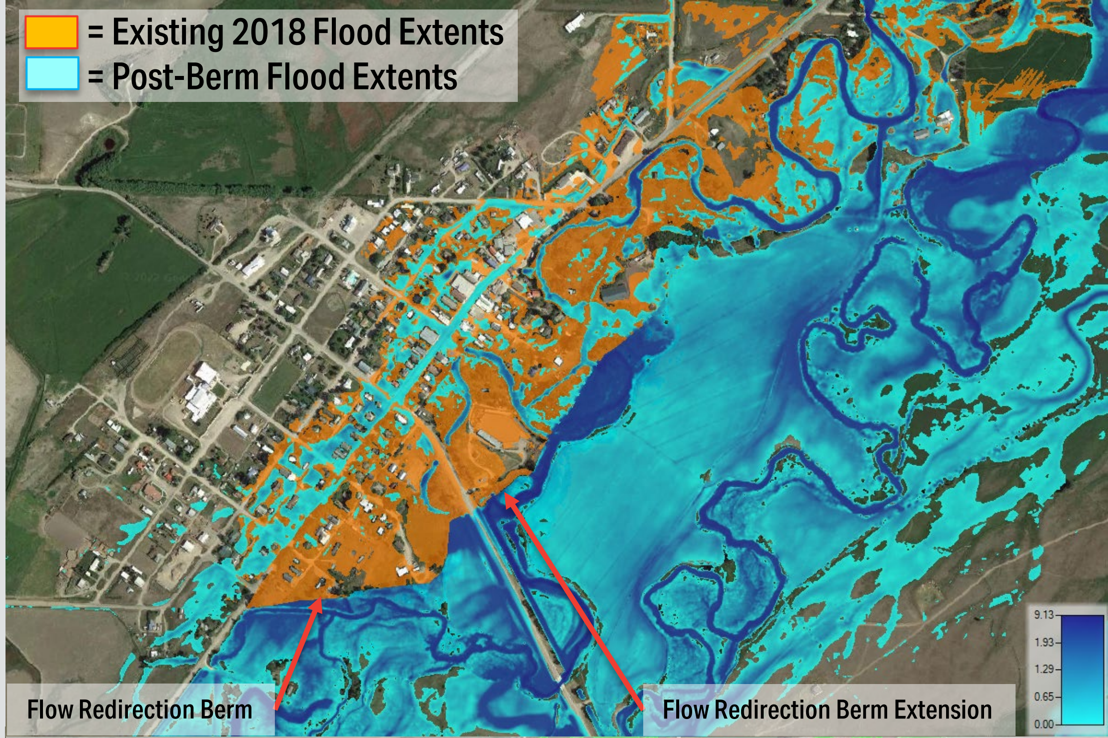

0.25
0.00
-0.25
-1.00

FLOW REDIRECTION BERM EXTENSION

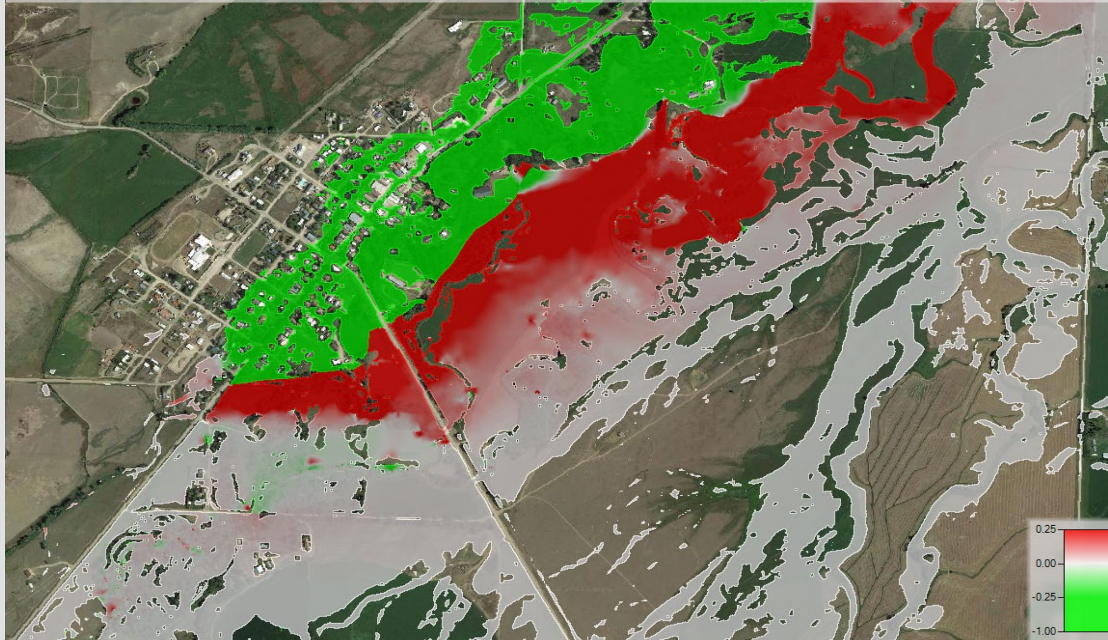
- NORTHEAST OF US 287
- BERM TO BLOCK FLOOD WATERS FROM ENTERING TOWN
- DEPTHS ALONG EXTENSION BERM ARE 0.3 – 5 FEET
- DEPTH INCREASES ALONG EXTENSION BERM ARE 1-4 FEET
- DEPTH INCREASES IN FIELD ADJACENT EXTENSION BERM ARE 0.01 – 0.65 FEET

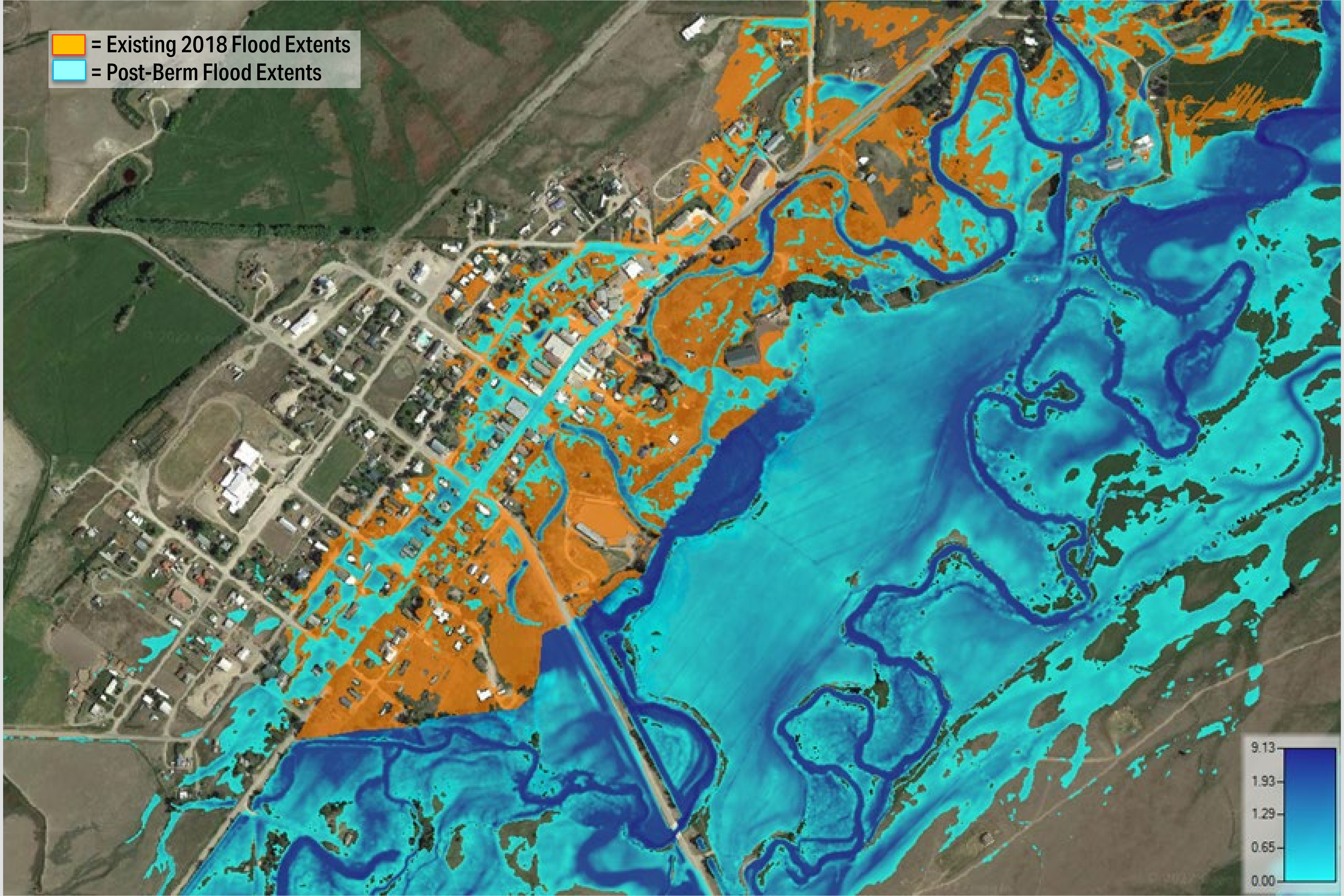
Model Results Percentage of Total Flow In Each Region Just Downstream of US 287

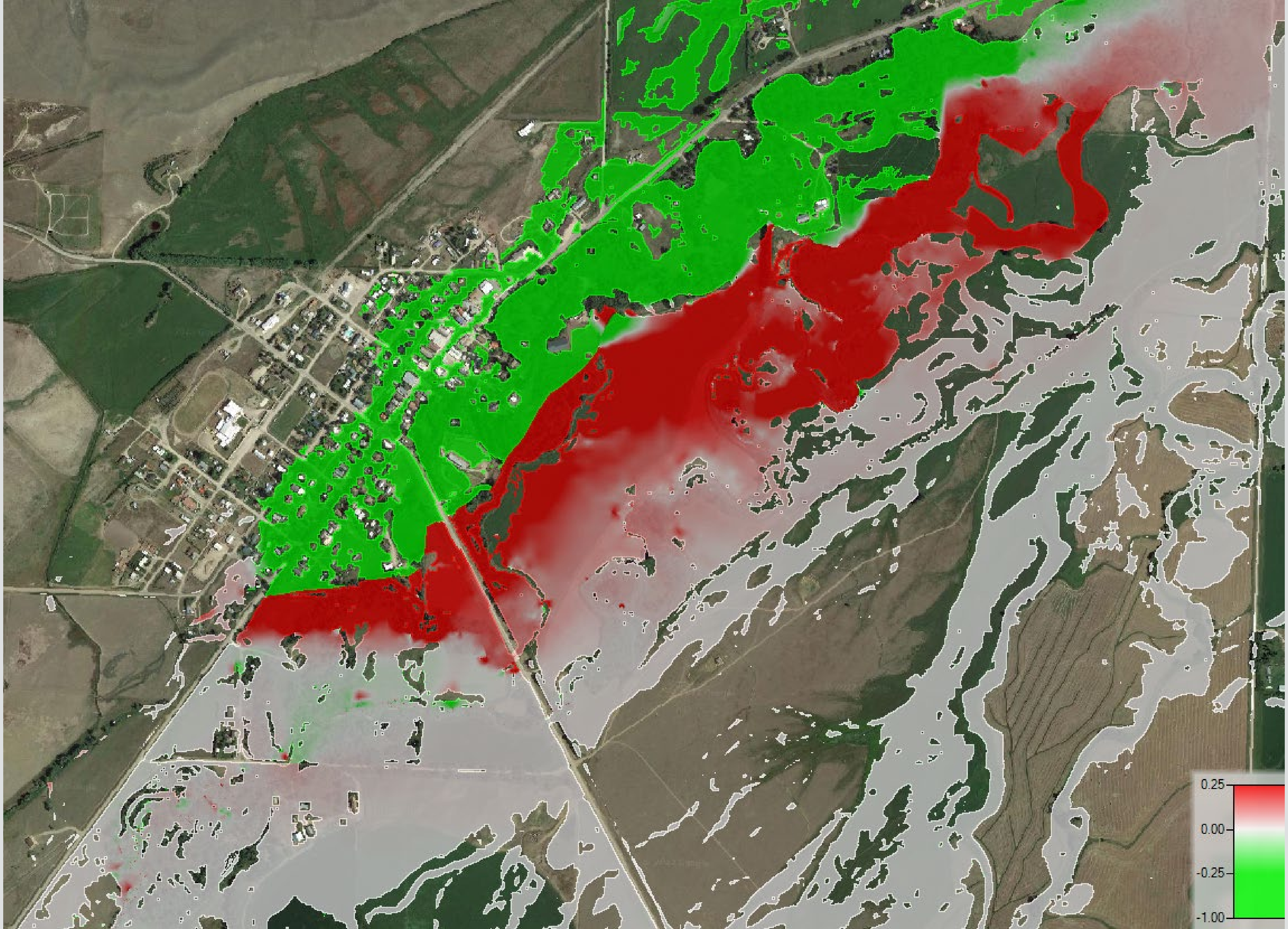
Scenario	Elk Creek Overflow + Floodplain	Elk Creek Main + Floodplain	Hogan Slough + Floodplain
2018 Flood	37.1%	42.9%	20%
Flow Redirection Berm Extension	32.5%	47.6%	20%



Flow Direction Berm Extension Depth Changes from Existing Conditions




= Existing 2018 Flood Extents
= Post-Berm Flood Extents
9.13
1.93
1.29
0.65
0.00


0.25
0.00
-0.25
-1.00

PERMITTING

- FEMA FLOODPLAIN STANDARDS/REGULATIONS
- PERMITTING FOR STATE AND COUNTY REGULATIONS
  - 310 – Lewis and Clark Conservation District
    - Work on bed or banks of perennial streams
  - 404 – U.S. Army Corps of Engineers
    - Placing fill or dredging in Waters of US
  - Floodplain – Local Floodplain Administrator
    - Work within the FEMA 100-year floodplain
    - Issued by Lewis and Clark County

COST-BENEFIT COMPARISON

Lower Cost, Lower Effort — Higher Cost, Higher Effort

Smallest Benefit

- Channel and Floodplain Debris Clearing
- Upstream of Clemons Road Berm and Canal Gate Addition
- Florence Canal Diversion
- 287 Bridge Resizing
  - Excavate aggregated materials
  - New bridges that have benches tied into the floodplain elevation
- Flow Redirection Berm Alone
- Elk Creek Overflow Diversion & Plug
- 287 Removal & Re-Alignment
- Hogan Slough Diversion Channel & US 287 Culvert Resizing
- Flow Redirection Berm with Extension
- Flow Redirection Berm Coupled with Elk Creek Overflow Diversion and Extension, & Overflow Channel Plug
- Flood Bypass Channel

Largest Benefit

RECOMMENDED ALTERNATIVES AND PHASING

ONLINE SURVEY FOR COMMENTS

- https://www.surveymonkey.com/r/augusta_pm2
- Comment on any flooding related topic
  - Emphasis on flood observations and mitigation alternatives
- Open until 5/22

NEXT STEPS

- COLLECT COMMENTS AND FEEDBACK FROM THIS MEETING
- MODIFY SIMULATIONS BASED ON COMMENT FEEDBACK
- FINAL REPORT – JUNE '22

- LONGER TERM:
  - Monitor and pursue funding opportunities

AUGUSTA FLOOD MITIGATION — MAY 2022 MEETING

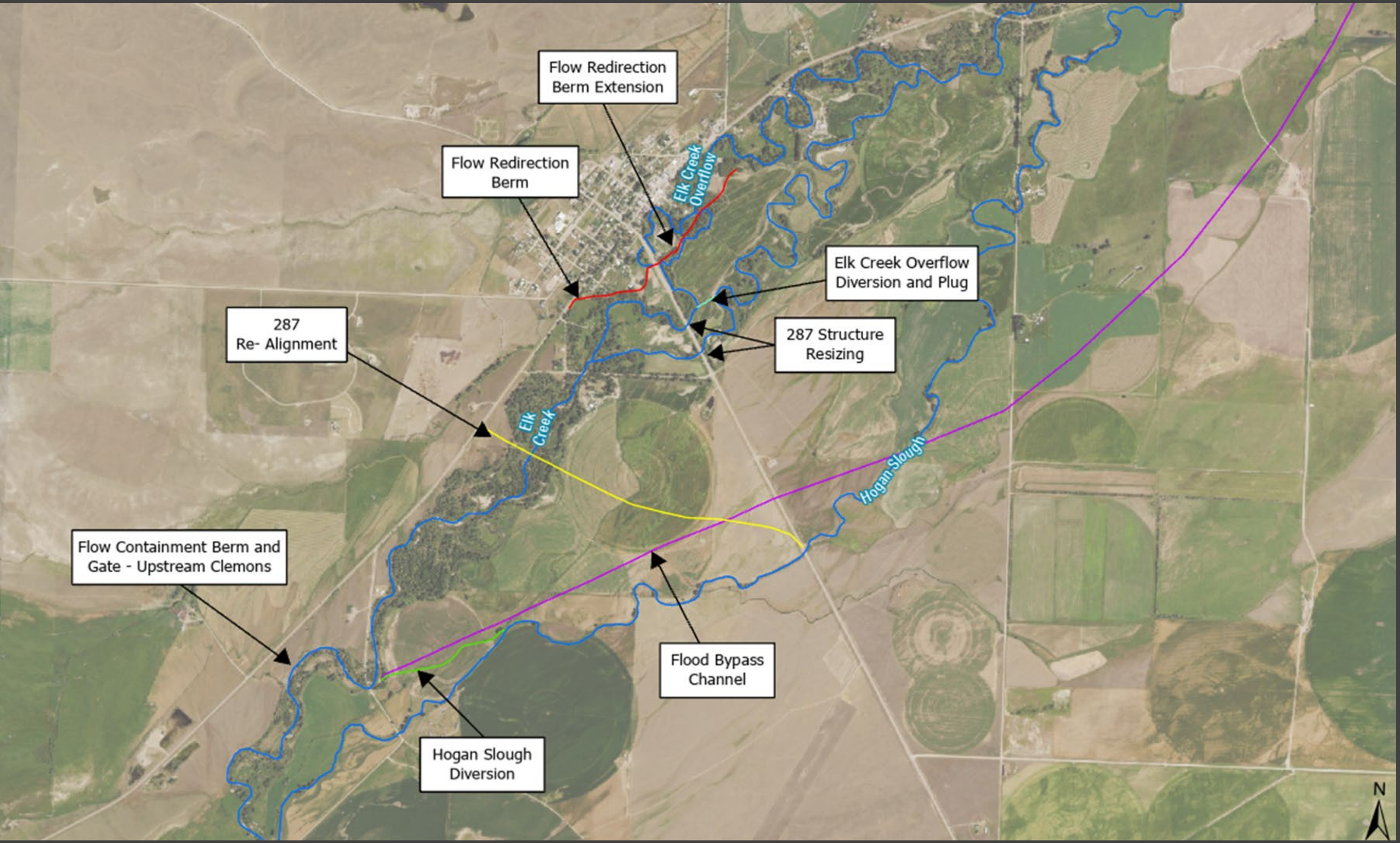


Photo by Mark Taylor

QUESTIONS AND DISCUSSION