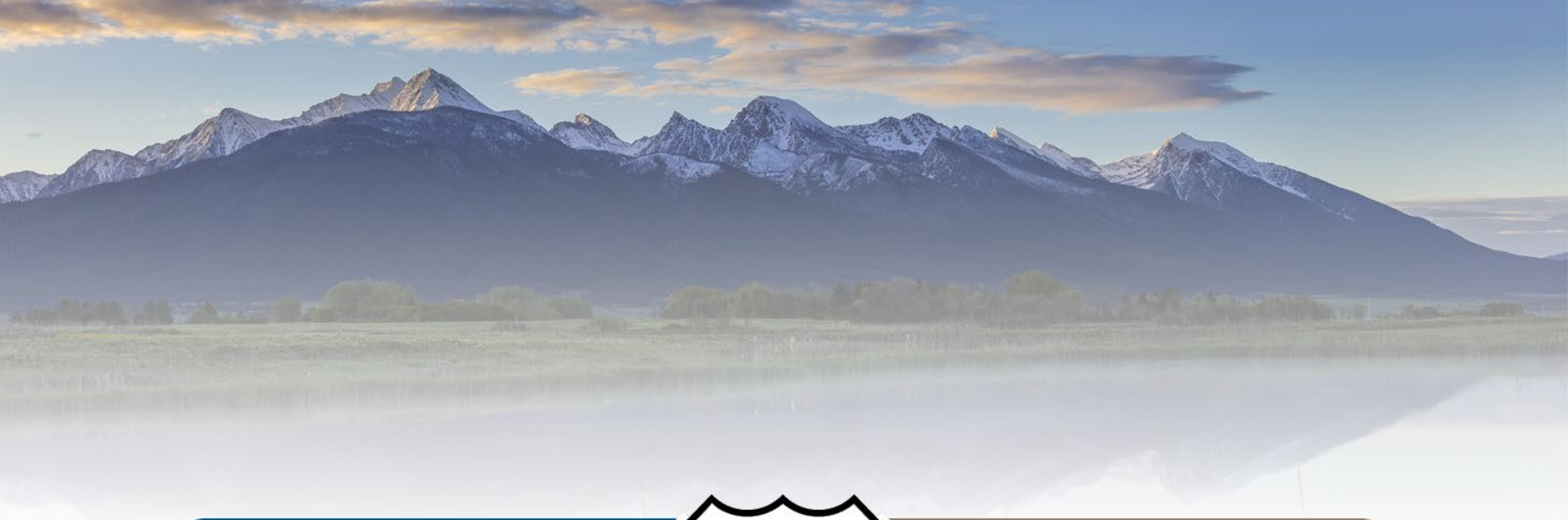
APPENDIX 3:

Structures and Hydraulic Feasibility Report

NINEPIPE CORRIDOR 93 FEASIBILITY STUDY



NINEPIPE CORRIDOR 93 FEASIBILITY STUDY

Structures and Hydraulic Feasibility Report

Technical Memorandum

October 17, 2022

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Montana Department of Transportation

MONTANA Department of Transportation

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RPA

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Acronyms and Abbreviations

cfs	cubic feet per second
CSKT	Confederated Salish and Kootenai Tribes
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
MDT	Montana Department of Transportation
RP	Reference Point
SEIS	Supplemental Environmental Impact Statement
US 93	US Highway 93
WVC	Wildlife-Vehicle Collision

Structures and Hydraulic Feasibility Report

1.0. INTRODUCTION

The intent of the *US 93 Ninepipe Corridor Feasibility Study* is to analyze the feasibility of the preferred alternative previously identified in the 2008 Supplemental Environmental Impact Statement (SEIS)[1]. The purpose of the action proposed in the SEIS was to improve traffic operations and the connectivity and safety of the transportation system. The preferred alternative was determined to best meet the purpose and need of the proposed action while minimizing costs and impacts to the area's natural resources.

The purpose of this document is to evaluate the proposed structures and wildlife crossing accommodations contained in the 2008 SEIS as well as those developed as part of the feasibility study to assess impacts and overall feasibility. This document also contains an evaluation of the most appropriate structure size and type for each crossing location given hydraulic conditions and wildlife crossing needs. Readily available hydraulic information was used to guide the analysis and assist in structure selection and bridge layout determinations. A full hydraulic analysis has not yet been completed. Should a project advance, a full hydraulic analysis will be needed to confirm assumptions made in this report.

1.1. Hydraulic Setting

The Ninepipe corridor crosses the Mission Creek and Crow Creek watersheds, both of which originate in the Mission Mountains Tribal Wilderness and drain west to the Flathead River downstream of Flathead Lake. Within the study area, the corridor crosses Ninepipe Reservoir, 2 kettle ponds, and Crow Creek. The area includes the Ninepipe National Wildlife Refuge and a core pothole wetland area, with thousands of pothole wetlands and vast amounts of land managed specifically for wildlife. The Crow Creek watershed, which lies at the north end of the Ninepipe area, is an especially important corridor for fish and wildlife.

2.0. FACTORS INFLUENCING STRUCTURE SELECTION

The following sections detail various factors that may influence the selection of structure type, size, and location along the Ninepipe segment. Most information was provided in the original SEIS. Updated information from the *Summary of Relevant Conditions Technical Memorandum*[2] is provided where applicable.

2.1. Hydraulic Considerations

The following sections discuss hydraulic conditions that may be impacted by the selection of alternative structures at the proposed US 93 crossings. Each section documents existing conditions and anticipated impacts from implementation of proposed improvements.

2.1.1. Surface Waters, Streams, and Irrigation Systems

Water resources located within the Ninepipe segment are illustrated in **Figure 1** and described below.

- **Siphon** is a non-jurisdictional irrigation system that crosses under US 93 at RP 40.2 via a 154-foot long, 18-inch diameter culvert.
- **Ninepipe Reservoir** is an off-channel water storage facility which receives water from the Kicking Horse Reservoir. US 93 crosses the inlet of the reservoir at RP 40.7 via a 77-foot-long timber bridge.

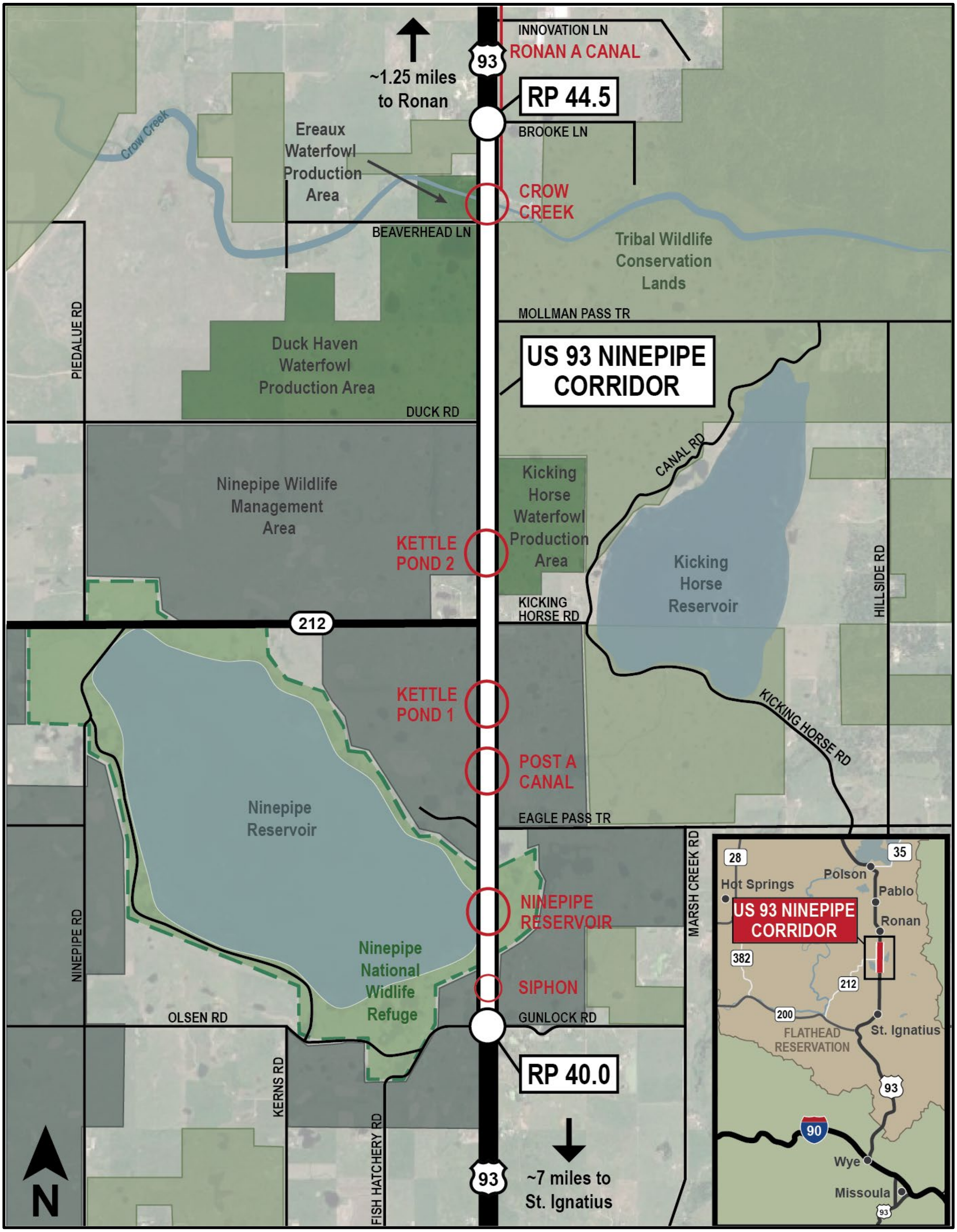

Figure 1: Study Area Water Features

- **Post A Canal** is conveyed under US 93 at RP 41.5 via a 121-foot-long, 73x45-inch reinforced concrete pipe.
- **Kettle Pond 1** is crossed by US 93 from RP 41.6 to 41.8 and **Kettle Pond 2** is crossed by US 93 from RP 42.5 to 42.6. US 93 crosses these ponds on earthen berms. A 24-inch corrugated steel pipe is used to equalize the water elevations at the kettle ponds on the east and west sides of the highway.
- **Crow Creek** flows through the project corridor between RP 44.1 and 44.2 and is conveyed under US 93 at approximately RP 44.2 through two 10x14-foot culverts.
- **Ronan A Canal** is located adjacent to US 93 between RP 44.2 and 45.1 on the westside of the highway.

Increasing the hydraulic openings at US 93 stream crossings would generally help improve stream interaction with the adjacent floodplain, increasing the value of the system for wildlife and other biological processes. However, a potential indirect effect of increasing the openings is an increase in downstream streamflow velocities. If increased streamflow velocities occur, they could contribute to erosion of unstable stream banks, movement of stream substrates, and flushing of sediment deposits.

Implementation of larger structures may impact stream channel dynamics by providing a wider opening for flows to pass through. Potential impacts include channel alterations such as substrate re-distribution and areas of local scour and erosion. The larger the structure the more likely downstream changes in channel balance would occur.

2.1.2. Storm Drainage

Water from Post Creek supplies Ninepipe and Kicking Horse Reservoirs. The SEIS noted that the 10-year flood flow is estimated to be 1,290 cubic feet per second (cfs).

The SEIS noted that the 100-year flood flow in Crow Creek at the US 93 crossing was estimated to be 1,020 cfs. The SEIS also reported that Crow Creek has previously overtopped the US 93 roadway due to inadequate conveyance capacity. The existing culverts are generally inadequate to convey high water flows during storms.

During the development of the final designs for a proposed project, measures to reduce the impact of increased stormwater flow rates would be implemented on portions of the highway that drain directly to sensitive receiving waters (category I and II wetlands and associated streams). Based on stormwater management criteria developed for other portions of US 93, peak flows from newly developed impervious areas draining directly to sensitive receiving waters should be reduced to match pre-developed peak flows for 24-hour duration storms with recurrence intervals of 2, 10, and 50 years.

To meet this standard, stormwater retention systems and detention systems (such as ponds) may be necessary. Where stormwater would discharge to sensitive receiving waters, treatment facilities such as wet ponds or biofiltration swales, would need to be constructed. Stormwater facilities should also be designed to reduce the long-term impact of roadway runoff pollutants on sensitive receiving waters. New or reconfigured stormwater outfalls and drainage ditches would have to be designed to accommodate increased flow rates resulting from larger bridge openings to prevent erosion over the long term.

2.1.3. Floodplains

Based on updated mapping conducted by the Federal Emergency Management Agency (FEMA) in 2013, the Ninepipe segment of US 93 passes through the following floodplains:

- <u>Ninepipe Reservoir</u>: Approximately 140 feet of US 93 roadway crosses Zone A - 1% annual chance flood (100-year floodplain) of the reservoir.
- <u>Crow Creek</u>: Approximately 645 feet of US 93 roadway crosses Zone A - 1% annual chance flood (100-year floodplain) associated with Crow Creek.

Based on floodplain mapping prepared in 1987, the SEIS noted that approximately 20 percent of the floodplain at Ninepipe Reservoir and approximately 5 percent of the floodplain at Crow Creek is spanned by the existing crossing structures at each location. There are no floodplains associated with the Kettle Ponds.

Increasing the stream and associated floodplain openings would increase channel capacity at highway crossings thereby reducing peak water surface elevations during 100-year flood and lesser high flow events. Any fill placed within the fringes of the 100-year floodplain boundaries due to roadway widening or increased vertical clearance would reduce overall flood storage. Still, it is expected that increasing stream and floodplain conveyance and storage within the crossings would have a greater beneficial effect on flood elevations than the negative impact of adjacent floodplain fill.

By spanning a greater portion of the floodplain, the proposed structures would result in greater connectivity between the surface water, adjacent wetlands, and upland riparian areas. It is also anticipated that increased openings could reduce flooding upstream. Similarly, larger openings could also contribute to flooding downstream. However, no major flooding issues are reported within the corridor, so the flooding risks associated with implementation of the proposed crossings are minimal.

2.1.4. Aquatic Organism Passage

Streams in the study corridor drain to two watersheds: the Post Creek drainage area of the Mission Creek watershed and the Crow Creek watershed. Crow Creek flows directly into the lower Flathead River. All streams in the area flow from east to west due to geologic controls. The Ninepipe Reservoir also provides aquatic habitat for fish. Fisheries resources and aquatic habitat within the project corridor have been heavily impacted by urbanization and water diversions for irrigation.

Ninepipe Reservoir provides habitat for largemouth bass, yellow and black bullhead, pumpkinseed sunfish, yellow perch, and rainbow trout. The water quality has degraded due to irrigation water withdrawals and inputs of stormwater runoff from US 93 crossing over the reservoir inlet causing undesirable fish habitat.

Crow Creek provides fish passage, has a low gradient, and is sinuous with deep run habitat. The segment of Crow Creek flowing under US 93 has been straightened and deep pools exist under the crossing structures. The streambank is mostly stable with reed canary grass, cattails, and sedges dominating. Brook trout, brown trout, and rainbow trout are documented in Crow Creek while largescale and longnose suckers, mountain whitefish, northern pikeminnow, redside shiner, and longnose dace are undocumented but expected.

The existing crossing structures within the corridor are poorly placed and undersized which limits the natural hydrologic regime of streams and wetlands. These conditions can, over time, reduce the functions and values of these streams, affecting their ability to provide fish habitat. Opening a greater area of the floodplain would generally enhance fisheries resources and allow previously impacted areas to be restored. The proposed culvert and bridge replacements would generally improve hydraulic conveyance capacity at stream crossings, improve hydrologic connectivity in streams, floodplains, and wetlands, provide greater vegetative cover on the stream banks and in riparian wetlands, and improve fish passage.

2.2. Wildlife Crossing Considerations

An analysis of relevant conditions for wildlife in the Ninepipe segment was completed January 2022 by Herrera to evaluate the suitability of the proposed structures for wildlife crossing accommodations.[3] The SEIS states that the structures identified in the preferred alternative are generally expected to facilitate movement by many species including turtles, deer, some small to large mammals, and grizzly bear. It is recognized that the benefits of all the structures would take time to realize as wildlife become accustomed to using the structures.

Open-span bridges are preferred by single grizzly bears and somewhat by family groups. New structures are most likely to be used by grizzly bears if vertical clearance exceeds 15 feet and wing fencing of at least

0.4 mile is used on each side to help funnel bears to the structures. Reduced clearance with a wider opening may be adequate in some locations where bears are less likely to cross or where an overpass structure can be accommodated nearby. Bears prefer to cross in dry areas and are unlikely to cross if there are only wet, swampy conditions. Similarly, structures would also likely be used by a variety of other small and large mammals if there is adequate dry land available on each side of the water bodies for animals to pass. Additional accommodations for grizzly bears and other wildlife, such as an overpass, could be considered at locations where grizzly bears have been documented crossing the highway and vehicle collisions have occurred.

The wildlife report notes that culverts and fencing systems have been shown to be effective in reducing turtle road mortality. Lighted boxes and larger diameter culverts are more likely to accommodate turtle passage since the species in the area may show reluctance to enter dark areas. Dry land culverts with flat bottoms and earthen substrate are best to facilitate turtle terrestrial movements. Wing or directional fencing would help funnel turtles to the culverts.

Larger structures would also benefit birds and waterfowl that could fly, swim, or walk through the structures. However, there is concern that fencing used to guide animals to the crossing structures might cause a collision hazard for birds and flying waterfowl. Fence markers, such as those used for sage grouse, and markings on power lines for trumpeter swans, could be explored to reduce waterfowl strikes on the fencing.

PREFERRED CROSSING LOCATIONS

The most appropriate structure type at each crossing location will depend on the type of wildlife that is expected to use the crossing. **Figure 2** illustrates anticipated crossing needs for wildlife in the corridor based on wildlife tracking data and locations of historic wildlife-vehicle collisions (WVC) on the highway. Additional information is provided below.

- **Ninepipe Reservoir**: The Ninepipe Reservoir crossing is located in a major drainage with high-quality habitat for grizzly bears. Concentrated grizzly bear use and mortality has occurred in the vicinity, and bears are likely to use this crossing regardless of whether an overpass structure is provided elsewhere in the corridor. This crossing is also expected to serve other small mammals, birds, and waterfowl.
- **Post A Canal**: Grizzly bears have been documented crossing US 93 in the vicinity of the canal and WVCs have occurred. Given the presence of grizzly bears and the elevation of adjacent terrain, this location is favorable for an overpass structure. Other small to large mammals, such as deer, elk, and racoons, may also cross at this location.
- **Kettle Pond 1**: Turtles are expected to use the crossing structure(s) at this location due to evidence of nesting areas in the vicinity and historic mortality rates. Birds and waterfowl are also expected to use the bridge(s) provided at this crossing. Grizzly bears are documented in the area and may use a crossing at this location if dry passage is provided.
- **Kettle Pond 2**: Similar to Kettle Pond 1, this crossing location is anticipated to be used most by turtles, birds, and waterfowl. Grizzly bears are less likely to cross in this location based on historic movement patterns.

Figure 2: Anticipated Wildlife Crossing Locations

- **Crow Creek**: Grizzly bears are known to cross in this area. Like the Ninepipe Reservoir, Crow Creek is in a major drainage with high-quality bear habitat. It is important to provide a large enough opening with some dry land to be inviting for the animals. A concentration of turtle mortality occurred near Beaverhead Lane, just south of Crow Creek. When the pond on the east side of the highway begins to dry out, turtles are known to cross US 93 to the permanent pond on the west side of the highway. Crossing structures at this location would also benefit other small to large mammals, birds, and waterfowl.

2.3. Geotechnical Considerations

A *Preliminary Geotechnical Analysis*[4] was completed by SK Geotechnical in January 2022 to understand liquefaction potential, identify bridge foundation types and sizes, and predict embankment settlement within the study area. The analysis shows minor liquefaction throughout the corridor, with liquefaction settlement ranging from less than 1/4 inch to about 3 inches and lateral spread ranging from less than 1 inch to over 15 inches. Liquefaction mitigation can be expected for the bridges at Ninepipe Reservoir and Crow Creek. Mitigation may also be needed at the kettle ponds to reduce slope instability although it is anticipated the culverts will be able to tolerate the anticipated level of liquefaction settlement and lateral spread.

The memorandum states that driven pipe piles are the most likely preferred bridge foundation alternative, however, drilled shafts could also be considered. The soils surrounding Crow Creek will require deeper pipe piles. It is anticipated that 2 to 3 feet of subexcavation and foundation material will be required for the large culverts located at the two kettle pond locations, other culverts along the corridor, and the potential pedestrian/bicycle underpass.

The embankment settlement calculations show between 3 to 7 inches of total settlement can be expected at the Ninepipe and Crow Creek bridges, and about 1 to 2 inches of settlement can be expected at the kettle pond locations. It will likely be necessary to surcharge the embankments at the Ninepipe and Crow Creek locations, and the surcharge will need to remain in place for about 3 to 9 months.

2.4. Constructability

Constructability will be an important consideration when determining the most appropriate and feasible structure. Longer structures would likely require construction of long detour routes around surface waters, while construction of shorter structures can generally accommodate detours within construction limits. Longer structures take more time to construct, increasing travel time impacts and delays for travelers. Extended construction periods will also require detours and temporary structures to be in service for longer periods which will also require more maintenance. When constructing longer, multi-span structures, specialized equipment is typically needed to erect the structures. For example, deeper and heavier beams require a larger crane compared to shorter, lighter, and shallower beams. Larger spans also require larger foundations, so larger pile driving equipment may be necessary to drive larger diameter piles deeper compared with a shorter bridge with a comparatively reduced load placed on the foundations. In addition to greater amounts of material, the need for specialized equipment and long detours makes longer, multi-span structures more costly to construct, especially if new right-of-way is necessary for detours. In some cases, detours may be reclaimed for the shared use path alignment.

To accommodate longer structures with greater vertical clearance, the roadbed will need to be raised in most locations. Modifications to driveways and adjacent approaches may also be necessary to accommodate the change in grade. It is also important to avoid too much undulation in the roadway caused by frequent changes in grade to accommodate the crossing structures.

3.0. CORRIDOR-WIDE STRUCTURE CONFIGURATION OPTIONS

Four corridor-wide options have been identified to address the hydraulic crossings at the Ninepipe Reservoir, Kettle Pond 1, Kettle Pond 2, and Crow Creek locations as well as a potential overpass crossing at Post A Canal. Option C-0 consists of the existing structure configurations (baseline) and was examined for comparison purposes. Option C-1 includes the structures recommended in the SEIS preferred alternative. Options C-2 and C-3 were developed for this feasibility study to improve wildlife passage opportunities. Option C-2 generally includes a single, longer bridge structure spanning the entire water body, compared to the SEIS preferred alternative that would use multiple structures to convey individual stream channels. To encourage greater use by wildlife, the larger structures also assumed 15 feet of vertical clearance under the structure. Option C-3 assumed that if a wildlife overpass were to be constructed at Post A Canal, smaller structures may be acceptable at other crossing locations. In addition to the provision of an overpass, this option generally provides the minimum bridge length needed at each crossing location based on the channel openings and surface water elevations. The minimum bridge dimensions were identified to minimize impacts at each location while still providing adequate hydraulic conveyance. At some locations, deviations from the minimum structure configurations were pursued due to specific wildlife crossing needs. The structures associated with each of the four options are listed below.

Baseline (Option C-0):

- Ninepipe Reservoir: Single 77-foot bridge with 10 feet of vertical clearance and minor culverts
- Kettle Pond 1: No structure, pond spanned by an earthen embankment with a 24-inch equalizer culvert
- Kettle Pond 2: No structure, pond spanned by an earthen embankment with a 24-inch equalizer culvert
- Crow Creek: Two 10x14-foot culverts

SEIS Preferred (Option C-1):

- Ninepipe Reservoir: Single 660-foot bridge with 10 to 12 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts
- Kettle Pond 1: Two 60-foot bridges with 10 to 12 feet of vertical clearance and two 4x6-foot culverts
- Kettle Pond 2: Two 60-foot bridges with 10 to 12 feet of vertical clearance and two 4x6-foot culverts
- Crow Creek: Two bridges (120-foot and 150-foot) with 10 to 12 feet of vertical clearance

Enlarged Wildlife Crossing Structures (Option C-2):

- Ninepipe Reservoir: Single 660-foot bridge with 15 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts
- Kettle Pond 1: Single 800-foot bridge with 15 feet of vertical clearance
- Kettle Pond 2: Single 800-foot bridge with 15 feet of vertical clearance
- Crow Creek: Single 500-foot bridge with 15 feet of vertical clearance

Wildlife Overpass Configuration (Option C-3):

- Ninepipe Reservoir: Single 300-foot bridge with 15 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts
- Post A Canal: Wildlife overpass
- Kettle Pond 1: Single 110-foot bridge with 10 to 12 feet of vertical clearance, two 4x6-foot culverts
- Kettle Pond 2: Single 110-foot bridge with 10 to 12 feet of vertical clearance, two 4x6-foot culverts
- Crow Creek: Single 500-foot bridge with 15 feet of vertical clearance

4.0. BRIDGE LAYOUT ANALYSIS

A planning-level analysis was performed for the proposed bridges at each of the four hydraulic crossing locations for Options C-0 through C-3. An overview of the preliminary hydraulic and structural analyses performed for this memorandum is provided below. Results of these analyses are provided in the following sections.

PLANNING-LEVEL HYDRAULIC ANALYSIS

A planning-level hydraulic analysis was performed for each of the four options. The analysis involved review of construction plans for the corridor, recent survey data containing high-water elevations, geotechnical constraints, and preliminary roadway alignments to determine the most appropriate bridge layouts for each location. These resources helped establish roadway and surface water elevations and channel widths in order to complete a preliminary assessment of hydraulic performance and structural capacity. More detail about the specific analysis used for each crossing location is contained in the following sections.

A full hydraulic analysis will be needed to confirm all assumptions made in this report. A full hydraulic analysis would involve development of a HEC-RAS model to establish the required channel opening width below the bridge structure and determine the minimum low beam elevation based on a 100-year flood event. These constraints would assist in refining the bridge opening and layout assumptions for use in a hydraulic model. The model would then be able to provide quantifiable estimates for hydraulic conveyance, floodplain impacts, and storm drainage needs.

In general, bridges that clear span the water channel are anticipated to demonstrate better hydraulic performance and reduce backwater elevations. It is desirable to minimize or eliminate the number of piers or foundations within the water channel to improve hydraulic performance and reduce impacts.

PLANNING-LEVEL STRUCTURAL ANALYSIS

Several beam types could be used to construct the proposed bridge options. Examples of different sized concrete and steel beams that could be used are provided in the sections below. Prestressed voided slab and bulb-tee superstructures were not considered since they typically are used on lower volume roads and don’t have concrete deck driving surfaces. Given the high traffic volumes on US 93 through the Ninepipe segment, a concrete deck is needed to withstand the anticipated loading over the desired design life of 75 years. The beam selection will dictate the approximate raise in grade that is required to construct the bridge with the desired vertical clearance. The beam size and type will also dictate the span length and the number of spans needed to construct the desired bridge structures. Greater numbers of spans also require a greater number of bridge piers or foundations. Bridge piers constructed in streams or in floodplains typically decrease hydraulic performance, result in greater impacts, are more susceptible to scour, and are more difficult and costly to construct.

In terms of constructability, all of the proposed bridge types can be constructed using typical construction methods. Bridges spanning longer distances would require larger foundations (i.e., larger diameter pipe piles and larger pile driving equipment) since they would have to support a greater load. The longer span bridges would also require larger construction equipment (i.e., larger cranes and transport equipment). While it is not fundamentally more difficult to construct long, multi-span bridges compared to short, single-span bridges, construction generally requires larger equipment, takes longer, and is more expensive.

During design it will be necessary to maintain close coordination with geotechnical engineers and the bridge design team to ensure span lengths and required foundations can be supported by the existing soils. For this planning-level analysis, it was assumed that the existing soils can withstand the loads of the proposed structures, although larger foundations or deeper pipe piles than those recommended in the geotechnical report are anticipated for longer span bridges. A full geotechnical analysis will be required during future design phases to verify these assumptions. Unaddressed geotechnical issues could cause problems during construction and reduce the service life of the bridge.

4.1. Ninepipe Reservoir

A list of the structure configurations analyzed for the Ninepipe Reservoir crossing location is provided below. **Table 1** provides a summary of the possible beam types that could be used in each bridge layout as well as approximated raises in roadway grade, span lengths, and number of spans needed to provide the proposed structure. Specific assumptions for the hydraulic and structural analysis at this location as well as additional considerations are provided in the following sections.

Ninepipe Reservoir:

- C-0: Baseline – Single 77-foot bridge with 10 feet of vertical clearance and minor culverts
- C-1: SEIS Preferred – Single 660-foot bridge with 10 to 12 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts
- C-2: Enlarged Wildlife Crossing Structures – Single 660-foot bridge with 15 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts
- C-3: Wildlife Overpass Configuration – Single 300-foot bridge with 15 feet of vertical clearance, two 12x22-foot culverts, and two 10x12-foot culverts

Table 1: Ninepipe Reservoir Bridge Layout Options

Option/Beam Type	Length (ft)	Width 1[a] (ft)	Width 2[b] (ft)	Vertical Clearance (ft)	Approx. Grade Raise (ft)	Span Length (ft)	# of Spans
C-0: Baseline	77	28	30.2	10	--	77	1
C-1: SEIS Preferred	660	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*3-4*	*50-75*	*9-13*
Concrete Prestressed Beam (Deep)					*6-7*	*100-125*	*5-7*
Steel Girder					*8-9*	*150-200*	*3-4*
C-2: Enlarged Wildlife Crossing Structures	660	40	42	15			
Concrete Prestressed Beam (Shallow)					*6-7*	*50-75*	*9-13*
Concrete Prestressed Beam (Deep)					*9-10*	*100-125*	*5-7*
Steel Girder					*11-12*	*150-200*	*3-4*
C-3: Wildlife Overpass Configuration[c]	300	40	42	15			
Concrete Prestressed Beam (Shallow)					*6-7*	*50-75*	*4-6*
Concrete Prestressed Beam (Deep)					*9-10*	*100-125*	*2-3*
Steel Girder					*11-12*	*150-200*	*2*

[a] Face of curb/bridge rail to face of curb/bridge rail. Width of proposed structures accommodates two (2) 12-foot travel lanes with 8-foot shoulders but does not include the width of a shared use path.
[b] Out to out deck width (including bridge rail). If shared use path is accommodated on the bridge under the proposed options, increase the bridge deck width by the width of the path (10 feet) plus one foot to accommodate pedestrian rail at the edge of the deck.
[c] This bridge layout represents the minimum design to satisfy both the hydraulic needs and wildlife crossing needs at this location. Dimensions are approximated and a full hydraulic analysis will be needed to verify assumptions.

ASSUMPTIONS

Based on information from the US 93 as-let plans in the Ninepipe segment, the Ninepipe Reservoir has a high-water elevation of 3,010 feet. Using an assumed 2 feet of freeboard, as required by the Lake County Floodplain Management Regulations, the low beam elevation of the bridges should be 3,012 feet. The proposed grade raise from the preliminary roadway alignment raises the new roadway to an elevation of about 3,038 feet at a minimum. The deepest proposed superstructure (12 feet) would sit at an elevation of 3,026 feet which is well above the estimated low beam elevation. It was assumed that the existing spill through abutment bridge opening with 2:1 embankment slopes would be perpetuated in the new bridge options. This type of bridge opening would, at a minimum, maintain the existing hydraulic performance at the reservoir, but would also likely improve performance by providing increased vertical clearance and a wider opening. The approximate raise in vertical grade is determined based on the required vertical clearance, the existing superstructure depth, beam depth for each beam type, as well as assumed deck, haunch, and crown thicknesses.

The minimum length for the crossing at this location was determined by assuming that the channel opening at the reservoir is approximately 40 feet (which matches original as-built plans) and spill through abutments with 2:1 embankment slopes would be used on either end of the bridge. Given the number of grizzly bear crossings and mortalities observed in this location historically, it is desirable to provide a crossing structure larger than the minimum length required for hydraulic performance to encourage use by grizzly bears. Since dry ground is necessary for grizzly bear use of crossings, a bridge length of 300 feet with 15 feet of vertical clearance is proposed. This structure configuration would ensure that at least 40 feet of dry ground for grizzly bear passage would be maintained year-round.

HYDRAULIC CONSIDERATIONS

All proposed options are expected to meet the hydraulic needs of the Ninepipe Reservoir crossing based on the proposed bridge openings.

Wetland impacts do not appear to be a factor in determination of the bridge length based on the fact that all proposed bridges will have the same typical section and width. However, as the approach roadway grade increases to accommodate wider and/or taller structures, the amount of impacts to wetlands increases due to the need for wider fill slopes.

Table 2 provides the proposed structure lengths for each of the Ninepipe Reservoir options and the approximate floodplain width at the crossing. Options C-1, C-2, and C-3 are all anticipated to have the greatest beneficial impact on the aquatic resources associated with the floodplain since they all span the entire 100-year floodplain as mapped by FEMA. Each of these options demonstrates an improvement to floodplain function compared to the existing configuration which only spans about 55 percent of the floodplain.

Table 2: Ninepipe Reservoir Floodplain Impacts

Bridge Layout	Approximate Floodplain Width (ft)[a]	Total Crossing Structure Length (ft)[b]	Percentage of Floodplain Spanned (structure length / floodplain width)[c]
C-0: Baseline	140	77	55%
C-1: SEIS Preferred	140	660	>100%
C-2: Enlarged Wildlife Crossing Structures	140	660	>100%
C-3: Wildlife Overpass Configuration	140	300	>100%

[a] *Source: FEMA 2013*
[b] *Comprises total length of all wildlife crossing structures identified at each location.*
[c] *Calculated by dividing the total crossing structure length by the approximate floodplain width. Where the total structure length exceeds the floodplain width, the percentage is stated as >100%. Note: bridge piers may be required within the floodplain.*

CONSTRUCTABILITY

Based on a preliminary alignment developed for Options C-1, C-2, and C-3, the roadway grade needs to be raised about 20 to 25 feet at Ninepipe Reservoir to accommodate the proposed structures and meet minimum design standards. This preliminary roadway alignment provides enough clearance to accommodate all beam size options for all the new bridge options and required vertical grade raises.

4.2. Kettle Pond 1

A list of the structure configurations analyzed for the Kettle Pond 1 crossing location is provided below. **Table 3** provides a summary of the possible beam types that could be used in each bridge layout as well as approximated raises in roadway grade, span lengths, and number of spans needed to provide the proposed structure. Specific assumptions for the hydraulic and structural analysis at this location as well as additional considerations are provided in the following sections.

Kettle Pond 1:

- C-0: Baseline – No structure, pond spanned by an earthen berm with an equalizer culvert

- C-1: SEIS Preferred – Two 60-foot bridges with 10 to 12 feet of vertical clearance and two 4x6-foot culverts
- C-2: Enlarged Wildlife Crossing Structures – Single 800-foot bridge with 15 feet of vertical clearance
- C-3: Wildlife Overpass Configuration – Single 110-foot bridge with 10 to 12 feet of vertical clearance and two 4x6-foot culverts

Table 3: Kettle Pond 1 Bridge Layout Options

Option/Beam Type	Length (ft)	Width 1[a] (ft)	Width 2[b] (ft)	Vertical Clearance (ft)	Approx. Grade Raise (ft)	Span Length (ft)	# of Spans
C-0: Baseline	--	--	--	--	--	--	--
C-1: SEIS Preferred	60 / 60	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*5-6*	*50-75*	*1 each*
C-2: Enlarged Wildlife Crossing Structures	800	40	42	15			
Concrete Prestressed Beam (Shallow)					*8-9*	*50-75*	*11-16*
Concrete Prestressed Beam (Deep)					*11-12*	*100-125*	*6-8*
Steel Girder					*13-14*	*150-200*	*4-5*
C-3: Wildlife Overpass Configuration[c]	~110	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*5-6*	*50-75*	*2*
Concrete Prestressed Beam (Deep)					*8-9*	*100-125*	*1*

[a] Face of curb/bridge rail to face of curb/bridge rail. Width of proposed structures accommodates two (2) 12-foot travel lanes with 8-foot shoulders but does not include the width of a shared use path.
[b] Out to out deck width (including bridge rail). If shared use path is accommodated on the bridge under the proposed options, increase the bridge deck width by the width of the path (10 feet) plus one foot to accommodate pedestrian rail at the edge of the deck.
[c] This bridge layout represents the minimum design to satisfy hydraulic needs at this location. It assumed that one 110-foot bridge would be constructed in addition to the culverts proposed in the SEIS preferred alternative. Note: the dimensions of the bridge are approximated, and a full hydraulic analysis will be needed to verify assumptions.

ASSUMPTIONS

Approximately 10 feet of elevation difference occurs between the existing roadway elevation and the surface elevation of Kettle Pond 1. No floodplain is associated with the kettle pond and no history of overtopping or flooding is known at this location.

It was assumed that spill through abutments with 2:1 embankment slopes would be used for the proposed bridges. The approximate raise in vertical grade for each option was determined based on the required vertical clearance, the existing superstructure depth, beam depth for each beam type, as well as assumed deck, haunch, and crown thicknesses.

To accommodate the proposed structures and meet minimum design requirements, about 10 to 18 feet of raise in roadway grade would be needed. Constructing a new bridge opening in a location where none existed before and using a minimum of 12 to 15 feet of vertical clearance, it is expected that all of the proposed bridges would meet minimum hydraulic performance requirements and improve hydraulic conditions overall.

The length for the bridges at this location was determined by assuming that a channel opening at the pond would be a minimum of 20 feet and spill through abutments with 2:1 embankment slopes would be used on either end of the bridge. To accommodate the abutments given the existing grade, 40 to 45 feet of length would be required on each end of the bridge. Due to the lack of flow between the two sides of the pond, and the low anticipated use by wildlife at this crossing, it was determined that only one bridge (conservatively estimated at 110 feet in length) would be needed at this location.

HYDRAULIC CONSIDERATIONS

Option C-2 is expected to meet all hydraulic needs of the Kettle Pond 1 crossing based on the proposed bridge opening. A more in-depth hydraulic analysis is required to confirm the hydraulic performance of C-1 and C-3 since the configurations consist of a combination of bridges and culverts which are difficult to analyze as a system without a hydraulic model.

Wetland impacts do not appear to be a major factor in determination of the bridge length. However, using two separate bridges (as in C-1) with an elevated roadway between bridges will likely result in more wetland impacts than a single, longer bridge (as in C-2) which would only require roadway approaches on each end of the Kettle Pond where no wetlands are present. Additionally, as the approach roadway grade increases to accommodate wider and/or taller structures, the likelihood of impacts to wetlands also increases due to the need for wider fill slopes.

As shown in **Table 3**, it was determined that the minimum bridge length needed to satisfy hydraulic requirements (C-3) is longer than the proposed bridge length in the SEIS preferred option (C-1). It was determined that the 60-foot bridges (C-1) would not satisfy hydraulic requirements based on the assumed channel opening, bridge structure depth, and embankment slopes.

CONSTRUCTABILITY

To accommodate the structures in C-1 and C-3 and meet minimum design standards, the roadway grade needs to be raised about 10 to 18 feet. To accommodate the structure in C-2, about 18 feet of grade raise is anticipated to be needed. The proposed changes in grade may be able to be reduced slightly since there is approximately 10 feet of clearance between the existing US 93 elevation and the Kettle Pond. The preliminary raises in grade would give enough clearance to accommodate all beam size options for all the new bridge options and required vertical grade raises.

While all of the proposed bridge layouts would be feasible to construct, the C-1 bridges would be easier to design and construct since they are single span structures. The larger, multiple-span bridge in C-2 may also require additional mitigation to reduce slope instability. A single span bridge with two abutment foundations at each end could likely be used for C-3, however, using a multiple span bridge may reduce the required grade raise at this location.

When constructing the bridges in all options, the existing roadway material would have to be excavated and removed to the bottom of the pond elevation in order to restore hydrologic connectivity. Removing all of the material under the 800-foot bridge in C-2 would be more costly than removing one or two smaller sections of embankment in C-3 and one smaller section of embankment in C-3.

4.3. Kettle Pond 2

A list of the structure configurations analyzed for the Kettle Pond 2 crossing location is provided below. **Table 4** provides a summary of the possible beam types that could be used in each bridge layout as well as approximated raises in roadway grade, span lengths, and number of spans needed to provide the proposed structure. Specific assumptions for the hydraulic and structural analysis at this location as well as additional considerations are provided in the following sections.

Kettle Pond 2:

- C-0: Baseline – No structure, pond spanned by an earthen berm with an equalizer culvert
- C-1: SEIS Preferred – Two 60-foot bridges with 10 to 12 feet of vertical clearance and two 4x6-foot culverts
- C-2: Enlarged Wildlife Crossing Structures – Single 800-foot bridge with 15 feet of vertical clearance
- C-3: Wildlife Overpass Configuration – Single 110-foot bridge with 10 to 12 feet of vertical clearance, two 4x6-foot culverts

Table 4: Kettle Pond 2 Bridge Layout Options

Option/Beam Type	Length (ft)	Width 1[a] (ft)	Width 2[b] (ft)	Vertical Clearance (ft)	Approx. Grade Raise (ft)	Span Length (ft)	# of Spans
C-0: Baseline	--	--	--	--	--	--	--
C-1: SEIS Preferred	60 / 60	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*3-4*	*50-75*	*1 each*
C-2: Enlarged Wildlife Crossing Structures	800	40	42	15			
Concrete Prestressed Beam (Shallow)					*4-5*	*50-75*	*11-16*
Concrete Prestressed Beam (Deep)					*7-8*	*100-125*	*6-8*
Steel Girder					*9-10*	*150-200*	*4-5*
C-3: Wildlife Overpass Configuration[g]	~110	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*3-4*	*50-75*	*2*
Concrete Prestressed Beam (Deep)					*6-7*	*100-125*	*1*

[a] Face of curb/bridge rail to face of curb/bridge rail. Width of proposed structures accommodates two (2) 12-foot travel lanes with 8-foot shoulders but does not include the width of a shared use path.
[b] Out to out deck width (including bridge rail). If shared use path is accommodated on the bridge under the proposed options, increase the bridge deck width by the width of the path (10 feet) plus one foot to accommodate pedestrian rail at the edge of the deck.
[c] This bridge layout represents the minimum design to satisfy hydraulic needs at this location. It assumed that one 110-foot bridge would be constructed in addition to the culverts proposed in the SEIS preferred alternative. Note: the dimensions of the bridge are approximated, and a full hydraulic analysis will be needed to verify assumptions.

ASSUMPTIONS

There is about 14 to 16 feet of elevation difference between the existing roadway elevation and the surface elevation of Kettle Pond 2. There is no floodplain associated with the kettle pond and there is no known history of overtopping or flooding at this location.

It was assumed that spill through abutments with 2:1 embankment slopes would be used for the proposed bridges. The approximate raise in vertical grade for each option was determined based on the required vertical clearance, the existing superstructure depth, beam depth for each beam type, as well as assumed deck, haunch, and crown thicknesses.

To accommodate the proposed structures and meet minimum design requirements, about 6 to 12 feet of raise in roadway grade would be needed. Constructing a new bridge opening in a location where none existed before and using a minimum of 12 to 15 feet of vertical clearance, it is expected that all of the proposed bridges would meet minimum hydraulic performance requirements and improve hydraulic conditions overall.

The length for the bridge at this location was determined by assuming that a channel opening at the pond would be a minimum of 20 feet and spill through abutments with 2:1 embankment slopes would be used on either end of the bridge. To accommodate the abutments given the existing grade, 45 to 50 feet of length would be required on each end of the bridge. Due to the lack of flow between the two sides of the pond, and the low anticipated use by wildlife at this crossing, it was determined that only one bridge (conservatively estimated at 110 feet in length) would be needed at this location.

HYDRAULIC CONSIDERATIONS

Option C-2 is expected to meet all hydraulic needs of the Kettle Pond 2 crossing based on the proposed bridge opening. A more in-depth hydraulic analysis is required to confirm the hydraulic performance of C-1 and C-3 since the configurations consist of a combination of bridges and culverts which are difficult to analyze as a system without a hydraulic model.

Wetland impacts do not appear to be a major factor in determination of the bridge length. However, using two separate bridges (as in C-1) with an elevated roadway between bridges will likely result in more wetland impacts than a single, longer bridge (as in C-2) which would only require roadway approaches on each end of the Kettle Pond where no wetlands are present. Additionally, as the approach roadway grade increases to accommodate wider and/or taller structures, the likelihood of impacts to wetlands also increases due to the need for wider fill slopes.

As shown in **Table 4**, it was determined that the minimum bridge length needed to satisfy hydraulic requirements (C-3) is longer than the proposed bridge length in the SEIS preferred option (C-1). It was determined that the 60-foot bridges would not satisfy hydraulic requirements based on the assumed channel opening, bridge structure depth, and embankment slopes.

CONSTRUCTABILITY

To accommodate the structures in C-1, C-2, and C-3 and meet minimum design standards, the roadway grade would need to be raised about 6 to 12 feet. The proposed changes in grade may be able to be reduced slightly since there is approximately 14 to 16 feet of clearance between the existing US 93 elevation and the Kettle Pond.

The preliminary raises in grade would give enough clearance to accommodate all beam size options for the C-1 bridges but may not give enough clearance to accommodate the larger, longer span beam options for C-2. For C-3, a single span bridge can likely be used for this crossing with two abutment foundations at the ends to simplify design and construction and reduce costs. However, using multiple spans would reduce the grade raise needed to accommodate the structure.

While all of the proposed bridge layouts would be feasible to construct, the C-1 bridges, and potentially the C-3 bridge, would be easier to design and construct since they are single span structures. The larger, multiple-span bridge in C-2 may also require additional mitigation to reduce slope instability.

When constructing the bridges in all options, the existing roadway material would have to be excavated and removed to the bottom of the pond elevation in order to restore hydrologic connectivity. Removing all of the material under the 800-foot bridge in C-2 would be more costly than removing two smaller sections of embankment in C-1 and one smaller section of embankment in C-3.

4.4. Crow Creek

A list of the structure configurations analyzed for the Crow Creek crossing location is provided below. The structure at Crow Creek is the same for both Options C-2 and C-3. **Table 5** provides a summary of the possible beam types that could be used in each bridge layout as well as approximated raises in roadway grade, span lengths, and number of spans needed to provide the proposed structure. Specific assumptions for the hydraulic and structural analysis at this location as well as additional considerations are provided in the following sections.

Crow Creek:

- C-0: Baseline – Two 10x14-foot culverts
- C-1: SEIS Preferred – Two bridges (120-foot and 150-foot) with 10 to 12 feet of vertical clearance
- C-2/C-3: Enlarged Wildlife Crossing Structures – Single 500-foot bridge with 15 feet of vertical clearance

Table 5: Crow Creek Bridge Layout Options

Option/Beam Type	Length (ft)	Width 1[a] (ft)	Width 2[b] (ft)	Vertical Clearance (ft)	Approx. Grade Raise (ft)	Span Length (ft)	# of Spans
C-0: Baseline	14 / 14	28	--	10	--	--	--
C-1: SEIS Preferred	120 / 150	40	42	10-12			
Concrete Prestressed Beam (Shallow)					*13-14*	*50-75*	*2 each*
Concrete Prestressed Beam (Deep)					*16-17*	*100-125*	*1 each*
Steel Girder					*18-19*	*150-200*	*1 each*
C-2/C-3: Enlarged Wildlife Crossing Structures / Wildlife Overpass Configuration	500	40	42	15			
Concrete Prestressed Beam (Shallow)					*16-17*	*50-75*	*7-10*
Concrete Prestressed Beam (Deep)					*19-20*	*100-125*	*4-5*
Steel Girder					*21-22*	*150-200*	*2-3*

[a] Face of curb/bridge rail to face of curb/bridge rail. Width of proposed structures accommodates two (2) 12-foot travel lanes with 8-foot shoulders but does not include the width of a shared use path.
[b] Out to out deck width (including bridge rail). If shared use path is accommodated on the bridge under the proposed options, increase the bridge deck width by the width of the path (10 feet) plus one foot to accommodate pedestrian rail at the edge of the deck.

ASSUMPTIONS

It was assumed that spill through abutments with 2:1 embankment slopes would be used for the proposed bridges. To accommodate the proposed structures and meet minimum design requirements, about 18 to 22 feet of raise in roadway grade would be needed. Replacing the existing undersized culverts with new bridge(s) and using a minimum of 12 to 15 feet of vertical clearance, it is expected that all of the proposed bridges would meet minimum hydraulic performance requirements and improve hydraulic conditions overall.

A smaller bridge satisfying minimum hydraulic requirements is not proposed for this location due to the desire by resource agencies to accommodate and encourage large mammal crossings at Crow Creek. Therefore, the bridges proposed in Options C-2 and C-3 are the same. Preliminary analysis also confirmed that the lengths proposed in the SEIS preferred option are adequate to satisfy hydraulic needs.

The approximate raise in grade for each option was determined based on the required vertical clearance, the existing superstructure depth, beam depth for each beam type, as well as assumed deck, haunch, and crown thicknesses. There is about 2 to 4 feet of elevation difference between the existing roadway elevation and the surface elevation of Crow Creek. This additional elevation could be used for clearance once excavated.

HYDRAULIC CONSIDERATIONS

Option C-2/C-3 is expected to meet all hydraulic needs of the Crow Creek crossing based on the proposed bridge opening. A more in-depth hydraulic analysis is required to confirm the hydraulic performance of C-1 since the configuration consists of a combination of bridges and culverts which are difficult to analyze as a system without a hydraulic model.

Wetland impacts do not appear to be a major factor in determination of the bridge length. However, using two separate bridges (as in C-1) with an elevated roadway between bridges will likely result in more wetland impacts than a single, longer bridge (as in C-2/C-3) which would only require roadway approaches on each end of Crow Creek where no wetlands are present. Additionally, as the approach roadway grade increases to accommodate wider and/or taller structures, the likelihood of impacts to wetlands also increases due to the need for wider fill slopes.

Table 6 provides the proposed structure lengths for each of the Crow Creek options and the approximate floodplain width at the crossing. Option C-2/C-3 is anticipated to have the greatest beneficial impact on the aquatic resources associated with the floodplain by providing the greatest stream and floodplain opening. Both C-1 and C-2/C-3 demonstrate an improvement to floodplain function by spanning 42 and 78 percent of the floodplain, respectively, compared to 4 percent of the floodplain that is currently spanned by the culverts at Crow Creek (C-0).

Table 6: Crow Creek Floodplain Impacts

Bridge Layout	Approximate Floodplain Width (ft)[a]	Total Crossing Structure Length (ft)[b]	Percentage of Floodplain Spanned (total structure length / floodplain width)[c]
C-0: Baseline	645	14/14	4%
C-1: SEIS Preferred	645	120/150	42%
C-2/C-3: Enlarged Wildlife Crossing Structures/Wildlife Overpass Configuration	645	500	78%

[a] *Source: FEMA 2013*
[b] *Comprises total length of all wildlife crossing structures identified at each location.*
[c] *Calculated by dividing the total crossing structure length by the approximate floodplain width. Where the total structure length exceeds the floodplain width, the percentage is stated as >100%. Note: bridge piers may be required within the floodplain.*

CONSTRUCTABILITY

To accommodate the structures in C-1 and meet minimum design standards, the roadway grade would need to be raised approximately 18 feet. To accommodate the structure in C-2/C-3, about 22 of grade raise would be needed. These raises in grade would give enough clearance to accommodate all beam size options for the C-1 bridges but may not give enough clearance to accommodate the larger, longer span beam options for C-2/C-3.

Both C-1 and C-2/C-3 are feasible to construct, however the C-1 bridges would be easier to design and construct since they are single span structures. The larger, multiple-span bridge in C-2/C-3 may also be more susceptible to liquefaction and may require larger and deeper pipe piles to withstand seismic events.

When constructing the bridges in both options, the existing roadway material would have to be excavated and removed to the bottom of the creek elevation in order to enhance hydrologic connectivity. Removing all of the material under the 500-foot bridge in C-2/C-3 would be more costly than removing two smaller sections of embankment in C-1.

5.0. WILDLIFE OVERPASS

During field investigations, inclusion of a wildlife overpass at Post A Canal was proposed to better facilitate wildlife crossings and reduce impacts to waterbodies. Provision of a wildlife overpass is assumed to provide an attractive crossing for grizzly bears and other large mammals and would reduce the need to provide larger, more impactful structures at hydraulic crossings. The Post A Canal is also favorable for siting because the terrain is already elevated, enabling easier construction of an overpass. Furthermore, numerous grizzly bear GPS crossings and animal mortalities have historically been observed at this location.

Initially, a structure similar to the overpass constructed outside Evaro in 2010 was considered. The structure is vegetated with a half-circle opening that is 49 feet in width and 197 feet in length. However, updated design standards recommend an oval crossing with a flattened top to increase the line of sight across the structure for animals. Research suggests that round, steep structures like the Evaro overpass, are unlikely to be used by grizzly bears, particularly family groups. Solitary grizzly bears and family groups are three and five times, respectively, more likely to use overpasses compared to underpasses when correctly designed.[5]

The arch for the overpass could be constructed of either prefabricated cast-in-place concrete or corrugated steel arches. In general, the overpass should be vegetated with native trees, shrubs, grasses, and soils with strategically placed cover to enhance the sense of security for animals. If designed and integrated correctly, an overpass can restore habitat connectivity. Wildlife fencing should be used to guide wildlife to the crossing and prevent intrusions onto the roadway right-of-way. Overpasses are best situated in areas bordered by elevated terrain, enabling the approach ramps and surface of structure to be at the same level as the adjacent land. If the structure is built on level ground, then approach ramps should have gentle slopes (5:1 or less). Flatter slopes generally require more fill, which extends the approach ramp farther out away from the structure.

Constructability of a wildlife overpass in this location is generally favorable. Since the structure would most likely be constructed with a prefabricated arch, structural design of the arch would be completed by the supplier. However, the holistic design of the structure to appropriately accommodate wildlife including width, ramp design, and vegetation would need to be coordinated with wildlife experts to ensure maximum functionality. Construction of the overpass and associated elements is unlikely to require special equipment or expertise and can be completed relatively quickly. Further geotechnical analysis would be needed to confirm soil stability and to determine the foundation type and size needed for the overpass. Implementation of an overpass can be somewhat costly compared to an underpass structure, especially due to the larger footprint and possible need for additional right-of-way.

6.0. SHARED USE PATH CROSSINGS

The SEIS recommended a separated shared use path along the corridor and indicated an underpass structure may be used to minimize wetland and right-of-way impacts. Potential alignments and crossings are listed below.

Shared Use Path Crossings:

- C-0: Baseline – No shared use path
- C-1: SEIS Preferred – Westside alignment south of Kettle Pond 2 and eastside alignment north of Kettle Pond 2 with underpass at Kettle Pond 2
- C-2: Crossing South of Ninepipe Reservoir – Westside alignment south of Ninepipe Reservoir and eastside alignment north of Ninepipe Reservoir with underpass at Ninepipe Reservoir
- C-3: Eastside Alignment – Eastside alignment throughout corridor with no underpass

Without hydraulic modeling and specific groundwater elevation data, it is difficult to determine the hydraulic feasibility of each potential shared use path crossing. Information from the geotechnical report indicates that the groundwater elevation is estimated to be 10-15 feet below the surface throughout the corridor. The grade of the roadway would have to be raised enough to ensure that the underpasses are not underwater, or pumps would have to be used to move water away from the crossing.

From a structural standpoint, it is expected that the crossing would be a culvert, since most pedestrian underpasses in Montana are culverts. Bridges are rarely used for pedestrian underpasses unless there is demand for more natural light through the crossing or other unique circumstances.

7.0. KEY FINDINGS AND FEASIBILITY DETERMINATION

This memorandum provides a planning-level analysis of four corridor-wide options with different structure types and configurations at key crossing locations within the Ninepipe segment of the US 93 corridor. A summary of key findings and considerations is provided below.

- When determining the most appropriate structure type, it is important to consider hydraulic conditions, wildlife crossing needs, geotechnical feasibility, and overall constructability.
- US 93 crosses six water resources within the Ninepipe segment. Underpass crossing structures to accommodate wildlife are proposed at four locations (Ninepipe Reservoir, Kettle Ponds 1 and 2, and Crow Creek). One option includes a wildlife overpass at Post A Canal.
- The existing structure at Crow Creek is inadequate to convey peak flows. Floodplains are associated with Ninepipe Reservoir and Crow Creek. These two resources are considered fish-bearing.

- Large mammals prefer larger structures with wider openings, greater vertical clearance (preferably 15 feet), and dry land for crossing.
- Larger structures may require additional mitigation to ensure stability including deeper pipe piles, wider foundations, subexcavation, and embankment surcharging.
- Construction requirements – including equipment size, construction duration, detour needs, raises in grade, and overall cost – vary slightly, with larger and longer structures being comparatively more difficult and costly to construct.
- Overall, it was found that all of the proposed bridges are feasible to construct within the Ninepipe segment. The bridges vary in terms of length, number of spans required, beam type, impacts, ability to satisfy hydraulic needs, and wildlife crossing accommodations.
    - In general, **Option C-0 (Baseline)** is inadequate to meet hydraulic needs and facilitate wildlife crossings.
    - **Option C-1 (SEIS Preferred)** generally serves all needs, but the proposed structures may not be tall enough for larger mammals. Hydraulic performance is questionable at the kettle pond locations without more detailed hydraulic modeling and analysis.
    - **Option C-2 (Enlarged Wildlife Crossing Structures)** satisfies hydraulic and wildlife crossing needs, however, the larger and longer structures would be more difficult and costly to construct, would require greater geotechnical mitigation, and would result in more impacts to adjacent natural resources.
    - **Option C-3 (Wildlife Overpass Configuration)** was developed under the assumption that if a wildlife overpass were to be constructed in the corridor, smaller structures may be acceptable at other crossing locations. The structures at other crossing locations were developed to satisfy minimum hydraulic needs, reduce impacts to adjacent natural resources and provide adequate crossing accommodations for the wildlife anticipated to use each crossing. Some structures may not be large enough to accommodate all wildlife, but paired with an overpass at Post A Canal, wildlife crossing needs are anticipated to be satisfied. A geotechnical analysis and consultation with wildlife experts would be needed to confirm design of the wildlife overpass structure.
- Additional hydraulic and geotechnical analyses are needed to confirm the feasibility of the proposed shared use path crossings.

REFERENCES

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