FINAL HYDRAULICS REPORT

FHWA Project WY PFH 26-1(3)-Sage Creek Road
Task Order No.: DTFH68-10-D-00001/T-11-025
(Section C, D, and E from STA 2585+00 to STA 3700+08)
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1.0 INTRODUCTION

The scope of work for this project is to perform environmental, engineering, hydraulic, geotechnical, right-of-way, and project management services towards delivery of a 100% plan set package for the Federal Highway Administration (FHWA), Central Federal Lands Highway Division (CFLHD) for proposed improvements to Wyoming Forest Highway 26, or Sage Creek Road.

Sage Creek Road is located between the City of Rawlins and Wyoming State Highway 70 (WY-70). It functions as the principle gateway between the City of Rawlins and the multitude of social, economic, and environmental resources associated with the adjacent lands, High Savery Dam and Reservoir, and Medicine Bow-Routt National Forest (MBNF). Various improvements for Sage Creek Road have been proposed through a cooperative effort between the U.S. Forest Service (USFS), CFLHD, Wyoming Department of Transportation (WYDOT), and Carbon County Road and Bridge. The long-term goal for the road is that it will be improved, enhancing the safety and reducing maintenance cost associated with the corridor.

The following were the main tasks in developing this report:

- Perform hydraulic analysis for adequate sizing of replacement culverts and energy dissipater as well as to determine the hydraulic adequacy of existing culverts.
- Determine adequacy of roadway ditches in terms of capacity and stability and evaluate requirement for permanent erosion control measures.

The purpose of this hydraulics report is to document the proposed drainage improvements of Sage Creek Road and document the assumptions made in the hydraulic analysis. The *Project Development and Design Manual* (PDDM) (U.S. Department of Transportation, 2008) was used as the main source of criteria. Per the PDDM, this roadway is classified as a Low-Standard Road.

1.1 PROJECT DESCRIPTION AND BACKGROUND

The following environmental studies have been completed for this project:

- Section C – Station (Sta.) 2245+00 to Sta. 2817+70 – Categorical Exclusion (CATEX)
- Section D – Sta. 2820+00 to Sta. 3154+56 – Environmental Assessment (EA) (Finding of No Significant Impact [FONSI] completed April 2010)
- Section E – Sta. 3160+00 to Sta. 3700+06 – EA (FONSI completed April 2010)

Section C is approximately 10.85 miles in length and will have a design speed of 55 miles per hour (mph). The roadway will be reconstructed with a traveled way surface of gravel course and will meet all accepted criteria (no design exceptions).

Section D is approximately 6.34 miles in length and will have a design speed of 45 mph. The roadway will be reconstructed with a traveled way surface of gravel course. One design exception currently is proposed near the High Savery Reservoir outlet. At this location, a 35 mph design speed sag vertical curve was used to eliminate impacts to adjacent facilities. No other design exceptions are proposed.

Section E is approximately 10.23 miles in length and will have a design speed of 25 mph. The roadway will be reconstructed with a traveled way surface of gravel course. Section E is in USFS land and it is desired to keep the proposed work as close to the existing conditions as possible. This includes matching existing side slopes and catching ground as soon as possible. This requires some steep side slopes adjacent to the roadway.

Following the 70% Field Review, the remaining segment of Sage Creek Road was divided into multiple schedules and options to meet funding needs:

Option X (Sta. 2245+00 to Sta. 2892+00)
Sta. 2245+00 to Sta. 2817+69.560 (Section C) – 10.85 miles
Sta. 2820+000 to Sta. 2892+00 (Section D) – 1.36 miles

Schedule B (Sta. 2892+00 to Sta. 3700+05.84)
Sta. 2892+00 to Sta. 3154+55.77 (Section D) – 4.97 miles
Sta. 3160+00 to Sta. 3700+05.84 (Section E) – 9.96 miles
(No work zone from Sta. 3645+50 to Sta. 3660+00)

Schedule A (Sta. 3232+20 to Sta. 3700+05.84)
Sta. 3232+20 to Sta. 3700+05.84 (Section E) – 8.59 miles
(No work zone from Sta. 3645+50 to Sta. 3660+00)

A Value Engineering study was performed by FHWA in March of 2012. The following ideas were derived from this study:

- Reduce aggregate thickness
- Minimize riprap lined ditches
- Minimize temporary erosion control
- Full road closures

These ideas were discussed during the 70% Plans, Specifications, and Estimate (PS&E) review meeting as well as the 70% Field Review. It was agreed that all ideas would be investigated and implemented if applicable. All ideas, excluding reducing the check dams as temporary erosion control, have merit and were carried forward.

The major items of work include vertical alignment improvements that require roadway excavation and embankment, gabion walls, reinforces soil slopes, drainage improvements, fish passages, and aggregate surface course placement. There are several minor approach road realignments to match the improved vertical alignment. The American Association of State Highway and Transportation Officials (AASHTO) *Geometric Design of Very Low-Volume Roads* and WYDOT design standards have been used.

Schedule A is approximately 8.59 miles in length. The proposed design speed is 25 mph. The roadway will be reconstructed with aggregate surface course. Minor excavation will be performed that will return the slopes to their original slopes and grades thus removing “slumped” material near the roadway. With few opportunities to excavate the decision was made it implement reinforced soil slopes with welded wire face (RSS) and gabion walls (walls) to reduce required embankment material. Schedule A is an excavation project with an approximate waste of 10,000

cubic yards (CUYD). Fish passages are being constructed at Big Sandstone Creek (Sta. 3371+69) and Little Sandstone Creek (Sta. 3560+84). These fish passages are designed using the approved methodology agreed upon by FHWA and USFS. There is a no work zone located from Sta. 3645+50 to Sta. 3660+00 through Aspen Alley.

Schedule B is approximately 14.93 miles in length and includes Schedule A. The proposed design speed is 45 mph at the northern end and 25 mph at the southern end entering MBNF. The roadway will be reconstructed with aggregate surface course. Schedule B is an excavation project and is approximately balanced. The schedule includes (in addition to Schedule A) the replacement of a 60-inch culvert with a 90-inch culvert at Dirtyman Fork (Sta. 2951+99). This location suffered a culvert and subsequent roadway failure recently that was temporarily repaired by Carbon County, Wyoming. There is a no work zone located from Sta. 3645+50 to Sta. 3660+00 through Aspen Alley.

Option X is approximately 12.21 miles in length. The proposed design speed is 45 mph. The roadway will be reconstructed with aggregate surface course. A fish passage is being constructed at North Fork Savery Creek (Sta. 2591+22). This fish passage is designed using the approved methodology agreed upon by FHWA and USFS.

The major items of work include vertical alignment improvements that require roadway excavation, drainage improvements, and aggregate base surface course placement. There are several minor approach road realignments to match the improved vertical alignment. The AASHTO *Geometric Design of Very Low-Volume Roads* and WYDOT design standards will be used.

Currently, Sage Creek Road is divided into three separate roadway systems. These consist of a State Highway System Route, a Carbon County Route, and a Forest Development Road. The State Highway System Route was reconstructed in 2005. Project design standards were finalized in the FONSI (April 2010). The project is funded by Federal Lands Highway, Forest Highway Program.

The proposed road reconstruction will closely follow the existing road with widening as appropriate to improve safety and minimize impacts. Reconstruction will improve the alignment, grade, and width to current standards. The project includes grading, drainage structures, placement of crushed aggregate base, signing, and other safety-related features necessary to meet current design practice.

Sections C and D are characterized by the presence of open grass land and vegetation consisting mainly of sage brush and Section E consists mainly of forested areas. The roadway alignment follows a north-south direction up to Sta. 3170+00 and thereafter follows a winding pattern to the end of Section E. The major streams that cross the project area are the North Fork Savory Creek, Truck Driver's Creek, Deep Gulch, East Fork, Dirtyman Fork, Deep Creek, Big Sandstone Creek, and Little Sandstone Creek. There is an irrigation ditch crossing known as the Belvidere ditch belonging to USFS.

1.2 PROJECT LOCATION

The project area consists of part of Section C, Section D, and Section E. The project area is within range R87W and R88W and townships T14N, T15N and T16N, approximately 35 miles south of Rawlins. The project area location is shown in Figure 1.

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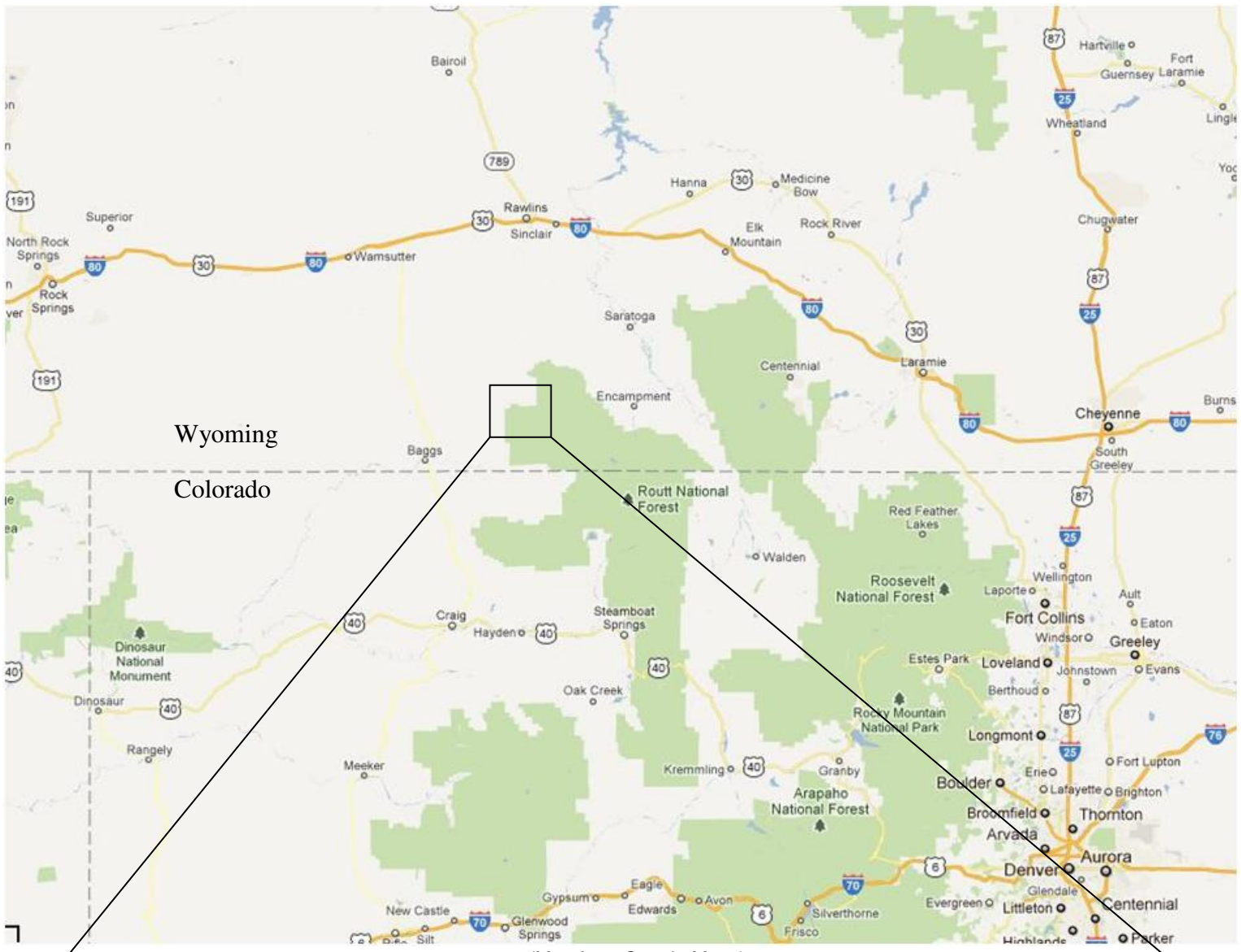

(Map from Google Maps)

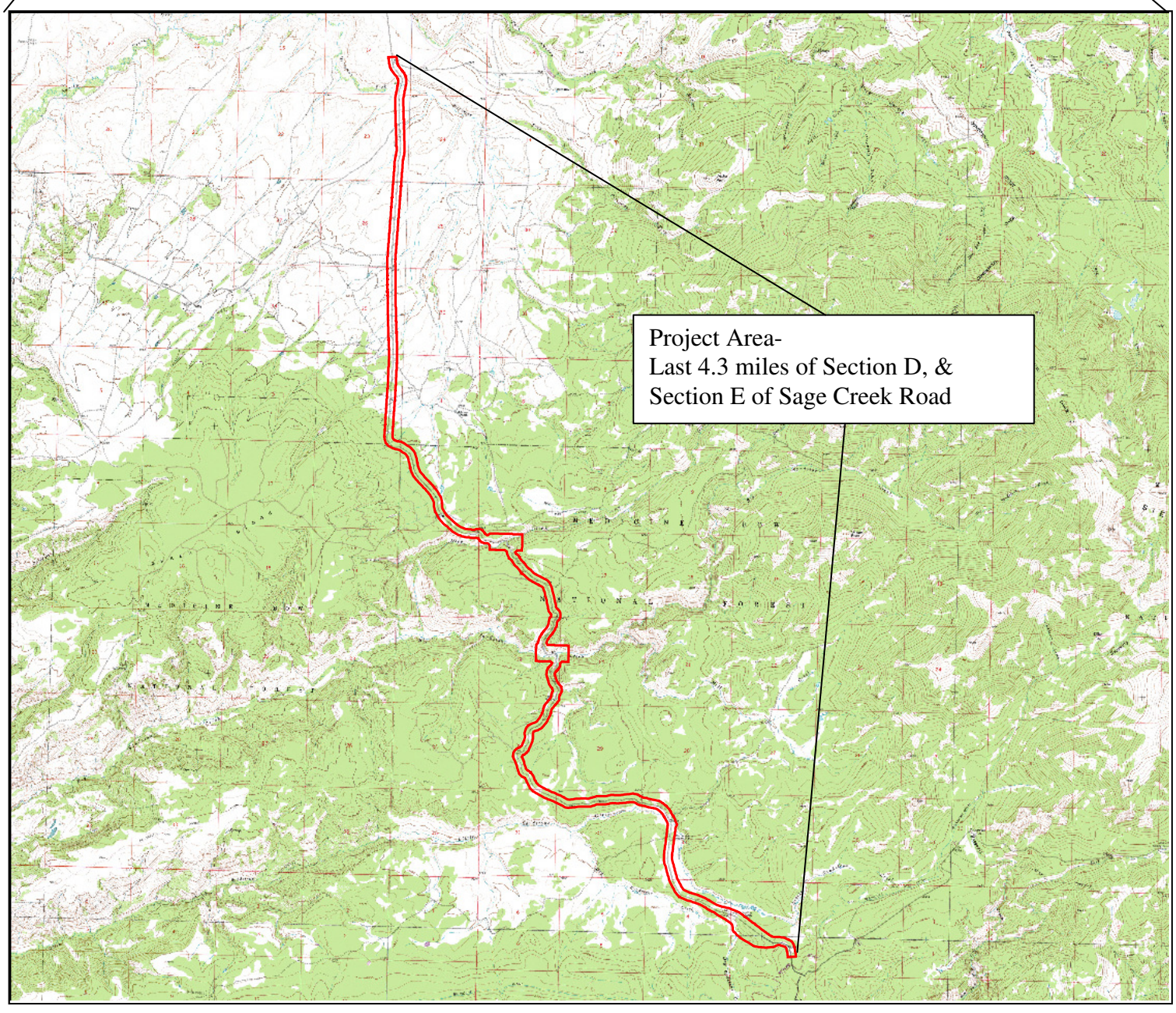

Figure 1. Location Map

2.0 HYDROLOGY

2.1 DRAINAGE BASIN DESCRIPTIONS

Watershed basin delineations were prepared using 20-foot contours from the U.S. Geological Survey (USGS) Quad maps and LIDAR topography. Elevations within the roadway right of way ranged from 7,400 feet to 8,400 feet. Within the project area, the following major perennial streams cross the project area:

North Fork Savory Creek	Sta. 2591+22
Truckdrivers Creek	Sta. 2729+96
Deep Gulch	Sta. 2765+20
Savery Creek	Sta. 2875+11
Dirtyman Fork	Sta. 2951+99
Deep Creek	Sta. 3280+90
Big Sandstone Creek	Sta. 3370+69
Little Sandstone Creek	Sta. 3560+84

Belvidere Ditch, an irrigation ditch is located at Sta. 3694+84.

Based on the National Resource Conservation Survey (NRCS) soil survey, most of the soils belong to the Soil Hydrologic Group D. The soil hydrologic index data developed by USGS (2003), in cooperation with the WYDOT, depict soils to have hydrologic indices varying from 2 to 4 (see Appendix A). Land cover consists mainly of scrubland /grassland and some forested areas. Basin maps for areas are included in Appendix B.

2.2 PRECIPITATION

Design rainfall used in this analysis was based on criteria obtained from the National Oceanic and Atmospheric Administration (NOAA) (1973). Per NOAA, the basins within the projects belong to Region 1–Wyoming East of Continental Divide and north of South Platte.

Point rainfall data pertaining to latitude 41.24 degree north and longitude 107.25 degree west were taken from the NOAA Atlas (1973). Design point rainfall values for the site are shown in Table 1. Based on NOAA's precipitation frequency estimates, intensity-duration-frequency curves for the area were generated. These curves were used with the Rational Method for the hydrologic analysis performed as part of the drainage calculations for areas with drainage areas of less than 200 acres. See Appendix C for NOAA precipitation data. Average temperatures in the project areas vary from 12 degrees Fahrenheit to 70 degrees Fahrenheit.

Table 1: Design Point Rainfall

Return Period	1-hour (inches)	6-hour (inches)	24-hour (inches)
2-year	0.65	0.95	1.30
5-year	0.90		
10-year	1.10		
25-year	1.25		
50-year	1.50		
100-year	1.66	2.17	2.91

2.3 FLOOD HISTORY

The project improvements lie within Flood Insurance Rate Map Panels numbered 5600080925B, 5600081525B, and 5600081125B. These panels are entirely outside 100-year and 500-year floodplains and are therefore not included in the county kit of Federal Emergency Management Agency (FEMA) mapped areas.

2.4 BASIS FOR DESIGN FREQUENCY

Design standards and criteria were obtained from Chapter 7 of the PDDM (CFLHD, 2008). Table 2 summarizes the design standards method adopted and criteria. Energy dissipaters were designed using HEC 14 methodology (FHWA, 2006). Ditch lining and erosion protection criteria and methods of outlet protection were established through discussion with the CFLHD staff and criteria from HEC 22 (FHWA, 2001). The decision to use 10-year design frequency for culverts greater than or equal to a 48-inch diameter instead of 25-year design frequency per the PDDM is based on discussion with CFLHD and rationale provided in the hydraulics report dated December 2010 submitted to CFLHD.

Table 2: Design Standards Method and Criteria

Roadway Classification	Low-standard road
Peak Flow Calculation	Drainage areas < 200 acres Rational Method Drainage areas ≥ 200 acres National Stream Flow Statistics Program (NSS Program)
Ditch Design	10-year frequency - Design Method -Manning's Equation
Ditch Lining/Ditch Protection	Ditch slope ≤ 3% no protection Ditch slope > 3% establish need for protection based on HEC 22 **Method of Erosion Protection:** Ditch slope 3% to 5% and drainage areas < 10 acres check dams Ditch slope > 5% or drainage areas >10 acres riprap lining
Cross Culverts <48-inch	25-year frequency - Design Method -FHWA Program HY8
Cross Culverts>=48-inch	10-year frequency- Design Method -FHWA Program HY8
Energy Dissipaters	25-year for cross culverts <48 inches 10-year for cross culverts ≥ 48 inches Method used-HEC 14 **Method of Outlet Protection:** Outlet velocity > 10 ft/sec riprap basins Outlet velocity<= 10 ft/sec riprap standard aprons
Urban vs. Rural	Rural

2.5 PREDICTION OF DESIGN DISCHARGE

Hydraulic analyses are based on the peak flow rates calculated using the Rational Method and the NSS Program (USGS, 2003).

The Rational Method calculations were based on Chapter 2 of FHWA's Hydraulic Design Series No. 2 (HDS 2), Highway Hydrology (USDOT, 2002). In determining the time of concentration, sheet flow travel time was used for the initial runoff, followed by the velocity method to determine the total time required. To avoid the iterative process, the initial time of concentration equation published by Urban Hydrology for Small Watersheds, TR-55 (NRCS, 1986) was used with a minimum time of concentration of 0.1 hour.

For basins having drainage areas greater than 200 acres the NSS Program was used. The basins are located within Region 1, the Rocky Mountains (see map in Appendix A). The equation established for this region has three parameters: drainage area, longitude of basin outlet, and mean basin elevation. The mean basin elevation is estimated as the spatially averaged elevation of the watershed using a USGS Digital Elevation Model within a Geographic Information Systems (GIS). A summary of the design discharges for the culvert crossings is provided in Table 5 in Section 4.1, Culverts.

2.6 EXISTING CULVERTS AND ASSUMPTIONS

There are 100 identified existing cross-culverts and 18 driveway culverts in Sections C, D, and E. There are 83 existing culvert crossings between Sta. 2580+00 and Section E summarized in this report. The hydraulic recommendations for the remaining 16 existing culverts located between the start of option Y to Sta. 2580+00 were presented in the previous drainage report submitted to CFLHD in March 2011. The following assumptions were made for this stretch of the project:

- **Culvert Inverts.** For Sections C and D, the inverts of the pipes were estimated from the TIN model obtained from CFLHD, and the location of the pipe from plan view in the Microstation DGN file. Adjustments, if necessary, were made to the pipe profiles to maintain adequate pipe cover with the existing roadway and also approximately match the existing ground at the inlet and outlet. Culverts in Section E were obtained from the survey file call out obtained from CFLHD.
- **Culvert Materials**. All culverts are assumed to be corrugated metal pipes (CMP).
- **Culvert Conditions.** Culvert conditions were obtained from field notes and site photos.

3.0 DESIGN DISCUSSION

Most of the hydrologic and hydraulic design work associated with this project is performed in compliance with the PDDM. Design criteria, methods, and frequencies used for different elements of the project are discussed in Table 2 of this report.

The drainage improvements to Section C and Section D are based on a series of assumptions made regarding size, material, and inverts of existing structures. It is therefore essential that field verification be made before the drainage recommendations are implemented.

3.1 DESIGN CONSIDERATIONS

3.1.1 Wetlands and Waters of the U.S.

A preliminary wetland delineation report was prepared by Hydro Logic, LLC of Laramie, Wyoming for WYDOT in 2006. The locations of all jurisdictional/non-jurisdictional wetlands and waters of the U.S. along the project corridor are listed and shown in plans attached to the report (WYDOT, 2006). This delineation report was submitted for verification and approval to the Wyoming Regulatory Office of the Omaha District of the U. S. Army Corps of Engineers (COE) on September 11, 2006, by FHWA (NWO-2006-40273-RWY). The delineation report was approved and project impacts on wetlands were evaluated by COE through a 404 permitting process. Related wetland mitigation plans for this project have been completed (ERO, 2008).

3.1.2 Future Land Use

The contributing basin areas of the project are located within unincorporated Carbon County and lands owned by the Bureau of Land Management. Per the draft comprehensive land use plan of Carbon County (WLC Engineering Surveying and Planning, 2010), the contributing basin areas are mostly zoned as rural agriculture.

3.2 HYDRAULIC ANALYSIS

3.2.1 Culverts

Culverts are used to convey runoff beneath the roadway (cross-drainage) or to provide conveyance at roadway access points, intersections, or driveways along existing or proposed side ditches. Cross culverts under Sage Creek Road were analyzed using HY8 Culvert Analysis software.

Table 3 summarizes the culvert requirements per the PDDM.

Table 3: Culverts

Storm Event:	25-year for cross culverts < 48 inches; 10-year for cross culverts ≥ 48 inches 10-year for roadside ditches
Headwater Elevation (HW)	• New: HW not to be greater than the bottom of the aggregate base layer of roadway low point • Existing: HW not to be greater than the shoulder hinge point and not allowed to spread onto roadway shoulder
HW/D Ratio	1.5 for culverts ≤ 48 inches 1.2 for culverts > 48 inches
Minimum Pipe Size	24 inches: cross culverts 18 inches: parallel culverts in ditches
Slope	Minimum: 0.5 to 2.0% Maximum: 25% for metal
Cover	FHA Standard 602-1: 24-inch to 96-inch requires 12 inches of cover
Anchors	Metal: Slopes 25% or greater
Materials	CMP
Maximum Culvert Skew	45 degrees with roadway centerline

3.2.2 Ditches

The existing roadside ditches consist of earth swales that collect stormwater runoff generated from the contributing sub-basins on the adjacent mountain slopes as well as the roadway section.

Proposed roadside ditches were analyzed using Manning's Equation. Table 4 summarizes the ditch requirements per the PDDM.

Table 4: Ditches

Storm Event	10-year
Depth	• New ditches: no greater than the bottom of the aggregate subbase layer of the roadway pavement • Existing ditches: no greater than the shoulder hinge point
Slope	Desired minimum: 1.0% Allowable minimum: 0.5%
Cross Section Shape	Vee

The method of erosion protection used for ditches was established per criteria listed in Table 2.

3.2.3 Culvert Materials, End Treatment, and Outlet Protection

It is recommended that riprap aprons/riprap basins as outlet protection be required for most of the existing culvert outlets. The cross culverts were designed and evaluated for the calculated design storm flow rates using HY 8 Culvert Analysis software.

CMP is proposed for use with the culverts requiring replacement. Per the PDDM, it is required that culverts have end treatments to increase efficiency, embankment stability, aesthetics, and safety for vehicles. At most of the proposed culvert locations, the proposed outlets include scour protection by means of riprap aprons or riprap basins. Locations with riprap aprons or basins are not designed with flared end sections at the outlets. Culverts with sizes greater than or equal to 48

inches in diameter are provided with headwalls and wingwalls. Culverts that do to not require riprap aprons are provided with flared end sections at the outlets. The hydraulics summary and recommendations for cross culverts are summarized in Table 5 and Table 6 in Section 4.1, Culverts.

At some culverts, the required riprap apron or riprap basin length would not be contained within the right of way. In these areas, the basin was extended to the right of way.

3.2.4 Temporary Erosion Control

Erosion control measures will be used to protect the existing system and outfalls from sediment transport during construction. To that end, an erosion control plan was prepared for the project based on FHWA Best Management Practices for Erosion and Sediment Control. The following erosion control practices are recommended based on conversations with CFLHD:

- **Sediment Control Logs:** To be placed in proposed ditches.
- **Silt Fence:** With the large right of way corridor, silt fence is to be used minimally with the idea that sediment will most likely remain in the corridor. Areas where runoff could go into stream crossings, open waters, or wetlands will require silt fence. It is not to be used as a perimeter control.
- **Flexible Growth Mediums:** To be placed on slopes greater than 1:3.
- **Sediment Wattles:** To be placed on long slopes to prevent channelization of runoff on slopes.

Permanent (post construction) erosion control measures will include riprap check dams, riprap aprons, and riprap basins. Check dams and riprap were proposed for ditches having steep slopes and where the 10-year flow was large enough to cause potential erosion.

4.0 RECOMMENDED DESIGN

The recommended design for culverts is based on hydraulic evaluation and a series of assumptions regarding material, inverts, and condition of the culverts for Sections C and D. **It is essential that field verification is carried out and the hydraulic calculations re-evaluated before implementation of the recommended design.**

Appendix A contains NSS data, Appendix B contains basin map delineations, Appendix C contains NOAA data Intensity Duration Frequency Curves, Appendix D contains NSS outputs, Appendix E contains Rational Method calculations, Appendix F contains HY8 outputs, and Appendix G contains site photos.

4.1 CULVERTS

Based on underlying assumptions discussed previously, hydraulic calculations and roadway impacts require that out of the 98 identified existing cross culverts and 17 driveway culverts. Three culvert crossings are proposed to be fish passage. A total of 79 culverts are proposed to be replaced. New culverts are proposed at eight locations. Table 5 provides a hydraulic summary of the culverts. Table 6 summarizes recommendations for the culverts.

The cross culverts were designed/evaluated for the calculated design storm flow rates using HY8 Culvert Analysis software. The culvert lengths and slopes were obtained from LIDAR based data and no field verification has been made. Material is assumed to be CMP and culvert conditions are based on field notes.

Table 5: Culverts Hydraulics Summary

Basin ID	Station	Drainage Area (acres)	Design Year	Design Flow(cfs)	Existing Size (in)	Proposed Size (in)	Outlet Velocity[1] (fps)	HW/D Ratio[1]	Allowable HW/D
C2	2245+55.30	9.10	25	3.79	36" CMP	-	5.76	0.27	1.5
C3	2251+82.56	13.80	25	6.35	36" CMP	-	7.43	0.34	1.5
C4	2262+39.25	91.00	25	25.11	36" CMP	-	8.14	0.78	1.5
C5	2298+14.06	44.00	25	11.78	30" CMP	-	8.84	0.63	1.5
C6	2388+27.88	58.00	25	16.75	30" CMP	-	9.53	0.79	1.5
C7	2403+98.05	1.20	25	1.28	24" CMP	24" CMP	3.32	0.26	1.5
C8	2410+15.67	96.70	25	38.10	30" CMP	-	8.71	2.68	1.5
C9	2425+58.06	18.60	25	7.50	30" CMP	-	7.32	0.48	1.5
C10	2438+64.97	51.60	25	13.19	30" CMP	-	6.07	0.72	1.5
C11	2446+27.06	22.70	25	8.01	24" CMP	-	10.29	0.75	1.5
C12	2456+47.09	7.20	25	2.35	30" CMP	-	5.90	0.26	1.5
C13	2475+41.29	111.0	25	38.36	24" CMP	-	12.21	5.91	1.5
C14	2490+54.11	6.98	25	3.18	36" CMP	-	5.41	0.24	1.5
C15	2532+40.41	1,190.00	25	70.70	42" CMP	-	9.12	1.39	1.5
C17	2540+50.39	112.86	25	30.59	24" CMP	-	12.33	3.19	1.5
P1	2580+00.00	61.00	25	19.45	-	24" CMP	9.56	1.40	1.5
77	2591+21.97	8,573.00	10	247.30	54" CMP	90" CMP	10.63	1.10	1.2

Table 5: Culverts Hydraulics Summary

Basin ID	Station	Drainage Area (acres)	Design Year	Design Flow(cfs)	Existing Size (in)	Proposed Size (in)	Outlet Velocity[1] (fps)	HW/D Ratio[1]	Allowable HW/D
78	2665+80.09	205.00	25	17.20	18" CMP	30" CMP	6.07	0.89	1.5
P2	2710+00.00	2.00	25	1.57	-	24" CMP	3.13	0.33	1.5
79	2729+96.47	893.00	10	39.60	48" CMP	48" CMP	9.28	0.66	1.2
80	2765+19.68	2,767.00	10	98.90	48" CMP	-	13.81	1.26	1.2
81	2798+09.62	54.00	25	20.71	18" CMP	30" CMP	8.93	0.92	1.5
82	2821+98.61	126.00	25	47.47	30" CMP	36" CMP	9.47	1.25	1.5
83	2875+11.18	14,805.00	10	384.90	72" CMP	-	14.65	2.03	1.2
P3	2904+47.5	30.00	25	15.26	-	24" CMP	7.03	1.13	1.5
1	2951+98.94	16,420.00	10	418.60	60" CMP	90" CMP	13.70	1.14	1.2
2	2982+50.00	1,637.00	10	61.30	36" CMP	48" CMP	12.24	0.86	1.2
P4	3003+00.00	25.00	25	10.69	-	24" CMP	7.33	0.86	1.5
3	3013+93.82	44.00	25	18.65	18" CMP	30" CMP	6.25	0.96	1.5
4	3035+07.70	155.00	25	48.92	24" CMP	42" CMP	7.75	1.03	1.5
5	3058+67.75	1,097.00	10	47.60	24" CMP	48" CMP	7.27	0.85	1.2
6	3066+61.91	162.00	25	50.90	24" CMP	42" CMP	8.79	0.97	1.5
7	3079+25.48	115.00	25	36.10	30" CMP	36" CMP	7.41	1.09	1.5
8	3093+60.48	315.00	25	24.40	24" CMP	30" CMP	6.95	1.12	1.5
9	3105+69.26	292.00	25	22.10	30" CMP	-	11.75	0.94	1.5
10	3116+27.17	557.00	25	40.10	36" CMP	42" CMP	8.97	0.82	1.5
11	3130+45.00	42.00	25	17.30	18" CMP	30" CMP	6.08	0.90	1.5
12	3152+08.13	164.00	25	73.96	36" CMP	-	15.02	2.04	1.5
13	3167+83.89	27.00	25	13.40	18" CMP	24" CMP	9.01	1.00	1.5
14	3173+92.70	9.00	25	5.00	18" CMP	-	6.73	0.89	1.5
15	3180+44.51	158.00	25	49.70	24" CMP	42" CMP	12.18	0.93	1.5
16	3186+42.07	8.00	25	5.60	18" CMP	24" CMP	5.37	0.58	1.5
17	3193+67.60	107.00	25	40.70	18" CMP	42" CMP	8.67	0.83	1.5
18	3200+26.32	105.00	25	43.40	18" CMP	42" CMP	9.56	0.86	1.5
19	3204+91.10	13.00	25	8.00	18" CMP	24" CMP	7.02	0.72	1.5
20	3209+45.03	213.00	25	18.50	24" CMP	30" CMP	8.60	0.85	1.5
21	3214+89.10	13.00	25	7.00	18" CMP	24" CMP	7.57	0.65	1.5
22	3222+73.59	126.00	25	39.60	18" CMP	42" CMP	7.16	0.82	1.5
23	3229+73.81	101.00	25	34.00	48" CMP	36" CMP	8.52	0.94	1.5
24	3233+46.64	16.00	25	6.00	18" CMP	-	5.24	1.00	1.5
25	3236+37.96	59.00	25	26.00	18" CMP	36" CMP	8.80	0.78	1.5
26	3249+51.96	6.00	25	3.00	18" CMP	-	4.02	0.62	1.5
27	3256+40.21	5.00	25	2.00	18" CMP	-	8.77	0.44	1.5
28	3262+59.49	13.00	25	9.00	18" CMP	24" CMP	11.19	0.72	1.5
29	3264+72.12	25.00	25	17.30	18" CMP	-	9.79	3.98	1.5

Table 5: Culverts Hydraulics Summary

Basin ID	Station	Drainage Area (acres)	Design Year	Design Flow(cfs)	Existing Size (in)	Proposed Size (in)	Outlet Velocity[1] (fps)	HW/D Ratio[1]	Allowable HW/D
P5	3272+00.00	20.00	25	8.00	-	24" CMP	5.05	0.73	1.5
30	3280+90	2,883.00	10	129.00	84" CMP	-	-	-	1.2
31	3288+05.81	115.00	25	37.00	37" CMP	36" CMP	9.00	1.01	1.5
32	3291+85.11	8.00	25	3.03	18" CMP	-	7.04	0.62	1.5
33	3296+01.99	12.00	25	5.80	18" CMP	-	6.68	0.92	1.5
34	3300+33.05	4.00	25	2.80	18" CMP	-	3.93	0.59	1.5
35	3303+29.89	4.00	25	2.60	18" CMP		6.02	0.54	1.5
36	3309+00.87	2.00	25	1.00	18" CMP	24" CMP	4.23	0.23	1.5
37	3335+07.77	5.00	25	3.00	18" CMP	-	6.62	0.53	1.5
38	3337+02.76	2.00	25	1.10	18" CMP	24" CMP	7.03	0.23	1.5
39	3341+92.13	5.00	25	2.20	18" CMP	24" CMP	6.17	0.33	1.5
P6	3350+00.00	10.00	25	4.00	-	24" CMP	6.96	0.46	1.5
40	3357+43.15	10.00	25	6.00	18" CMP	-	6.32	0.93	1.5
41	3364+41	3.00	25	4.00	18" CMP	-	8.18	0.74	1.5
42	3370+69.21	14,613.00	10	485.00	96" CMP	128"X82" CM)	9.59	0.44	1.2
43	3373+51.55	4.00	25	2.90	18" CMP	-	5.13	0.59	1.5
44	3377+13.34	1.00	25	1.30	18" CMP	-	4.47	0.37	1.5
45	3381+50.79	5.00	25	4.00	18" CMP	-	6.23	0.71	1.5
46	3386+03.81	90.00	25	42.20	18" CMP	42" CMP	8.50	0.85	1.5
47	3389+33.38	16.00	25	11.20	18" CMP	24" CMP	9.30	0.87	1.5
48	3401+20.44	179.00	10	52.20	48" CMP	48" CMP	10.55	0.85	1.2
49	3405+78.32	14.00	25	9.30	18" CMP	24" CMP	8.56	0.77	1.5
50	3416+09.40	5.00	25	2.60	18" CMP	24" CMP	4.51	0.38	1.5
51	3420+01.39	15.00	25	7.00	18" CMP	-	7.66	1.05	1.5
52	3422+67.27	5.00	25	2.90	18" CMP	24" CMP	4.65	0.40	1.5
53	3428+37.67	21.00	25	14.20	18" CMP	30" CMP	8.82	0.71	1.5
54	3447+96.02	230.00	25	19.10	24" CMP	30" CMP	11.96	0.84	1.5
55	3451+70.38	5.00	25	2.70	24" CMP	24" CMP	4.93	0.38	1.5
56	3462+36.64	59.00	25	22.90	24" CMP	30" CMP	6.76	1.06	1.5
57	3466+97.56	6.00	25	2.70	18" CMP	-	3.89	0.58	1.5
58	3484+51.84	3.00	25	1.70	18" CMP	-	4.53	0.44	1.5
59	3527+22.43	1.00	25	0.80	18" CMP	-	3.89	0.29	1.5
60	3527+84.90	6.00	25	3.50	18" CMP	24" CMP	4.34	0.45	1.5
61	3539+95.38	8.00	25	2.70	18" CMP	-	6.42	0.55	1.5
P7	3549+98.16	17.00	25	6.00	-	24" CMP	5.46	0.60	1.5
P8	3558+98.16	7.00	25	4.00	-	24" CMP	7.83	0.45	1.5
62	3560+81.73	3,652.00	10	135.30	5'X6'	108" CMP	3.93	0.46	1.2

Table 5: Culverts Hydraulics Summary

Basin ID	Station	Drainage Area (acres)	Design Year	Design Flow(cfs)	Existing Size (in)	Proposed Size (in)	Outlet Velocity[1] (fps)	HW/D Ratio[1]	Allowable HW/D
					Arch				
63	3570+45.56	15.00	25	7.00	18" CMP	24" CMP	4.83	0.74	1.5
64	3574+28.47	19.00	25	10.00	18" CMP	24" CMP	5.38	0.88	1.5
65	3581+98.98	11.00	25	4.09	18" CMP	24" CMP	4.10	0.53	1.5
66	3586+34.94	18.00	25	8.20	18" CMP	24" CMP	6.18	0.73	1.5
67	3593+50.21	7.00	25	3.40	18" CMP	24" CMP	3.88	0.49	1.5
68	3598+51.06	6.00	25	2.10	18" CMP	-	4.70	0.49	1.5
69	3610+85.59	1.00	25	0.50	18" CMP	24" CMP	3.20	0.20	1.5
70	3627+21.93	1.00	25	0.90	18" CMP	24" CMP	2.70	0.22	1.5
71	3644+60	1.00	25	0.30	18" CMP	REMOVE	NA	NA	NA
72	3672+16.62	5.00	25	3.30	18" CMP	-	6.78	0.63	1.5
73	3677+12.60	4.00	25	3.30	18" CMP	24" CMP	5.32	0.43	1.5
74	3685+03.80	5.00	25	3.20	18" CMP	-	6.08	0.62	1.5
75	3690+29.37	2.00	25	1.00	18" CMP	-	3.46	0.33	1.5
76	3699+25.03	1.00	25	1.00	18" CMP	24" CMP	6.27	0.29	1.5

1. Hydraulics is dependent on assumed inverts, material, and sizes measured per procedure described in Section 2.6

Table 6: Culvert Recommendations [1]

Station	Existing Pipe	Proposed Pipe	Recommended Improvements	Remark
2245+55.30	36" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2251+82.56	36" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2262+39.25	36" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2388+27.88	30" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2298+14.06	30" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2403+98.05	24" CMP	24" CMP	Add end section to inlet and outlet. Add standard riprap apron to outlet.	
2410+15.67	30" CMP	-	Upsize to 36-inch CMP. Add riprap basin to outlet.	Recommended improvements cannot be constructed because of right of way constraints
2425+58.06	30" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2438+64.97	30" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	Recommended improvements not applied because the culvert is deep; however, standard riprap apron will be added
2446+27.06	24" CMP	-		
2456+47.09	30" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2475+41.29	24" CMP	-	Upsize to 42-inch CMP. Add riprap basin to outlet.	Recommended improvements cannot be constructed because the culvert is deep
2490+54.11	36" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	
2532+40.41	42" CMP	-	Add end section to inlet. Add standard riprap apron to outlet.	Recommended improvements cannot be constructed because of right of way constraints
2540+50.39	24" CMP	-	Upsize to 36-inch CMP. Add riprap basin to outlet.	Recommended improvements cannot be constructed because of right of way constraints
2580+00	-	24" CMP	Install new culvert with end section at inlet and standard riprap apron at outlet.	Low point with no outlet
2591+21.97	54" CMP	90" CMP	Replace with fish passage structure per design criteria. Twenty-seven inches of culvert will remain embedded.	Fish passage
2665+80.09	18" CMP	30" CMP	Upsize and add end section at inlet and standard riprap apron at outlet.	

Table 6: Culvert Recommendations [1]

Station	Existing Pipe	Proposed Pipe	Recommended Improvements	Remark
2710+00.00	N/A	24" CMP	Install new culvert with end section at inlet and standard riprap apron at outlet.	Existing low point with no outlet
2729+96.47	48" CMP	48" CMP	Replace culvert due to extreme skew. Add headwall/wingwall and standard riprap.	
2765+19.68	48" CMP	-	Deep culvert in good condition. Add headwall/wingwall and riprap basin to outlet.	HW/D criteria is not met
2798+09.62	18" CMP	30" CMP	Upsize and add end section at inlet and standard riprap apron at outlet.	
2821+98.61	30" CMP	36" CMP	Upsize and add end section at inlet and standard riprap apron at outlet.	
2875+11.18	72" CMP	-	Deep culvert in good condition. Keep.	HW/D criteria is not met
2904+47.5	N/A	24" CMP	Install new culvert with end section at inlet and standard riprap apron at outlet.	
2951+98.94	60" CMP	90" CMP	Carbon County made recent repairs. Replace and add riprap basin at outlet.	Reviewed for fish passage but not recommended
2982+50.00	36" CMP	48" CMP	Replace culvert. Undercut at outlet. Riprap Basin is required.	
3003+00.00	N/A	24" CMP	Install new culvert with end section at inlet and standard riprap apron at outlet.	Low point with no outlet
3013+93.82	18" CMP	30" CMP	Upsize and add end sections to inlet and standard riprap apron to outlet.	
3035+07.70	24" CMP	48" CMP	Upsize and add end sections to inlet and standard riprap apron to outlet.	
3058+67.75	24" CMP	48" CMP	Upsize. Add end section upstream and standard riprap apron at outlet. Stream used for irrigation by adjacent rancher.	
3066+61.91	24" CMP	42" CMP	Upsize to conform to hydraulic standards. Add end section upstream and standard riprap apron at outlet.	
3079+25.48	30" CMP	36" CMP	Upsize to conform to hydraulic standards. Add end section upstream and standard riprap apron downstream.	
3093+60.48	24" CMP	30" CMP	Upsize. Add end section upstream and standard riprap apron downstream.	
3105+69.26	30" CMP	-	Add end section at inlet and riprap apron at outlet.	
3116+27.17	36" CMP	42" CMP	Upsize and add end section at inlet and riprap apron at outlet. Removal of trees from outlet side may be required.	
3130+45.00	18" CMP	30" CMP	Upsize and add end sections to inlet and standard riprap apron to outlet.	

Table 6: Culvert Recommendations [1]

Station	Existing Pipe	Proposed Pipe	Recommended Improvements	Remark
3152+08.13	36" CMP	-	Deep culvert, keep. Add riprap basin at outlet and end section at inlet.	HW/D criteria are not met. Recommended improvements have been modified to be constructed within the right of way constraints
3167+83.89	18" CMP	24" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3173+92.70	18" CMP	24" CMP	Add riprap apron at outlet.	
3180+44.51	24" CMP	42" CMP	Replace with end section at inlet and standard riprap apron at outlet.	
3186+42.07	18" CMP	24" CMP	Field notes recommend replacement and riprap apron at outlet.	
3193+67.60	18" CMP	42" CMP	Replace. Add end section at inlet and riprap apron at outlet.	
3200+26.32	18" CMP	42" CMP	Replace. Add end section at inlet and riprap apron at outlet.	
3204+91.10	18" CMP	24" CMP	Field notes recommend replacement.	
3209+45.03	24" CMP	30" CMP	Riprap apron required at outlet. End section at inlet.	
3214+89.10	18" CMP	24" CMP	Field notes recommend replacement.	
3222+73.59	18" CMP	42" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3229+73.81	18" CMP	36" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3233+46.64	18" CMP	24" CMP	Add riprap apron at outlet.	
3236+37.96	18" CMP	36" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3249+51.96	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3256+40.21	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3262+59.49	18" CMP	24" CMP	Upsize and add end section at inlet and standard riprap apron at outlet.	
3264+72.12	18" CMP	-	Condition okay. Very deep culvert. Keep.	HW/D criteria is not met
3272+00.00	N/A	24" CMP	Install new culvert with end section at inlet and standard riprap apron at outlet.	
3280+90	84" CMP	-	Deep cover, keep culvert.	Deep Creek identified as fish barrier that needs to remain in place.
3288+05.81	36" CMP	36" CMP	Replace. D/S end damaged. Add end section to inlet and standard riprap apron to outlet.	
3291+85.11	18" CMP	-	Erosion upstream. Pipe is buried. Clean.	
3296+01.99	18" CMP	-	Keep. Add end sections to inlet and riprap apron at outlet.	

Table 6: Culvert Recommendations [1]

Station	Existing Pipe	Proposed Pipe	Recommended Improvements	Remark
3300+33.05	18" CMP	-	Keep. Add end sections to inlet and riprap apron at outlet.	
3303+29.89	18" CMP	24" CMP	Keep. Add riprap apron at outlet.	
3309+00.87	18" CMP	24" CMP	Field notes recommend replacement.	
3335+07.77	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3337+02.76	18" CMP	24" CMP	Field notes recommend replacement.	
3341+92.13	Not known	24" CMP	Outlet not found. Clean. Add end sections if none.	
3350+00.00	N/A	24" CMP	New ditch relief culvert with end-section at inlet and riprap apron at outlet.	
3357+43.15	18" CMP	24" CMP	Add end sections to inlet.	
3364+41	18" CMP	-	Keep.	
3370+69.21	8' CMP	128"X82" CM)	Replace per forest service advice. Identified as fish passage. Add headwalls, wing-walls and riprap basin.	Identified as waters of US per FONSI.
3373+51.55	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3377+13.34	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3381+50.79	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3386+03.81	18" CMP	42" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3389+33.38	18" CMP	24" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3401+20.44	42" CMP	48" CMP	Replace and upsize. Culvert in poor condition. Add end section to inlet and riprap apron at outlet.	
3405+78.32	18" CMP	24" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3416+09.40	18" CMP	24" CMP	Extreme skew. Replace. Add end sections to inlet and outlet.	
3420+01.39	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3422+67.27	18" CMP	24" CMP	Upsize. Add end section at inlet and outlet.	
3428+37.67	18" CMP	30" CMP	Upsize. Add end sections to inlet and outlet.	
3447+96.02	24" CMP	30" CMP	Replace. Add end section at inlet and riprap apron at outlet.	
3451+70.38	18" CMP	24" CMP	Upsize. Riprap apron required at outlet. End section at inlet.	
3462+36.64	24" CMP	30" CMP	Upsize and add end section to inlet and outlet. Probable wetland impact.	

Table 6: Culvert Recommendations [1]

Station	Existing Pipe	Proposed Pipe	Recommended Improvements	Remark
3466+97.56	18" CMP	-	Upsize and add end section to inlet and outlet.	
3484+51.84	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3527+22.43	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3527+84.90	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3539+95.38	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3549+98.16	N/A	24" CMP	New ditch relief culvert with end-section at inlet and riprap apron at outlet.	
3558+98.16	N/A	24" CMP	New ditch relief culvert with end-section at inlet and riprap apron at outlet.	
3560+81.73	5'X6' Arch	108" CMP	Upsize with headwalls and wing walls. Identified as fish passage.	
3570+45.56	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3574+28.47	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3581+98.98	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3586+34.94	18" CMP	24" CMP	Keep. Add end sections to inlet and outlet.	
3593+50.21	18" CMP	24" CMP	Field notes recommend replacement.	
3598+51.06	18" CMP	-	Keep. Add end sections to inlet and outlet.	
3610+85.59	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3627+21.93	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	
3644+60	18" CMP	REMOVE	Eliminate.	
3672+16.62	18" CMP	-	Upsize. Add end sections to inlet and outlet.	
3677+12.60	18" CMP	24" CMP	Field notes recommend replacement.	
3685+03.80	18" CMP	-	Upsize. Add end sections to inlet and outlet.	
3690+29.37	18" CMP	-	Upsize. Add end sections to inlet and outlet.	
3699+25.03	18" CMP	24" CMP	Upsize. Add end sections to inlet and outlet.	

1. *All recommendations are based on assumptions discussed in Section 2.6 of this report. It is necessary that field verification be carried out before implementation of these recommendations*

4.2 FISH PASSAGE

Three fish passage culvert replacements were identified in this schedule. These culvert replacements were analyzed using HEC-26, Culvert Design for Aquatic Organism Passage. Bed material samples were not taken before design, so assumptions on grain size distribution were made. Samples will be collected and actual bed material sizes will be incorporated for the final design. Fish passage culverts were designed based on brook trout swimming characteristics and to maintain a stable bed during high flow passage events.

The existing stream and culvert conditions at Sta. 2951+99, Dirtyman Fork, are not conducive for a fish passage culvert replacement. The existing culvert slope is approximately 6% and the culvert length is greater than 150 feet. Without significant upstream and downstream channel improvements a fish passage culvert replacement is not feasible. A bridge alternative was identified to provide adequate fish passage; however, this improvement would require a bridge span of approximately 18 feet. Due to the existing conditions of this stream location and depth of cover, the project team recommends this culvert replacement not provide fish passage.

The existing culvert at Sta. 2591+22, North Fork Savery Creek, was noted for replacement and designed to provide fish passage. A 90-inch pipe culvert is proposed for this replacement with 27 inches of embedment. The embedment should consist of 18 inches of native bed material over 9 inches of armoring rock. The armored sublayer is recommended to be 6-inch rock (D50).

The existing culvert at Sta. 3370+69, Big Sandstone Creek, was noted for replacement and designed to provide fish passage. A 128-inch by 82-inch elliptical culvert is proposed for this replacement with 24 inches of embedment. The embedment should consist of 15 inches of native bed material over 9 inches of armoring rock. The armored sublayer is recommended to be 6-inch rock (D50).

The existing culvert at Sta. 3560+83, Little Sandstone Creek, was also noted for replacement and designed to provide fish passage. A 108-inch pipe culvert is proposed for this replacement with 36 inches of embedment. The embedment should consist of 27 inches of native bed material over 9 inches of armoring rock. The armored sublayer is recommended to be 6-inch rock (D50).

4.3 DITCHES

The drainage areas for all proposed ditches were estimated by examining the surveyed contours and USGS topographic map. From Sta. 2245+00 to the end of Section E, there are approximately 57 right (looking up station) and 62 left (looking up station) proposed ditches. The drainage basin areas of these ditches varied from 0.4 acre to approximately 40 acres. Drainage basin contributing to each of these ditches were delineated and categorized based on basin area and slopes. Six categories were identified and representative basins were selected from each category as presented in Table 7. A detailed hydrological analysis was done for a representative basin belonging to each category and the 10-year design flows per unit area for these representative areas were estimated. These flows per unit area for each category were then applied to each basin belonging to that category to obtain the 10-year design flow.

Table 7: Ditches Categories

Category	Slope	Area	Representative Ditch				
			Station	Slope	Q10	Area	Unit Flow/Area
1	S<2%	<2 acres	3225+00 to 3226+00 LT	0.003	0.4	0.5	0.8
2	S<2%	>2 acres	3250+50 to 3253+50 LT	0.009	0.8	2.7	0.3
3	2%≤S<5%	<2 acres	3056+70 to 3057+50 LT	0.040	0.4	0.7	0.6
4	2%≤S<5%	>2 acres	2669+00 to 2675+00 RT	0.040	1.5	3.9	0.4
5	5%≤S	<2 acres	2718+00 to 2720+00 LT	0.070	0.4	0.7	0.6
6	5%≤S	>2 acres	3291+50 to 3295+12 RT	0.080	2.2	7.6	0.3

A Manning's Equation analysis was done to determine that capacity of each proposed ditch is adequate. HEC-22 hydraulic analysis was done for ditches with slopes greater than 3% to evaluate requirement of ditch linings. If permanent erosion protection was found necessary per the HEC-22 analysis, then the method of erosion protection applicable to the particular ditch was recommended based on drainage areas and slope of the ditch, as discussed in Table 2. A detailed summary of ditches and recommendations are presented in Table 8. There were many locations where the ditch backslopes were flatter than 6:1. These ditches are not considered for lining and are not reported in the table.

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Table 8: Ditch Summary

Ditch Stations				Ditch Characteristics				Ditch Capacity				Comments
				Left Side Slope	Right Side Slope	Channel Slope, S	Depth (ft)	Capacity, Q(cfs)	Drainage Area (Acres)	Q10	Sufficient Capacity for 10-Year Storm?	
Right	2247+00	to	2248+00	3.0	9.0	0.0075	1	14	1.1	0.9	Yes --> OK	
Right	2255+00	to	2255+50	3.0	17.0	0.0075	1	23	4.7	1.2	Yes --> OK	
Right	2256+50	to	2257+00	3.0	14.0	0.0075	1	20	6.7	1.7	Yes --> OK	
Right	2292+50	to	2293+00	3.0	3.0	0.0600	1	19	13.5	3.8	Yes --> OK	Riprap Ditch (9-inch) Class 2
Right	2296+00	to	2296+50	3.0	5.0	0.0355	1	20	5.8	2.2	Yes --> OK	
Right	2321+20	to	2325+50	3.0	3.0	0.0229	1	12	0.9	0.5	Yes --> OK	
Right	2332+50	to	2332+61	3.0	3.0	0.0510	1	18	3.6	1.0	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	2345+00	to	2346+50	3.0	3.0	0.0123	1	9	1.7	1.3	Yes --> OK	
Right	2372+00	to	2372+50	3.0	3.0	0.0035	1	5	0.2	0.2	Yes --> OK	
Right	2479+00	to	2486+00	3.0	2.0	0.0073	1	5	1.2	0.9	Yes --> OK	
Right	2523+00	to	2527+50	3.0	2.5	0.0799	1	20	3.8	1.1	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	2596+50	to	2602+00	3.0	2.5	0.0693	1	19	0.6	0.4	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	2612+50	to	2622+00	3.0	3.0	0.1099	1	26	0.9	0.6	Yes --> OK	Riprap Ditch (9-inch) Class 2
Right	2656+50	to	2661+00	3.0	2.5	0.0570	1	17	2.2	0.6	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	2669+00	to	2675+00	3.0	3.0	0.0405	1	16	3.9	1.5	Yes --> OK	Representative basin for slope between 2% and 5% and basin <2 acres
Right	2701+00	to	2703+60	3.0	3.0	0.0279	1	13	4.2	1.6	Yes --> OK	
Right	2718+00	to	2720+00	3.0	2.5	0.0650	1	18	2.2	0.6	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	2741+50	to	2744+50	1.5	3.0	0.0638	1	14	0.5	0.3	Yes --> OK	
Right	2744+50	to	2761+00	1.5	3.0	0.0970	1	18	3.4	0.9	Yes --> OK	
Right	2769+00	to	2783+00	1.5	3.0	0.0732	1	15	2.5	0.7	Yes --> OK	
Right	2956+50	to	2957+80	3.0	3.0	0.0307	1	14	3.2	1.2	Yes --> OK	
Right	2976+50	to	2978+50	3.0	4.0	0.0557	1	22	0.4	0.3	Yes --> OK	
Right	2985+50	to	2993+50	3.0	2.0	0.0850	1	19	1.4	0.8	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	3056+50	to	3057+50	3.0	3.0	0.0369	1	15	4.0	1.5	Yes --> OK	
Right	3062+00	to	3065+00	3.0	3.0	0.0290	1	13	1.0	0.6	Yes --> OK	
Right	3089+50	to	3091+00	3.0	2.0	0.0486	1	14	2.0	0.8	Yes --> OK	Check Dam
Right	3097+50	to	3099+50	3.0	3.0	0.0424	1	16	2.3	0.9	Yes --> OK	Check Dam
Right	3188+00	to	3192+00	3.0	3.0	0.0055	1	6	2.5	0.6	Yes --> OK	
Right	3195+50	to	3198+50	4.0	3.0	0.0210	1	13	0.4	0.2	Yes --> OK	
Right	3210+50	to	3213+00	4.0	3.0	0.0150	1	11	1.7	1.3	Yes --> OK	
Right	3216+oo	to	3222+00	3.0	3.0	0.0050	1	5	4.0	1.0	Yes --> OK	
Right	3225+00	to	3228+00	3.0	3.0	0.0065	1	6	3.0	0.8	Yes --> OK	
Right	3288+50	to	3290+00	3.0	3.0	0.0770	1	22	2.0	0.6	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	3291+50	to	3295+12	3.0	1.5	0.0770	1	16	7.6	2.1	Yes --> OK	Riprap Ditch (6-inch), Representative basin for slope >5% and basin > 2 acres
Right	3295+70	to	3296+00	3.0	3.0	0.0670	1	20	12.2	3.4	Yes --> OK	Riprap ditch (9-inch) Class 2
Right	3304+00	to	3305+25	3.0	3.0	0.0550	1	18	4.0	1.1	Yes --> OK	Riprap ditch (6-inch) Class 1
Right	3306+00	to	3308+00	3.0	3.0	0.0550	1	18	2.9	0.8	Yes --> OK	Riprap ditch (6-inch) Class 1

Ditch Stations				Ditch Characteristics				Ditch Capacity				Comments
				Left Side Slope	Right Side Slope	Channel Slope, S	Depth (ft)	Capacity, Q(cfs)	Drainage Area (Acres)	Q10	Sufficient Capacity for 10-Year Storm?	
Right	3309+00	to	3312+50	3.0	3.0	0.0550	1	18	1.5	0.9	Yes --> OK	
Right	3330+00	to	3331+00	3.0	3.0	0.1023	1	25	5.0	1.4	Yes --> OK	Riprap Ditch (9-inch) Class 2
Right	3332+50	to	3334+25	3.0	3.0	0.1023	1	25	5.0	1.4	Yes --> OK	Riprap ditch (9-inch) Class 2
Right	3341+00	to	3345+00	3.0	1.7	0.1023	1	19	4.0	1.1	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	3346+70	to	3350+00	3.0	1.1	0.1052	1	16	10.5	2.9	Yes --> OK	Riprap Ditch (9-inch) Class 2
Right	3352+50	to	3356+00	3.0	1.1	0.1052	1	16	10.5	2.9	Yes --> OK	Riprap ditch (9-inch) Class 2
Right	3361+00	to	3363+00	3.0	1.7	0.1203	1	21	3.2	0.9	Yes --> OK	Riprap ditch (9-inch) Class 2
Right	3371+50	to	3372+81	3.0	1.7	0.0391	1	12	0.9	0.6	Yes --> OK	
Right	3375+50	to	3377+00	3.0	1.7	0.0391	1	12	3.9	1.5	Yes --> OK	Check Dam
Right	3378+00	to	3380+92	3.0	1.7	0.0391	1	12	1.3	0.8	Yes --> OK	
Right	3383+50	to	3385+00	3.0	1.7	0.0465	1	13	2.4	0.9	Yes --> OK	Check Dam
Right	3391+00	to	3393+50	3.0	1.7	0.0875	1	18	2.5	0.7	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	3395+25	to	3396+00	3.0	1.7	0.0872	1	18	2.4	0.7	Yes --> OK	Riprap Ditch (6-inch) Class 1
Right	3396+00	to	3400+75	3.0	1.7	0.0420	1	12	9.2	3.5	Yes --> OK	Check Dam
Right	3423+39	to	3425+50	3.0	1.5	0.0290	1	10	4.9	1.9	Yes --> OK	Check Dam
Right	3449+00	to	3451+00	3.0	1.7	0.0460	1	13	10.0	3.8	Yes --> OK	Check Dam
Right	3451+00	to	3455+41	3.0	1.7	0.0370	1	11	5.3	2.0	Yes --> OK	Check Dam
Right	3680+63	to	3685+00	3.0	1.7	0.0470	1	13	2.0	0.8	Yes --> OK	
Right	3685+00	to	3690+00	3.0	1.7	0.0525	1	14	2.4	0.7	Yes --> OK	
Right	3695+00	to	3697+00	3.0	1.6	0.0426	1	12	7.7	2.9	Yes --> OK	Check Dam
Left	2321+20	to	2325+50	3.0	3.0	0.0229	1	12	0.6	0.4	Yes --> OK	
Left	2345+00	to	2345+50	3.0	3.0	0.0123	1	9	4.2	1.1	Yes --> OK	
Left	2372+00	to	2372+50	3.0	3.0	0.0350	1	15	0.3	0.2	Yes --> OK	
Left	2396+00	to	2396+50	3.0	3.0	0.0644	1	20	3.8	1.1	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	2462+50	to	2466+76	3.0	3.0	0.0790	1	22	8.7	2.4	Yes --> OK	Riprap Ditch 9-inch) Class2
Left	2479+50	to	2484+55	3.0	2.5	0.0732	1	19	2.8	0.8	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	2521+50	to	2527+00	6.0	3.0	0.0799	1	34	2.7	0.7	Yes --> OK	Riprap Ditch 9-inch) Class2
Left	2572+00	to	2574+00	2.5	3.0	0.0950	1	22	2.5	0.7	Yes --> OK	Riprap Ditch 9-inch) Class2
Left	2596+50	to	2602+00	3.0	2.0	0.0693	1	17	1.4	0.9	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	2612+50	to	2622+00	3.0	3.0	0.1099	1	26	1.6	1.0	Yes --> OK	Riprap Ditch 9-inch) Class2
Left	2656+50	to	2661+00	3.0	2.5	0.0570	1	17	22.1	6.1	Yes --> OK	Riprap Ditch 9-inch) Class2
Left	2669+00	to	2675+00	3.0	3.0	0.0405	1	16	0.5	0.3	Yes --> OK	
Left	2701+00	to	2703+60	3.0	3.0	0.0279	1	13	4.1	1.6	Yes --> OK	
Left	2718+00	to	2720+00	3.0	2.5	0.0650	1	18	0.7	0.4	Yes --> OK	Representative slope >5% and basin < 2 acres
Left	2741+00	to	2744+50	3.0	1.5	0.0639	1	14	0.4	0.2	Yes --> OK	Rock cut ditch
Left	2744+50	to	2761+50	3.0	1.5	0.0973	1	18	2.5	0.7	Yes --> OK	Rock cut ditch
Left	2769+00	to	2783+00	3.0	1.5	0.0737	1	15	39.0	10.8	Yes --> OK	Rock cut ditch
Left	2879+00	to	2880+50	3.0	4.0	0.0588	1	22	10.0	2.8	Yes --> OK	Riprap Ditch (6-inch) Class 1

Ditch Stations				Ditch Characteristics				Ditch Capacity				Comments
				Left Side Slope	Right Side Slope	Channel Slope, S	Depth (ft)	Capacity, Q(cfs)	Drainage Area (Acres)	Q10	Sufficient Capacity for 10-Year Storm?	
Left	2941+50	to	2944+00	12.0	4.0	0.1021	1	68	6.0	1.7	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	2956+50	to	2960+50	3.0	4.0	0.0307	1	16	3.5	1.3	Yes --> OK	
Left	2977+50	to	2978+00	3.0	4.0	0.0570	1	22	1.0	0.6	Yes --> OK	
Left	2985+50	to	2995+50	2.0	4.0	0.0851	1	23	1.7	1.1	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3056+70	to	3057+50	6.0	4.0	0.0370	1	25	0.6	0.4	Yes --> OK	Representative basin for slope between 2% and 5% and basin < 2 acres
Left	3063+00	to	3065+00	8.0	4.0	0.0300	1	28	0.2	0.1	Yes --> OK	
Left	3070+00	to	3070+50	3.0	4.0	0.0300	1	16	0.7	0.4	Yes --> OK	
Left	3088+00	to	3091+00	4.0	4.0	0.0486	1	23	0.3	0.2	Yes --> OK	
Left	3197+00	to	3198+00	3.0	3.0	0.0210	1	11	0.3	0.2	Yes --> OK	
Left	3225+00	to	3226+00	3.0	3.0	0.0029	1	4	0.5	0.4	Yes --> OK	Representative basin for slope <2% and basin < 2acres
Left	3231+00	to	3232+50	3.0	3.0	0.0068	1	6	1.3	1.0	Yes --> OK	
Left	3238+50	to	3242+50	3.0	3.0	0.0590	1	19	0.5	0.3	Yes --> OK	
Left	3250+50	to	3253+50	3.0	3.0	0.0085	1	7	2.7	0.7	Yes --> OK	Representative basin for slope<2% and basin >2acres
Left	3259+50	to	3261+50	2.0	3.0	0.0441	1	13	4.6	1.7	Yes --> OK	Check Dam
Left	3265+50	to	3266+00	3.0	3.0	0.0015	1	3	0.4	0.3	Yes --> OK	
Left	3270+75	to	3271+30	3.0	3.0	0.0600	1	19	3.2	0.9	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3275+70	to	3279+50	3.0	3.0	0.0880	1	23	7.0	1.9	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3283+00	to	3284+00	3.0	3.0	0.0650	1	20	2.7	0.7	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3287+00	to	3288+00	3.0	3.0	0.0640	1	20	2.2	0.6	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3322+00	to	3326+00	3.0	3.0	0.0670	1	20	5.7	1.6	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3331+00	to	3335+00	3.0	3.0	0.1033	1	25	4.0	1.1	Yes --> OK	Riprap Ditch (6-inch) Class 1
Left	3366+50	to	3367+50	3.0	3.0	0.0527	1	18	1.6	1.0	Yes --> OK	Check Dam
Left	3371+50	to	3372+00	3.0	3.0	0.0390	1	15	22.0	8.4	Yes --> OK	Riprap Ditch(9-inch) Class 2
Left	3403+00	to	3411+50	2.0	3.0	0.0910	1	19	6.4	1.8	Yes --> OK	Riprap Ditch(9-inch) Class 2
Left	3413+00	to	3414+60	2.0	3.0	0.0440	1	13	6.5	2.5	Yes --> OK	Check Dam
Left	3431+00	to	3433+50	3.0	3.0	0.0500	1	17	0.8	0.5	Yes --> OK	Check Dam
Left	3464+00	to	3464+50	2.0	3.0	0.0470	1	14	2.0	0.8	Yes --> OK	Check Dam
Left	3511+50	to	3515+00	3.0	3.0	0.0280	1	13	2.4	0.9	Yes --> OK	
Left	3520+50	to	3524+00	3.0	3.0	0.0230	1	12	0.8	0.5	Yes --> OK	
Left	3532+30	to	3540+00	2.0	3.0	0.0390	1	13	8.1	3.1	Yes --> OK	Check Dam
Left	3540+00	to	3543+00	2.0	3.0	0.0308	1	11	3.7	1.4	Yes --> OK	Check Dam
Left	3551+00	to	3558+00	2.0	3.0	0.0510	1	14	8.8	2.4	Yes --> OK	Check Dam
Left	3554+00	to	3559+00	2.0	3.0	0.0510	1	14	6.0	1.7	Yes --> OK	Check Dam
Left	3663+00	to	3664+50	2.0	3.0	0.0426	1	13	0.5	0.3	Yes --> OK	Check Dam
Left	3667+68	to	3668+00	2.0	3.0	0.0590	1	15	0.5	0.3	Yes --> OK	Check Dam

4.4 APPROACH ROAD CULVERTS

Approach roads were examined to determine if a culvert was required. The following reasons explain the rationale for culvert installation:

- Changes in the profile of the roadway affecting ditch and culvert elevations.
- Field review notes indicating a culvert is damaged and needs replacement.
- Current or future conditions showing a culvert is needed to continue ditch flow from one side of the approach road to the other.
- A ponded area needing to be drained.
- Hydrology calculations indicating overtopping in the design storm condition and a larger culvert is required to meet design requirements.

Table 69 summarizes access road culvert recommendations. The first couple of stations do not have basin areas and flows as this was not part of the scope of the work. Instead, a project decision was made to replace the existing culverts with equivalent pipe size and material.

Approach road culverts cross sections were not provided; therefore, detailed analysis for these culverts could not be conducted and detailed hydraulic have not been provided. However, a performance curve for 18-inch and 24-inch CMPs is provided and is included in Appendix F. This curve shows the relationship between headwater elevation and discharge to adhere to the maximum headwater to diameter ratio of 1.5.

Table 9: Summary of Access Roads

Station	Basin Area (acres)	Q10 (cfs)	Existing Pipe Size (CMP)	Proposed Pipe Size (CMP)	Notes and Recommendations
2361+23.44	-	-	-	18”	Install 18" CMP with end sections.
2383+86.10	-	-	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2387+76.59	-	-	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2393+36.45	-	-	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2404+11.68	-	-	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2535+60.04	-	-	-	18”	Install 18" CMP with end sections.
2626+89.87	-	-	18”	-	Protect existing 18” CMP in place.
2696+01.69	0.78	0.40	18”	-	Protect existing 18” CMP in place.
2712+17.06	2.02	2.37	-	18"	Install 18" CMP with end sections.
2791+52.03	11.47	6.5	18”	18”	Remove 18" CMP; install 18" CMP with end sections.

Table 9: Summary of Access Roads

Station	Basin Area (acres)	Q10 (cfs)	Existing Pipe Size (CMP)	Proposed Pipe Size (CMP)	Notes and Recommendations
2820+13.03	4.95	4.91	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2833+37.70	7.30	3.18	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
2885+29.45	49.77	21.5	18"	24”	Remove 18" CMP, install 24" CMP with end sections. Hydrologic calculations require 30” to pass 10-year flow.
2895+03.90	3.50	3.48	18”	-	Clean existing 18" CMP.
3004+95.00	3.60	3.49	18"	-	Protect existing 18” CMP in place.
3070+00.00	0.82	1.10	18"	-	Protect existing 18” CMP in place.
3136+01.78	10.33	5.6	-	18”	Install 18" CMP with end sections.
3193+14.99	2.05	1.84	8"	18"	Remove 8" CMP, install 18" CMP with end sections.
3234+35.25	69.87	34.1	18"	18"	Remove 18" CMP; install 18" CMP with end sections, cover issues, hydrologic calculations require 30” to pass 10-year flow.
3312+84.32	0.52	0.45	18”	18”	Remove 18" CMP; install 18" CMP with end sections.
3445+18.80	5.94	5.74	18”	18"	Remove 18" CMP; install 18" CMP with end sections.
2361+23.44	-	-	-	18”	Install 18" CMP with end sections.
2383+86.10	-	-	18”	18”	Remove 18" CMP; install 18" CMP with end sections.

5.0 SUMMARY

Drainage improvements include adding eight new cross culverts/ditch reliefs and replacing 77 culverts. Drainage improvements recommended also include cleaning/refurbishing existing cross culverts, lengthening/shortening culverts, providing outlet protection, adding flared end sections, and providing temporary and permanent erosion control measures.

This Final Hydraulics Report was prepared in accordance with the PDDM.

6.0 REFERENCES

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