Memo

To:	Mike Will		
From:	Tammy Kirkbride		
Phone:	303.221.7275	**Date:**	September 10, 2012
Ref:	Beartooth Highway WY HPP4-1(7) Beartooth Highway Package	**cc:**	Ken Burns, Kristin Lang, Martine Fils-Aime
Subject:	Final Hydrology and Hydraulics Report: Addendum 2		

Since the *Wyoming Forest Highway Project Beartooth: Highway Project Beartooth: Highway WY HPP 4-1(4) Final Hydrology and Hydraulics Report* submittal, a Beartooth Highway Project Funding and Delivery Plan was completed and endorsed by the Steering Committee in the fall of 2011. This updated plan provided a modification to the original design approach providing flexibility in the design to meet the limited funding and project needs. The HPP 4-1(7) project from Station 49+331 to Station 50+790 uses this flexible approach and has reduced the pavement width to 8.4 meters. This technical memo serves as a summary of the hydrology and hydraulic results produced by reducing the proposed roadway template to 8.4 meters.

1.0 Assumptions

As the majority of the contributing basins are offsite basins and the horizontal and vertical roadway alignment remains as is, it is assumed that the hydrology will not need modification or analysis. Therefore, the basin areas, time of concentrations, and flows in the report were used for this analysis.

2.0 Prediction of Design Discharges

A summary of the design discharges is provided in Table 1.

Table 1. Peak Flows

Basin	Area (hectares)	Q_{10} (cms)	Q_{50} (cms)
49+425	6.24	0.339	0.591
49+564	1.18	0.071	0.121
49+664	1.11	0.062	0.105
49+862	1.20	0.059	0.104
50+098	0.56	0.030	0.053
50+165	0.44	0.031	0.051
50+230	5.21	0.300	0.527
50+330	1.24	0.056	0.101
50+604	2.44	0.157	0.257
50+762	1.11	0.085	0.140

3.0 Culverts

Cross culverts were analyzed using Haestad's CulvertMaster software and the Nebraska Department of Roads Brokenback Culvert Analysis Program (BCAP). Table 2 is a summary of applicable criteria per the *Drainage Design Criteria* Memo. Table 3 is a culvert analysis summary for proposed culverts.

Table 2. Culvert Design Criteria

Design Feature	Design Criteria
Design Storm	50 year
Headwater to Diameter Ratio (HW/D)	Diameter ≤ 1200 mm, HW/D = 2.0
Minimum Pipe Size	Ditch Culverts = 450 mm Cross Culverts = 600 mm
Maximum Flow Rate	30 m^3/mm
Slope	0.5% Minimum 10.0% Maximum
End Treatments	End section required for D < 1200 mm
Outlet Protection	Erosion protection required for V > 2 meters/second (m/s)

Table 3. Culvert Analysis Summary

Station	Diameter (mm)	Q_{50} (cms)	HW/D	Velocity (m/s)	Comments
49+425	750	0.591	1.02	4.47	Install standard riprap pad, exceeds maximum slope criteria that requires a variance
49+564	600	0.121	0.57	1.26	Drop inlet
49+664	600	0.105	0.52	1.23	Drop inlet
49+862	600	0.104	0.52	2.49	Install standard riprap pad, exceeds maximum slope criteria that requires a variance
50+098	600	0.053	0.37	1.00	Drop inlet
50+165	600	0.051	0.36	1.13	Wetland impacts
50+604	600	0.257	0.65	1.64	Brokenback culvert (elbow at inlet)
50+762	600	0.140	0.60	1.32	Clean existing culvert

Cross culverts diameters were not modified; however, with the reduction in pavement width, the culvert length has been reduced.

Originally, the existing cross culvert at Station 50+762 was to be replaced; however, it is recommended to keep the existing culvert in place and instead, to be cleaned for the following reasons:

- Minimal grading is occurring at this location as it is the proposed road tie into the existing road
- Minimize wetland impacts: There are wetlands on both ends of the culverts
- Utilize existing structure: There are no reports or history of drainage issues or lack of culvert performance

Furthermore, it is recommended that the Contracting Officer (CO) field verify if this culvert warrants replacement.

4.0 Ditches

Ditches were analyzed using Haestad's FlowMaster software. Table 4 is a summary of applicable criteria per the *Drainage Design Criteria* Memo.

Table 4. Ditch Design Criteria

Design Feature	Design Criteria
Design Storm	10 year
Minimum Freeboard	300 mm or bottom of aggregate base layer
Paved Ditch Spread	No encroachment into the travel lane

Table 5. Ditch Analysis Summary

Basin	Q_{10} (cms)	Design Spread (m)	Allowable Spread (m)	Design Depth (m)	Allowable Depth (m)	Velocity (m/s)	Comments
49+425	0.339			0.25	0.30	1.76	V-Ditch
		1.68	1.70	0.15	0.15	2.74	Paved ditch
49+564	0.071	0.93	1.70	0.08	0.15	1.85	Paved ditch
49+664	0.062	0.89	1.70	0.08	0.15	1.79	Paved ditch
49+862	0.059	-	-	0.11	0.30	1.10	V-Ditch
50+098	0.030	0.66	1.70	0.06	0.15	1.58	Paved ditch
50+165	0.031	-	-	0.09	0.30	1.00	V-Ditch
50+230	0.300	-	-	0.43	0.46	0.66	V-Ditch
50+330	0.056	-	-	0.14	0.30	1.02	V-Ditch, outfalls to riprap apron
		0.92	1.70	0.08	0.15	1.49	Paved ditch
50+604	0.157	-	-	0.16	0.30	1.00	V-Ditch
50+762	0.085	-	-	0.09	0.40	0.91	V-Ditch

There have been no modifications in the shape or type of the ditches.

5.0 Summary

Culvert, ditch, and riprap analysis yielded comparable results and fulfilled the criteria outlined in the drainage report. Hydraulics modifications are not warranted due to the proposed improvements.

There are 2 proposed culverts in the original plans that do not meet the minimum slope criteria, a variance to the hydraulics design criteria will be required.

The culvert at Station 50+762 no longer will require a new culvert, but will utilize the existing culvert unless the CO warrants a new culvert.

6.0 References

"Wyoming Forest Highway Project: Beartooth Highway WY HPP 4-1 (4): Final Hydrology and Hydraulics Report," PBS&J, January 2005.

Culvert Calculator Report
49+425

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,922.68	m	Headwater Depth/Height	1.02	
Computed Headwater Elevation	2,921.95	m	Discharge	0.5910	m³/s
Inlet Control HW Elev.	2,921.83	m	Tailwater Elevation	2,917.58	m
Outlet Control HW Elev.	2,921.95	m	Control Type	Entrance Control	

Grades					
Upstream Invert	2,921.18	m	Downstream Invert	2,917.58	m
Length	23.00	m	Constructed Slope	0.156174	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.25	m
Slope Type	Steep		Normal Depth	0.25	m
Flow Regime	Supercritical		Critical Depth	0.47	m
Velocity Downstream	4.47	m/s	Critical Slope	0.017627	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.76	m
Section Size	750 mm		Rise	0.76	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,921.95	m	Upstream Velocity Head	0.20	m
Ke	0.50		Entrance Loss	0.10	m

Inlet Control Properties					
Inlet Control HW Elev.	2,921.83	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.5	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

49+564 Grate Inlet On Grade

Project Description

Solve For	Efficiency

Input Data

Discharge		0.12	m³/s
Slope		0.05415	m/m
Gutter Width		1.50	m
Gutter Cross Slope		0.10	m/m
Road Cross Slope		0.02	m/m
Roughness Coefficient		0.016	
Grate Width		0.76	m
Grate Length		0.76	m
Grate Type	45˚ Tilt Bar		
Clogging		50.00	%

Options

Grate Flow Option	Exclude None

Results

Efficiency	62.21	%
Intercepted Flow	0.08	m³/s
Bypass Flow	0.05	m³/s
Spread	1.01	m
Depth	0.10	m
Flow Area	0.05	m²
Gutter Depression	0.12	m
Total Depression	0.12	m
Velocity	2.37	m/s
Splash Over Velocity	1.14	m/s
Frontal Flow Factor	0.64	
Side Flow Factor	0.03	
Grate Flow Ratio	0.97	
Active Grate Length	0.38	m

Culvert Calculator Report
49+564

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,929.70	m	Headwater Depth/Height	0.57	
Computed Headwater Elevation	2,928.85	m	Discharge	0.1210	m³/s
Inlet Control HW Elev.	2,928.81	m	Tailwater Elevation	2,928.42	m
Outlet Control HW Elev.	2,928.85	m	Control Type	Outlet Control	

Grades					
Upstream Invert	2,928.50	m	Downstream Invert	2,928.42	m
Length	15.45	m	Constructed Slope	0.005242	m/m

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.22	m
Slope Type	Mild		Normal Depth	0.30	m
Flow Regime	Subcritical		Critical Depth	0.22	m
Velocity Downstream	1.26	m/s	Critical Slope	0.015343	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,928.85	m	Upstream Velocity Head	0.04	m
Ke	0.50		Entrance Loss	0.02	m

Inlet Control Properties					
Inlet Control HW Elev.	2,928.81	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

49+664 Grate Inlet On Grade

Project Description

Solve For	Efficiency

Input Data

Discharge		0.11	m³/s
Slope		0.05415	m/m
Gutter Width		1.50	m
Gutter Cross Slope		0.10	m/m
Road Cross Slope		0.06	m/m
Roughness Coefficient		0.016	
Grate Width		0.76	m
Grate Length		0.76	m
Grate Type	45˚ Tilt Bar		
Clogging		50.00	%

Options

Grate Flow Option	Exclude None

Results

Efficiency	65.20	%
Intercepted Flow	0.07	m³/s
Bypass Flow	0.04	m³/s
Spread	0.96	m
Depth	0.10	m
Flow Area	0.05	m²
Gutter Depression	0.06	m
Total Depression	0.06	m
Velocity	2.29	m/s
Splash Over Velocity	1.14	m/s
Frontal Flow Factor	0.66	
Side Flow Factor	0.03	
Grate Flow Ratio	0.98	
Active Grate Length	0.38	m

Culvert Calculator Report
49+664

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,934.90	m	Headwater Depth/Height	0.52	
Computed Headwater Elevation	2,934.02	m	Discharge	0.1050	m³/s
Inlet Control HW Elev.	2,933.98	m	Tailwater Elevation	2,933.39	m
Outlet Control HW Elev.	2,934.02	m	Control Type	Entrance Control	

Grades					
Upstream Invert	2,933.70	m	Downstream Invert	2,933.39	m
Length	19.52	m	Constructed Slope	0.015830	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.20	m
Slope Type	Steep		Normal Depth	0.20	m
Flow Regime	Supercritical		Critical Depth	0.21	m
Velocity Downstream	1.23	m/s	Critical Slope	0.015246	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,934.02	m	Upstream Velocity Head	0.08	m
Ke	0.50		Entrance Loss	0.04	m

Inlet Control Properties					
Inlet Control HW Elev.	2,933.98	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
49+862

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,946.45	m	Headwater Depth/Height	0.52	
Computed Headwater Elevation	2,945.07	m	Discharge	0.1040	m³/s
Inlet Control HW Elev.	2,945.00	m	Tailwater Elevation	2,941.70	m
Outlet Control HW Elev.	2,945.07	m	Control Type	Entrance Control	

Grades					
Upstream Invert	2,944.76	m	Downstream Invert	2,941.70	m
Length	26.59	m	Constructed Slope	0.115131	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.12	m
Slope Type	Steep		Normal Depth	0.12	m
Flow Regime	Supercritical		Critical Depth	0.20	m
Velocity Downstream	2.49	m/s	Critical Slope	0.015241	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,945.07	m	Upstream Velocity Head	0.07	m
Ke	0.50		Entrance Loss	0.04	m

Inlet Control Properties					
Inlet Control HW Elev.	2,945.00	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

50+098 Grate Inlet On Grade

Project Description

Solve For	Efficiency

Input Data

Discharge		0.05	m³/s
Slope		0.06100	m/m
Gutter Width		1.50	m
Gutter Cross Slope		0.10	m/m
Road Cross Slope		0.05	m/m
Roughness Coefficient		0.016	
Grate Width		0.76	m
Grate Length		0.76	m
Grate Type	45˚ Tilt Bar		
Clogging		50.00	%

Options

Grate Flow Option	Exclude None

Results

Efficiency	74.24	%
Intercepted Flow	0.04	m³/s
Bypass Flow	0.01	m³/s
Spread	0.73	m
Depth	0.07	m
Flow Area	0.03	m²
Gutter Depression	0.07	m
Total Depression	0.07	m
Velocity	2.01	m/s
Splash Over Velocity	1.14	m/s
Frontal Flow Factor	0.74	
Side Flow Factor	0.04	
Grate Flow Ratio	1.00	
Active Grate Length	0.38	m

Culvert Calculator Report
50+098

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,948.04	m	Headwater Depth/Height	0.37	
Computed Headwater Elevation	2,947.07	m	Discharge	0.0530	m³/s
Inlet Control HW Elev.	2,947.04	m	Tailwater Elevation	2,946.73	m
Outlet Control HW Elev.	2,947.07	m	Control Type	Outlet Control	

Grades					
Upstream Invert	2,946.84	m	Downstream Invert	2,946.73	m
Length	21.99	m	Constructed Slope	0.005001	m/m

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.14	m
Slope Type	Mild		Normal Depth	0.19	m
Flow Regime	Subcritical		Critical Depth	0.14	m
Velocity Downstream	1.00	m/s	Critical Slope	0.015341	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,947.07	m	Upstream Velocity Head	0.02	m
Ke	0.50		Entrance Loss	0.01	m

Inlet Control Properties					
Inlet Control HW Elev.	2,947.04	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

Culvert Calculator Report
50+165

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,943.97	m	Headwater Depth/Height	0.36	
Computed Headwater Elevation	2,942.99	m	Discharge	0.0510	m³/s
Inlet Control HW Elev.	2,942.96	m	Tailwater Elevation	2,942.19	m
Outlet Control HW Elev.	2,942.99	m	Control Type	Entrance Control	

Grades					
Upstream Invert	2,942.77	m	Downstream Invert	2,942.19	m
Length	26.66	m	Constructed Slope	0.022052	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.13	m
Slope Type	Steep		Normal Depth	0.13	m
Flow Regime	Supercritical		Critical Depth	0.14	m
Velocity Downstream	1.13	m/s	Critical Slope	0.015367	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,942.99	m	Upstream Velocity Head	0.05	m
Ke	0.50		Entrance Loss	0.03	m

Inlet Control Properties					
Inlet Control HW Elev.	2,942.96	m	Flow Control	Unsubmerged	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

NEBRASKA DEPARTMENT OF ROADS
Broken-Back Culvert Analysis Program (BCAP)

PROJECT INFO

Project:	Beartooth: Addendum 2
Station or Location:	50+604
Date:	09 / 07 / 2012

DISCHARGE DATA

Minimum:	0.157 cms
Design Discharge:	0.257 cms
Maximum:	0.257 cms
Number of Barrels:	1

TAILWATER DATA

Type:	Constant Elevation
Elevation:	2947.641 m

CULVERT DATA

Type:	Circular Pipe
Pipe Diameter:	0.600000033579754 m
Culvert Material:	Corr. Metal Pipe
Inlet Type:	Flared End Section
Roughness Coefficient:	0.024
Outlet Section Roughness Coeff.:	0.024
Inlet Section Slope:	N.A.
Steep Section Slope:	0.3142 m/m
Outlet Section Slope:	0.0164 m/m

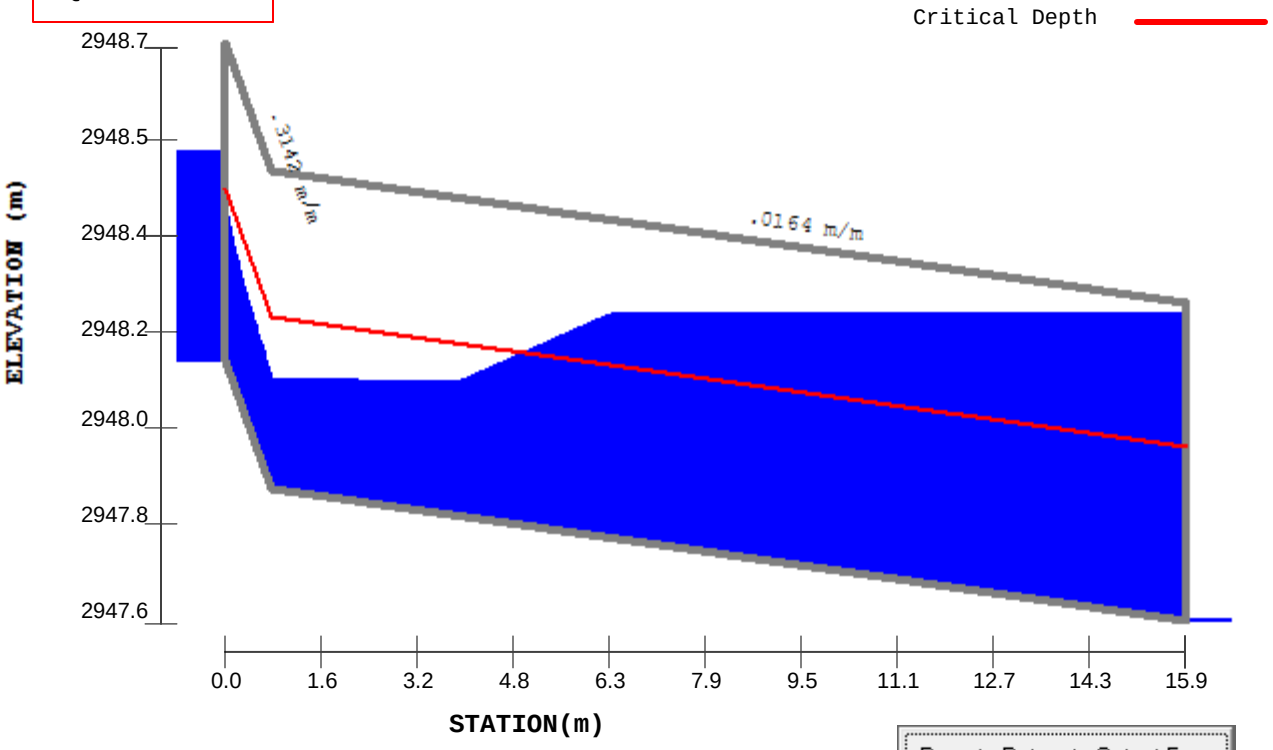
CULVERT PROFILE DATA

Type:	Single Broken-Back
Inlet Station:	0.000 m
Inlet Elevation:	2948.131 m
Lower Break Station:	0.774 m
Lower Break Elevation:	2947.888 m
Outlet Station:	15.850 m
Outlet Elevation:	2947.641 m

Circle Pipe Culvert
Diameter=0.600000033579754 m
Culvert Material: Corr. Metal Pipe

Inlet Type
Flared End Section
Rough. Coeff.= 0.024
Outlet Sec. Rough. Coeff.= 0.024

Q = 0.257 cms



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Culvert Calculator Report
50+762

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	2,953.77	m	Headwater Depth/Height	0.60	
Computed Headwater Elevation	2,952.85	m	Discharge	0.1400	m³/s
Inlet Control HW Elev.	2,952.82	m	Tailwater Elevation	2,952.34	m
Outlet Control HW Elev.	2,952.85	m	Control Type	Outlet Control	

Grades					
Upstream Invert	2,952.49	m	Downstream Invert	2,952.34	m
Length	17.20	m	Constructed Slope	0.008490	m/m

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.24	m
Slope Type	Mild		Normal Depth	0.28	m
Flow Regime	Subcritical		Critical Depth	0.24	m
Velocity Downstream	1.32	m/s	Critical Slope	0.015504	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	0.61	m
Section Size	600 mm		Rise	0.61	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	2,952.85	m	Upstream Velocity Head	0.06	m
Ke	0.50		Entrance Loss	0.03	m

Inlet Control Properties					
Inlet Control HW Elev.	2,952.82	m	Flow Control	N/A	
Inlet Type	Headwall		Area Full	0.3	m²
K	0.00780		HDS 5 Chart	2	
M	2.00000		HDS 5 Scale	1	
C	0.03790		Equation Form	1	
Y	0.69000				

49+425 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.05420	m/m
Left Side Slope	0.03	m/m (H:V)
Right Side Slope	6.00	m/m (H:V)
Discharge	0.34	m³/s

Results

Normal Depth	0.25	m
Flow Area	0.19	m²
Wetted Perimeter	1.79	m
Hydraulic Radius	0.11	m
Top Width	1.53	m
Critical Depth	0.30	m
Critical Slope	0.02051	m/m
Velocity	1.76	m/s
Velocity Head	0.16	m
Specific Energy	0.41	m
Froude Number	1.58	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.25	m
Critical Depth	0.30	m
Channel Slope	0.05420	m/m
Critical Slope	0.02051	m/m

49+425 Paved Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.05766	m/m
Discharge	0.34	m³/s

Section Definitions

Station (m)	Elevation (m)
0+01	2925.39
0+01	2925.39
0+02	2925.39
0+02	2925.24
0+02	2925.27
0+05	2925.52

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+01, 2925.39)	(0+02, 2925.27)	0.013
(0+02, 2925.27)	(0+05, 2925.52)	0.016

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth		0.15	m
Elevation Range	2925.24 to 2925.52 m		
Flow Area		0.12	m²
Wetted Perimeter		1.73	m
Hydraulic Radius		0.07	m
Top Width		1.68	m

49+425 Paved Ditch

Results

Normal Depth		0.15	m
Critical Depth		0.23	m
Critical Slope		0.00494	m/m
Velocity		2.74	m/s
Velocity Head		0.38	m
Specific Energy		0.53	m
Froude Number		3.22	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.15	m
Critical Depth	0.23	m
Channel Slope	0.05766	m/m
Critical Slope	0.00494	m/m

49+564 Paved Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.05415	m/m
Discharge	0.07	m³/s

Section Definitions

Station (m)	Elevation (m)
0+01	2925.39
0+01	2925.39
0+02	2925.39
0+02	2925.24
0+02	2925.27
0+05	2925.52

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+01, 2925.39)	(0+02, 2925.27)	0.013
(0+02, 2925.27)	(0+05, 2925.52)	0.016

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	0.08	m
Elevation Range	2925.24 to 2925.52 m	
Flow Area	0.04	m²
Wetted Perimeter	0.97	m
Hydraulic Radius	0.04	m
Top Width	0.93	m

49+564 Paved Ditch

Results

Normal Depth		0.08	m
Critical Depth		0.13	m
Critical Slope		0.00557	m/m
Velocity		1.85	m/s
Velocity Head		0.17	m
Specific Energy		0.26	m
Froude Number		2.90	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth		0.00	m
Length		0.00	m
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	m
Profile Description			
Profile Headloss		0.00	m
Downstream Velocity		Infinity	m/s
Upstream Velocity		Infinity	m/s
Normal Depth		0.08	m
Critical Depth		0.13	m
Channel Slope		0.05415	m/m
Critical Slope		0.00557	m/m

49+664 Paved Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.05415	m/m
Discharge	0.06	m³/s

Section Definitions

Station (m)	Elevation (m)
0+01	2925.39
0+01	2925.39
0+02	2925.39
0+02	2925.24
0+02	2925.27
0+05	2925.52

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+01, 2925.39)	(0+02, 2925.27)	0.013
(0+02, 2925.27)	(0+05, 2925.52)	0.016

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	0.08	m
Elevation Range	2925.24 to 2925.52 m	
Flow Area	0.03	m²
Wetted Perimeter	0.92	m
Hydraulic Radius	0.04	m
Top Width	0.89	m

49+664 Paved Ditch

Results

Normal Depth		0.08	m
Critical Depth		0.12	m
Critical Slope		0.00563	m/m
Velocity		1.79	m/s
Velocity Head		0.16	m
Specific Energy		0.24	m
Froude Number		2.89	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth		0.00	m
Length		0.00	m
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	m
Profile Description			
Profile Headloss		0.00	m
Downstream Velocity		Infinity	m/s
Upstream Velocity		Infinity	m/s
Normal Depth		0.08	m
Critical Depth		0.12	m
Channel Slope		0.05415	m/m
Critical Slope		0.00563	m/m

49+862 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.05415	m/m
Left Side Slope	3.00	m/m (H:V)
Right Side Slope	6.00	m/m (H:V)
Discharge	0.06	m^3/s

Results

Normal Depth	0.11	m
Flow Area	0.05	m^2
Wetted Perimeter	1.01	m
Hydraulic Radius	0.05	m
Top Width	0.98	m
Critical Depth	0.13	m
Critical Slope	0.02284	m/m
Velocity	1.10	m/s
Velocity Head	0.06	m
Specific Energy	0.17	m
Froude Number	1.50	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.11	m
Critical Depth	0.13	m
Channel Slope	0.05415	m/m
Critical Slope	0.02284	m/m

50+098 Paved Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.06100	m/m
Discharge	0.03	m³/s

Section Definitions

Station (m)	Elevation (m)
0+01	2925.39
0+01	2925.39
0+02	2925.39
0+02	2925.24
0+02	2925.27
0+05	2925.52

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+01, 2925.39)	(0+02, 2925.27)	0.013
(0+02, 2925.27)	(0+05, 2925.52)	0.016

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth	0.06	m
Elevation Range	2925.24 to 2925.52 m	
Flow Area	0.02	m²
Wetted Perimeter	0.68	m
Hydraulic Radius	0.03	m
Top Width	0.66	m

50+098 Paved Ditch

Results

Normal Depth		0.06	m
Critical Depth		0.09	m
Critical Slope		0.00591	m/m
Velocity		1.58	m/s
Velocity Head		0.13	m
Specific Energy		0.19	m
Froude Number		2.98	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth		0.00	m
Length		0.00	m
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	m
Profile Description			
Profile Headloss		0.00	m
Downstream Velocity		Infinity	m/s
Upstream Velocity		Infinity	m/s
Normal Depth		0.06	m
Critical Depth		0.09	m
Channel Slope		0.06100	m/m
Critical Slope		0.00591	m/m

50+165 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.06110	m/m
Left Side Slope	2.00	m/m (H:V)
Right Side Slope	6.00	m/m (H:V)
Discharge	0.03	m^3/s

Results

Normal Depth	0.09	m
Flow Area	0.03	m^2
Wetted Perimeter	0.73	m
Hydraulic Radius	0.04	m
Top Width	0.70	m
Critical Depth	0.10	m
Critical Slope	0.02490	m/m
Velocity	1.00	m/s
Velocity Head	0.05	m
Specific Energy	0.14	m
Froude Number	1.52	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.09	m
Critical Depth	0.10	m
Channel Slope	0.06110	m/m
Critical Slope	0.02490	m/m

50+230 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00344	m/m
Left Side Slope	2.00	m/m (H:V)
Right Side Slope	3.00	m/m (H:V)
Discharge	0.30	m³/s

Results

Normal Depth	0.43	m
Flow Area	0.45	m²
Wetted Perimeter	2.30	m
Hydraulic Radius	0.20	m
Top Width	2.13	m
Critical Depth	0.31	m
Critical Slope	0.01817	m/m
Velocity	0.66	m/s
Velocity Head	0.02	m
Specific Energy	0.45	m
Froude Number	0.46	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.43	m
Critical Depth	0.31	m
Channel Slope	0.00344	m/m
Critical Slope	0.01817	m/m

50+330 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.03570	m/m
Left Side Slope	1.50	m/m (H:V)
Right Side Slope	4.00	m/m (H:V)
Discharge	0.06	m³/s

Results

Normal Depth	0.14	m
Flow Area	0.05	m²
Wetted Perimeter	0.84	m
Hydraulic Radius	0.07	m
Top Width	0.78	m
Critical Depth	0.15	m
Critical Slope	0.02295	m/m
Velocity	1.02	m/s
Velocity Head	0.05	m
Specific Energy	0.19	m
Froude Number	1.23	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.14	m
Critical Depth	0.15	m
Channel Slope	0.03570	m/m
Critical Slope	0.02295	m/m

50+330 Paved Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Channel Slope	0.03570	m/m
Discharge	0.06	m³/s

Section Definitions

Station (m)	Elevation (m)
0+01	2925.39
0+01	2925.39
0+02	2925.39
0+02	2925.24
0+02	2925.27
0+05	2925.52

Roughness Segment Definitions

Start Station	Ending Station	Roughness Coefficient
(0+01, 2925.39)	(0+02, 2925.27)	0.013
(0+02, 2925.27)	(0+05, 2925.52)	0.016

Options

Current Roughness Weighted Method	Pavlovskii's Method
Open Channel Weighting Method	Pavlovskii's Method
Closed Channel Weighting Method	Pavlovskii's Method

Results

Normal Depth		0.08	m
Elevation Range	2925.24 to 2925.52 m		
Flow Area		0.04	m²
Wetted Perimeter		0.96	m
Hydraulic Radius		0.04	m
Top Width		0.92	m

50+330 Paved Ditch

Results

Normal Depth		0.08	m
Critical Depth		0.11	m
Critical Slope		0.00574	m/m
Velocity		1.49	m/s
Velocity Head		0.11	m
Specific Energy		0.19	m
Froude Number		2.36	
Flow Type	Supercritical		

GVF Input Data

Downstream Depth		0.00	m
Length		0.00	m
Number Of Steps		0	

GVF Output Data

Upstream Depth		0.00	m
Profile Description			
Profile Headloss		0.00	m
Downstream Velocity		Infinity	m/s
Upstream Velocity		Infinity	m/s
Normal Depth		0.08	m
Critical Depth		0.11	m
Channel Slope		0.03570	m/m
Critical Slope		0.00574	m/m

50+604 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.02614	m/m
Left Side Slope	6.00	m/m (H:V)
Right Side Slope	6.00	m/m (H:V)
Discharge	0.16	m³/s

Results

Normal Depth	0.16	m
Flow Area	0.16	m²
Wetted Perimeter	1.97	m
Hydraulic Radius	0.08	m
Top Width	1.94	m
Critical Depth	0.17	m
Critical Slope	0.02047	m/m
Velocity	1.00	m/s
Velocity Head	0.05	m
Specific Energy	0.21	m
Froude Number	1.12	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.16	m
Critical Depth	0.17	m
Channel Slope	0.02614	m/m
Critical Slope	0.02047	m/m

50+762 V Ditch

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.04781	m/m
Left Side Slope	4.00	m/m (H:V)
Right Side Slope	20.00	m/m (H:V)
Discharge	0.09	m³/s

Results

Normal Depth	0.09	m
Flow Area	0.09	m²
Wetted Perimeter	2.13	m
Hydraulic Radius	0.04	m
Top Width	2.12	m
Critical Depth	0.10	m
Critical Slope	0.02412	m/m
Velocity	0.91	m/s
Velocity Head	0.04	m
Specific Energy	0.13	m
Froude Number	1.38	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	m
Length	0.00	m
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	m
Profile Description		
Profile Headloss	0.00	m
Downstream Velocity	Infinity	m/s
Upstream Velocity	Infinity	m/s
Normal Depth	0.09	m
Critical Depth	0.10	m
Channel Slope	0.04781	m/m
Critical Slope	0.02412	m/m