U. S. Department of Agriculture
Natural Resources Conservation Service
Northern Plains Engineering Team
Lakewood, Colorado

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Hydraulic Analysis Report

Job Number: Co0103
Short Job Description: Willow Creek
Location: Creede; Mineral County, Colorado

Description of Job

The overall job is a community and multiple agency project to restore and maintain the Willow Creek watershed and stream, in and near the town of Creede, Colorado. This report provides the results of a hydraulic analysis of the existing flume, which conveys Willow Creek through town.

Report Contributor

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Summary

In the upper portion of the flume, flow is projected to first leave the channel at two locations: station 02+05.5 and station 26+92.7 (see Figure 3). This first occurs at a discharge of approximately 1550 cfs. The expected frequency of occurrence of such an event is unknown, but is less frequent than the estimated 100-year discharge estimate of 1131 cfs, at the railroad crossing. Events above 1550 cfs will cause localized to extensive flooding of Creede.

The railroad bridge is a significant obstacle to flow passing through the flume. At high flow, piers and chord structures restrict the flow, forcing the flow to pass over and around the structure. This first occurs at a discharge of approximately 925 cfs, less than the computed 50-year discharge of 969 cfs. If debris is caught on these piers, the capacity will be further reduced. Once the flow leaves the channel, this high flow situation can lead to erosion on the east and west sides of the railroad line, in the vicinity of the tailings pile on the east side of the stream. Mobilization of the tailings may be a possibility, resulting in water-quality degradation. Negative impacts to the proposed "sinuous stream" on the west side of the railroad tracks may also be a possibility. Bridge removal may be justified to minimize such risks.

Background

The US Army Corps of Engineers constructed a masonry flume through the town of Creede, Colorado in the early 1950's to help control flooding within this San Juan Mountain town. Significant maintenance is required to sustain the structure and it is felt that the existing flume's useful life is nearing its end. The Natural Resources Conservation Service is designing a new structure to replace this masonry flume. In support of this and other work within the basin, a hydrology report was prepared (dated 2/6/2002) that details a regional hydrologic study to determine the most appropriate flow frequencies for this basin. In addition, it was deemed necessary to determine the capacity of the existing flume. This report details the findings of the hydraulic analysis that determines this capacity.

Hydraulic Analysis

A HEC-RAS analysis was performed for the existing flume channel. HEC-RAS is an Army Corps of Engineers program that performs one-dimensional steady and unsteady flow computations. The steady flow portion of the model can handle simple reaches, dendritic systems, and full channel networks in both subcritical, supercritical, or mixed flow regimes. (Subcitical and supercritical flow are the two fundamental flow regimes found in open channel/natural flow scenarios. Supercritical or rapid flow is best characterized as a flow situation where disturbances, such as a wave, cannot propagate upstream.) HEC-RAS's fundamental computational procedure consists of the solution of the one-dimensional energy equation or standard step. Momentum or empirical equations are used by the model when flow is rapidly varied. In Willow Creek at Creede's flume, the flow is supercritical, gradually varied, and unhindered by permanent obstructions (bridge supports) except near the end of the flume, at the railroad crossing.

The computer model consists of 52 measured cross-sections within the 5103 ft length of the flume and includes the modeling of the railroad bridge. The drainage areas are 36.1 and 37.9 square miles, respectively, at the beginning and end of the flume. Figure 1 is a photograph of a typical flume section. Given the lack of complexity and variability of flow, the model is relatively simple. However, the supercritical flow that the channel forces upon the stream necessitates the use of many cross-sections, to insure accuracy. The 52 cross-sections were interpolated, creating a total of 162 cross-sections that were used in the analysis. The model is only valid to the point where flow first leaves a point in a channel. Once overtopped, the model is not valid for that point and all points downstream. The bridge geometry, specifically the bridge piers, are skewed at an angle of approximately 15 degrees to the direction of flow – this is taken into account in the model and does effect the capacity of the bridge cross-section.

Figure 1: Willow Creek at Creede flume, looking upstream. At station 09+25.

The cross-sections are valid in an unblocked situation. However, temporary obstructions occur every winter in the form of ice-dams. If an event occurred while these ice obstructions are still in place, a more dynamic flow situation will occur and these modeling results will not be valid. Additionally, woody debris will pass through the flume during high flow events, quite possibly snagging on overlying bridges, causing obstructions and rapidly varied flow. The railroad bridge and it's piers will assuredly retain debris during high flow events, further reducing flow capacity through this section. Hence, these results indicate the best-case flow scenario for the flume. Questions on how the flume will perform given specific obstruction scenarios will require model modification.

As in any hydraulic model, selection of the channel roughness (Manning's "n") is important. Figure 2 provides a photograph of the typical existing channel condition. Manning's "n" estimates of 0.027 for the smoother upper sloped sides and 0.035 for the rougher lower sloped sides and channel bottom were used in this analysis. The HEC-RAS hydraulic reference manual (USACE, 2001) was used in the roughness estimation.

Figure 2: Typical surface condition, Willow Creek at Creede flume.

Table 1 from the Flood-Frequency analysis report is included below. HEC-RAS was run for the 1.25-year though 100-year flow events at the Willow Creek at railroad crossing site (ID 6490). In addition, two more events were run: one for the first railroad overtopping event (less than the 50-year); and another for the first overflow event in the upper reaches of the channel. The channel will first overflow at the railroad bridge **-** the piers of this bridge provide significant flow obstruction.

Abbreviated results of the model analysis are provided in Table 2 and Figure3.

Table 1: Recommended discharge-frequency values at various points within the Willow Creek watershed (Yochum & Hyde, 2002).

ID	Description	Discharge Frequencies						
		100-yr (cfs)	50-yr (cfs)	25-yr (cfs)	10-yr (cfs)	5-yr (cfs)	2-yr (cfs)	1.25-yr (cfs)
6480	Willow Crk at confluence with Rio Grande	1213	1046	888	689	546	353	232
6490	Willow Crk at Railroad Crossing	1131	969	817	627	493	313	203
6500	Willow Crk at Creede gaging station	1073	915	769	586	458	288	185
6520	W Willow Crk at confluence with E Willow Crk	532	457	386	296	232	144	90
6530	W Willow Crk at Nelson Creek (inclusive)	382	325	273	206	159	96	58
6540	E Willow Crk at confluence with W Willow Crk	942	807	681	523	412	264	172
6550	E Willow Crk at road crossing near Phoenix Mine	733	623	522	398	311	196	127

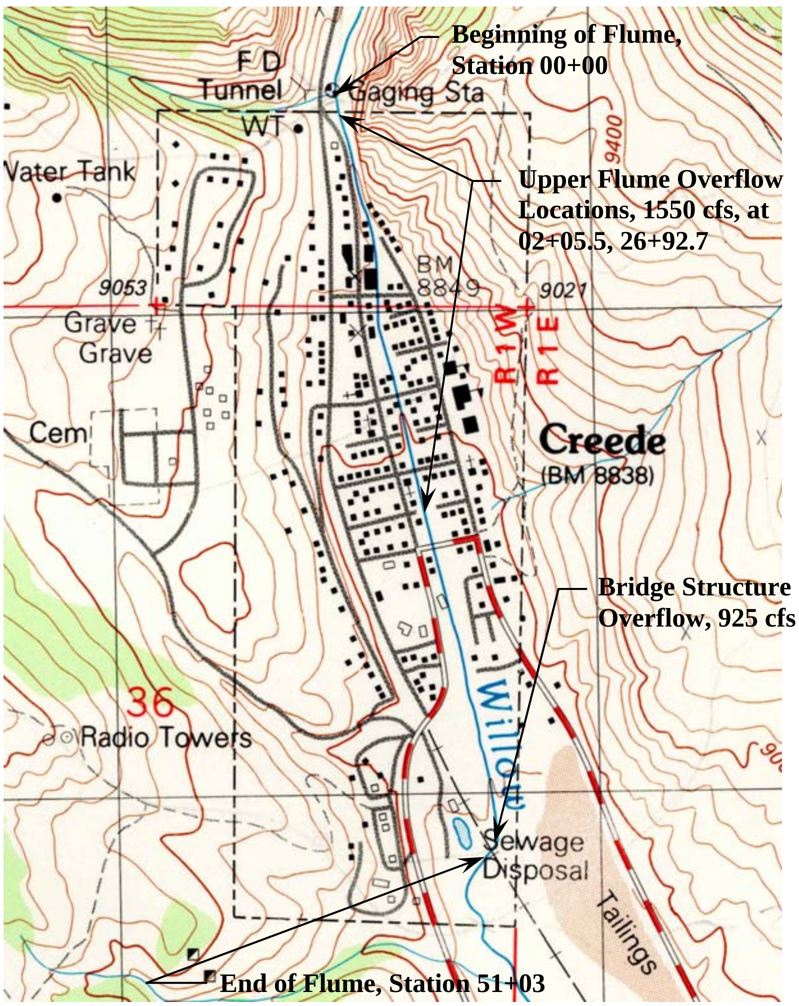

Figure 3: Willow Creek at Creede overflow locations.

Table 2: Abbreviated results of hydraulic analysis. Velocity and shear are average values.

Station	ID	1.25-year				10-year			
		Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)	Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)
00+27	49973	203	15.45	5.74	7.48	627	18.29	4.22	7.63
02+05.5	49794.5	203	8.69	3.67	1.88	627	12.03	1.93	2.83
09+74.5	49025.5	203	9.73	5.73	2.53	627	13.34	4.06	3.68
19+97	48003	203	9.27	4.7	2.25	627	13.23	3.16	3.6
26+92.7	47308.3	203	7.54	4.44	1.39	627	10.65	2.62	2.19
30+71	46929	203	8.81	4.69	2.02	627	12.3	3	3.08
39+34	46066	203	9.04	4.68	2.07	627	12.62	3.01	3.17
50+53	44947	203	3.88	4.59	0.33	627	4.66	1.44	0.36
Station	ID	Bridge Overflow				50-year			
		Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)	Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)
00+27	49973	925	19.02	3.39	7.42	969	19.06	3.28	7.36
02+05.5	49794.5	925	13.45	1.12	3.28	969	13.63	1.01	3.33
09+74.5	49025.5	925	14.71	3.23	4.11	969	14.89	3.13	4.17
19+97	48003	925	14.88	2.43	4.21	969	15.09	2.33	4.29
26+92.7	47308.3	925	10.77	1.4	2.02	969	10.87	1.27	2.03
30+71	46929	925	13.68	2.19	3.51	969	13.86	2.08	3.57
39+34	46066	925	14.17	2.23	3.71	969	14.32	2.12	3.75
50+53	44947	925	18	4.64	7.17	969	----	----	----
Station	ID	100-year				Upper Overflow			
		Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)	Discharge (cfs)	Velocity (ft/s)	Freeboard (ft)	Shear (lb/ft^2)
00+27	49973	1131	19.31	2.88	7.24	1550	19.73	1.95	6.97
02+05.5	49794.5	1131	14.25	0.65	3.54	1550	15.79	-0.15	4.09
09+74.5	49025.5	1131	15.48	2.75	4.36	1550	16.76	1.9	4.8
19+97	48003	1131	15.8	2	4.57	1550	17.38	1.27	5.21
26+92.7	47308.3	1131	11.33	0.85	2.14	1550	12.38	-0.15	2.4
30+71	46929	1131	14.44	1.71	3.75	1550	15.74	0.87	4.18
39+34	46066	1131	15.03	1.78	4.01	1550	16.56	1.01	4.59
50+53	44947	1131	----	----	----	1550	----	----	----

Conclusions

The railroad bridge is a significant obstacle to flow passing through the flume. At high flow, piers and chord structures restrict the flow, forcing the flow to pass over and around the structure. This first occurs at a discharge of approximately 925 cfs, less than the computed 50-year discharge of 969 cfs. Once the flow leaves the channel, this high flow situation can lead to erosion on the east and west sides of the railroad line, in the vicinity of the tailings pile. Mobilization of the tailings may be a possibility, resulting in water-quality degradation. Negative impacts to the proposed "sinuous stream" may also be a possibility. Bridge removal may be justified to minimize such risks.

In the upper portion of the flume, flow is projected to first leave the channel at two locations: at station 02+05.5 and station 26+92.7. This first occurs at a discharge of 1550 cfs. The expected frequency of occurrence of such an event is unknown, but is less-frequent than the estimated 100-year discharge estimate of 1131 cfs, at the railroad crossing (Yochum & Hyde, 2002). Events above this discharge will cause localized to extensive flooding of Creede. The actual expected flood extent for such larger events is beyond the scope of this study.

References

Yochum, S.E. Hyde, B., 2002, *Flood-Frequency Analysis Report for Willow Creek*, Natural Resources Conservation Service, Northern Plains Engineering Team, Lakewood, Colorado.

USACE, 2001, *HEC-RAS River Analysis System, Hydraulic Reference Manual Version, 3.0*, U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.