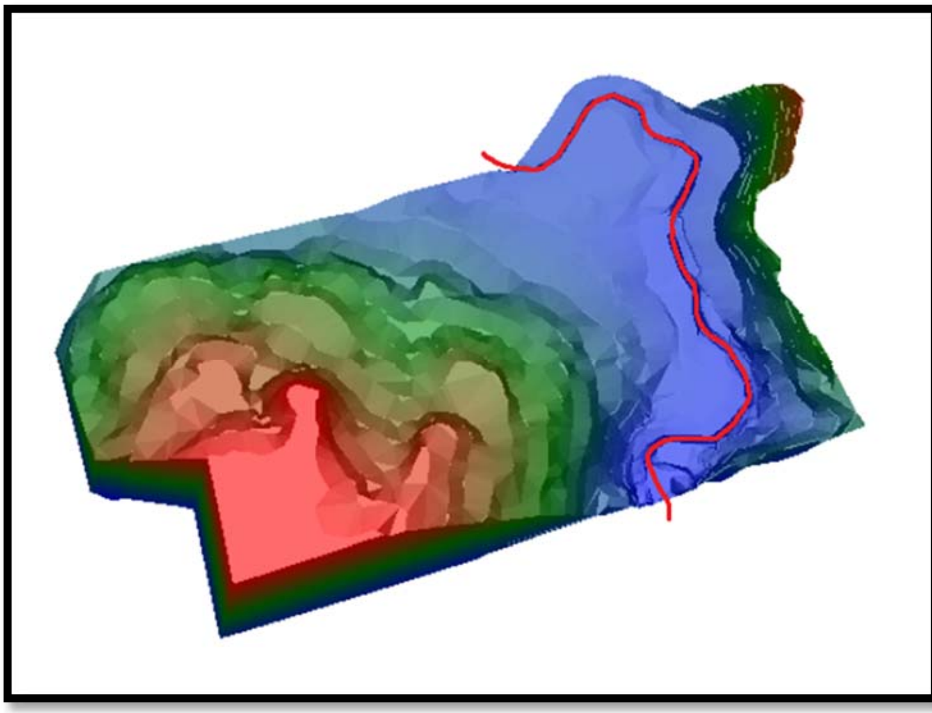
ATTACHMENT J-6

POSTMINE PAR 9B NFSC MAJOR CHANNEL DESIGN

Appendix J Volume 2 Attachment J-6

Post-mine PAR 9B
North Fork Spring Creek Major Channel Design

North Fork Spring Creek Channel Segment Design for PAR 9B
August 17, 2018



Introduction
The goal of stream reclamation is to approximate pre-mine channel morphology while meeting rule requirements in ARM 17.24.634(1)(e) that require reclaimed streams be able to safely pass the 100-year 6-hour runoff event. Appendix J of SMP C1979012 includes commitments for post-mine stream design and construction. Notably, major stream channel designs (includes North Fork Spring Creek) will be submitted to Montana DEQ for review and approval. This document details the channel design for a segment of North Fork Spring Creek in a reclamation project known as PAR 9B.

PAR 9B Setting
The designed stream segment that is the subject of this document is located in a reclaimed area known as PAR 9B and contains a segment of North Fork Spring Creek. North Fork Spring Creek is an ephemeral stream, flowing only in response to precipitation and/or snow melt events. The PAR 9B reclaimed area is approximately 8 acres and the reclaimed segment (as designed) of North Fork Spring Creek is approximately 890 feet long. The contributing drainage basin area to PAR 9B is approximately 4,300 acres (6.7 square miles). PAR 9B is located just downstream of the Carbone Flood Control Reservoir and is also immediately downstream of an undisturbed area that includes a broad flood plain and incised low-flow channel. Modeled runoff rates for each design storm event for the stream segment were taken from a SED-CAD study and are more fully documented in Appendix I of SMP C1979012.

Channel Design Terms and Definitions
Figure 1 depicts helpful terms and definitions used in this document.

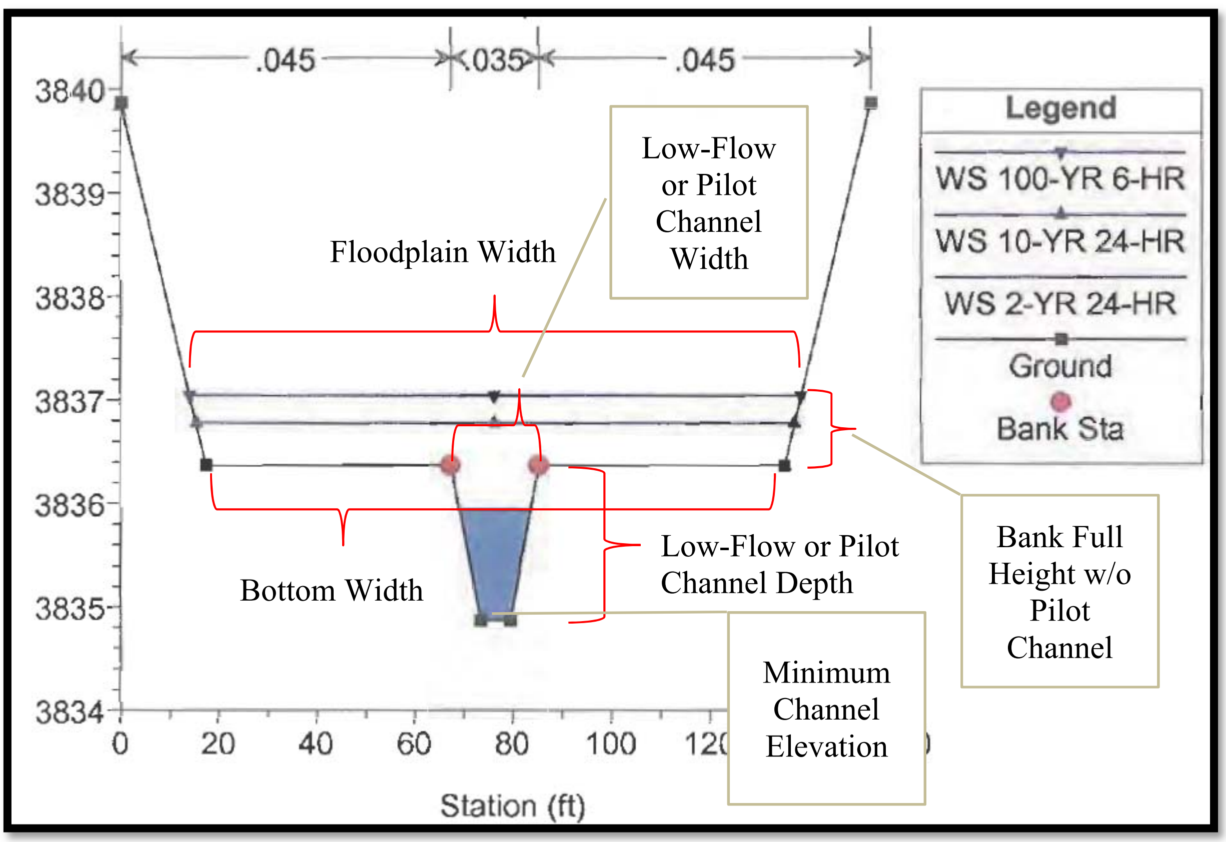


Figure 1. Stream Channel Cross-section Terms.

North Fork Spring Creek Characteristics (Pre-mine)

Detailed studies of the form and function of North Fork Spring Creek in the pre-mining condition have been completed and are fully documented in Appendix I of SMP C1979012. Studies completed include estimating storm flow runoff (done via SED CAD software) for design storm events and estimating the subsequent elevations of each flow event (done via HEC RAS software). Figure 2 depicts the pre-mine channel cross-sections in relation to where PAR 9B is located.

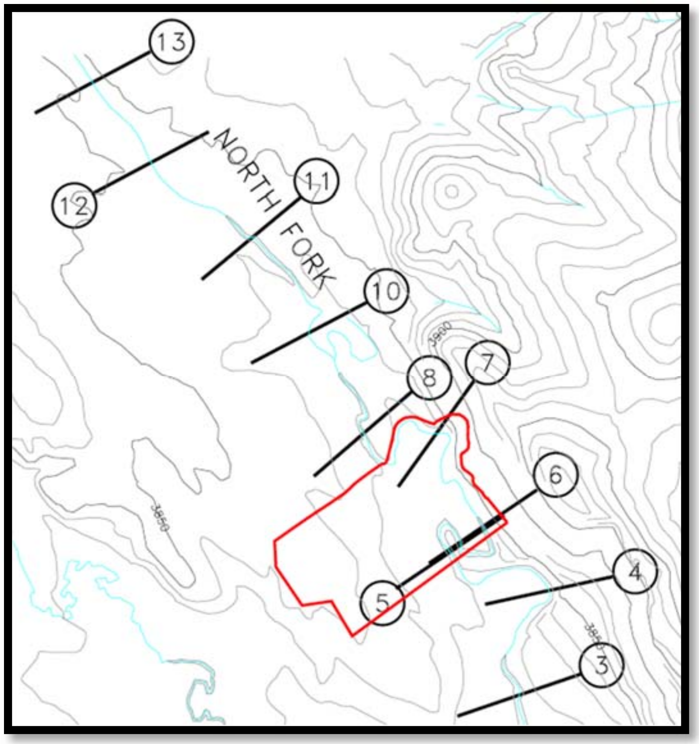


Figure 2. From Plate I-5, pre-mining HEC-RAS cross-section locations with PAR 9B boundary in red.

Table 1 below summarizes the modeled flow data of the seven most-relevant pre-mine stations from Appendix I Volume 2, Attachment I-5, Page I-5-4 from the TR1 Major Revision (to SMP C1979012) currently being evaluated by the Department. Note that these data represent modeled flows on the pre-mining channel before any disturbance as described in Appendix I.

Table 1. HEC-RAS Station Flow Data 100-year 6-hour runoff event (pre-mining condition)

Station #	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
13	434.97	6.14	84.6	61.1	0.8	3847.8	3845.0
12	434.97	3.23	134.8	132.2	0.6	3844.3	3842.3
11	434.97	5.02	155.5	197.2	0.7	3841.3	3838.9
10	434.97	4.22	103.1	148.1	0.9	3836.8	3835.4
8	434.97	5.62	155.4	213.1	0.6	3830.6	3826.4
7	434.97	6.78	79.2	81.3	0.8	3825.7	3822.1
6	434.97	1.69	304.2	189.0	0.3	3821.1	3819.4
5	434.97	5.51	136.8	179.0	0.6	3820.3	3815.7
Average	**434.97**	**4.78**	**144.2**	**150.1**	Slope = 0.007 ft/ft		

Conceptual Spring Creek Characteristics (Post-mine)
Conceptual-level design work for the major post-mine channels is contained in Appendix J of SMP C1979012. The conceptual channel location contains a comparable (slightly steeper) longitudinal profile than the pre-mine channel. The conceptual channel consists of a flood plain (capable of passing the 100-year, 6-hour flow event) and an inner pilot channel. The inner pilot channel (also called low-flow channel) is generally capable of conveying the runoff from a 2-year, 24-hour runoff event. The conceptual-level channel design geometry is based on pre-mine channel characteristics to the extent practicable and these modeling results are helpful in identifying overall channel dimensions and general characteristics for use in the final channel design.

Studies completed include estimating storm flow runoff for design storm events and estimating the subsequent elevations of each flow event. Figure 3 depicts the conceptual post-mine channel cross-sections in relation to where PAR 9B is located. Actual cross-sections depicting flow elevations are contained in Appendix J, Volume 2, Attachment J-2 of SMP C1979012.

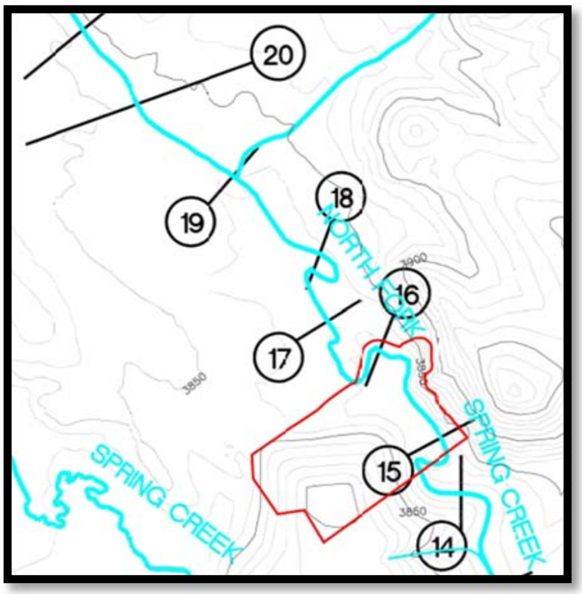


Figure 3. From Plate J-4, conceptual post-mining HEC-RAS cross-section locations with PAR 9B boundary in red.

Table 2 below summarizes the conceptual post-mine flow data of the six most-relevant stations from Appendix J Volume 2, Attachment J-2, pages J-2-5 and J-2-6 from TR1. Note that these data represent modeled flows on a **conceptual** post-mining channel design described in Appendix J. Also note the stations do not correlate exactly with the pre-mining condition stations.

Table 2. HEC-RAS Station Flow Data 100-year 6-hour runoff event (conceptual channel design, post-mining)

Station #	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
20	434.1	3.22	135.0	132.1	0.6	3844.7	3842.6
19	434.1	4.90	145.5	135.7	0.6	3841.6	3839.5
18	434.1	5.06	141.2	135.1	0.7	3838.4	3836.3
17	434.1	6.49	112.6	130.8	0.9	3835.0	3833.2
16	434.1	5.19	137.9	134.6	0.7	3831.8	3829.8
15	434.1	5.25	136.4	134.4	0.7	3828.7	3826.7
Average	**434.1**	**5.02**	**134.8**	**133.8**	**Slope = 0.008 ft/ft**		

PAR 9B North Fork Spring Creek Channel Design
Figure 4 depicts the design finish grade topography for the reclaimed lands inside PAR 9B, including the segment of North Fork Spring Creek that is the subject of this document. In general, the topography resembles the approved post-mine topography contained in Plate 4 of SMP C1979012. In some locations, micro-topographic features have been included to increase site topographic diversity.

A low-flow channel was designed to model pre-mine channel invert geometry and will be able to handle a 2-year, 24-hour runoff event. The primary flood plain will be capable of handling the flow from a 100-year, 6-hour runoff event. Modeled runoff rates from TR1 were used, which contain higher rates than the current permit (for conservativeness). Using the higher flows, the design shows its ability to handle both runoff events. To demonstrate this, five cross-sections were developed for the channel segment inside PAR 9B. Surface topography and runoff data were then modeled using the HEC-RAS hydrology model. Note that cross-section 28+40.47 is actually located completely on undisturbed land immediately upgradient of PAR 9B as depicted in Figure 4.

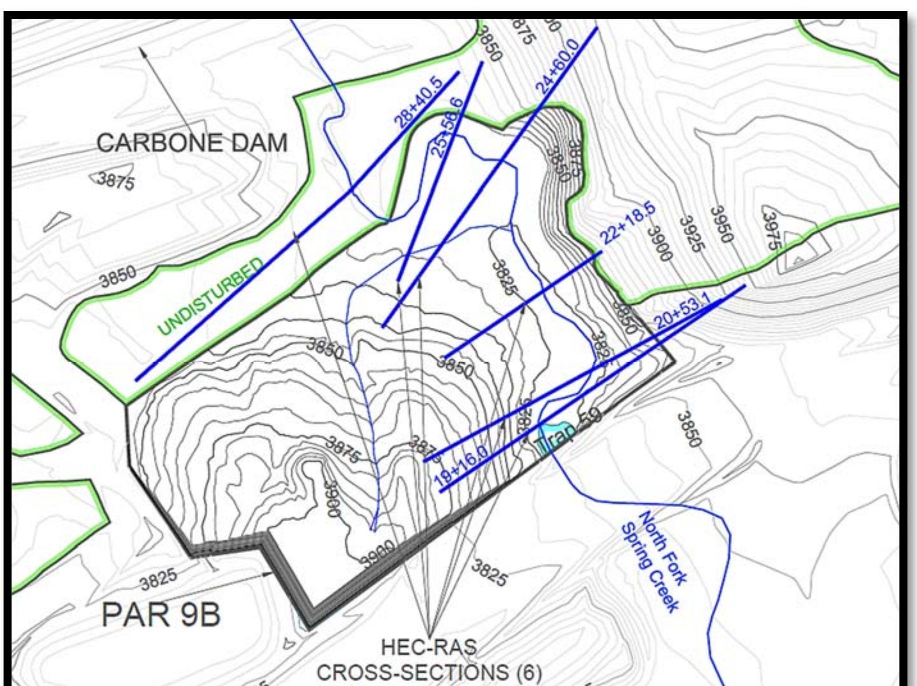


Figure 4. PAR 9B design topography with HEC-RAS cross-section locations in blue. Contour interval is five foot inside PAR 9B boundary and five foot outside the PAR 9B boundary.

Table 3 below summarizes the modeled flow data of six cross-sections using the runoff rates expected from the 100-year, 6-hour event from the post-mine TR1 data. Note that although the post-mine design stations 24+60.0 and 19+16.0 do correlate with the pre-mining stations 7 and 6, respectively, the topography between the two conditions is different, making the station data irrelevant for comparison. Figures 5 and 6 depict the HEC-RAS cross-sections and the flow elevations expected for the 2-year, 24-hour and 100-year, 6-hour runoff events.

Table 3. HEC-RAS Station Flow Data 100-year 6-hour runoff event (PAR 9B channel design, post-mining)

Cross-section ID	Flow Total (cfs)	Vel. (ft/s)	Flow Area (ft^2)	Top Flow Width (ft)	Froude # Chl	Water Surface Elev. (ft)	Minimum Channel Elev. (ft)
28+40.5	434.1	4.24	115.9	130.7	0.8	3830.1	3827.3
25+56.6	434.1	3.32	141.4	170.8	0.5	3828.9	3824.1
24+60.0	434.1	3.82	113.7	104.7	0.7	3828.3	3823.2
22+18.6	434.1	6.44	67.4	56.0	1.0	3823.4	3821.2
20+53.1	434.1	2.89	150.0	129.4	0.5	3823.9	3820.0
19+16.0	434.1	5.93	73.2	69.6	1.0	3822.5	3818.7
Average	**434.1**	**4.44**	**110.3**	**110.2**	Slope = 0.009 ft/ft		

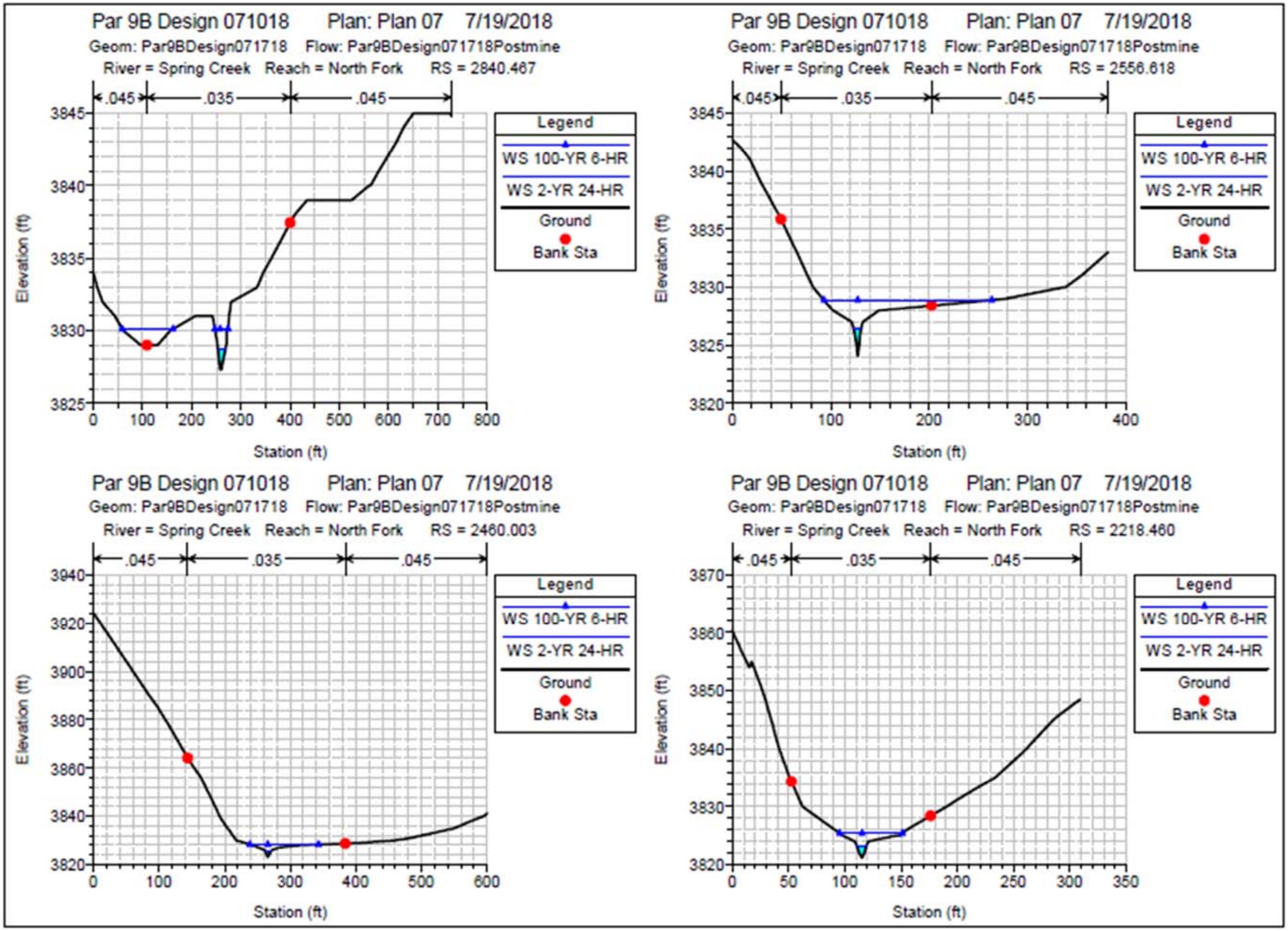


Figure 5. PAR 9B North Fork Spring Creek channel design segment HEC-RAS cross-sections

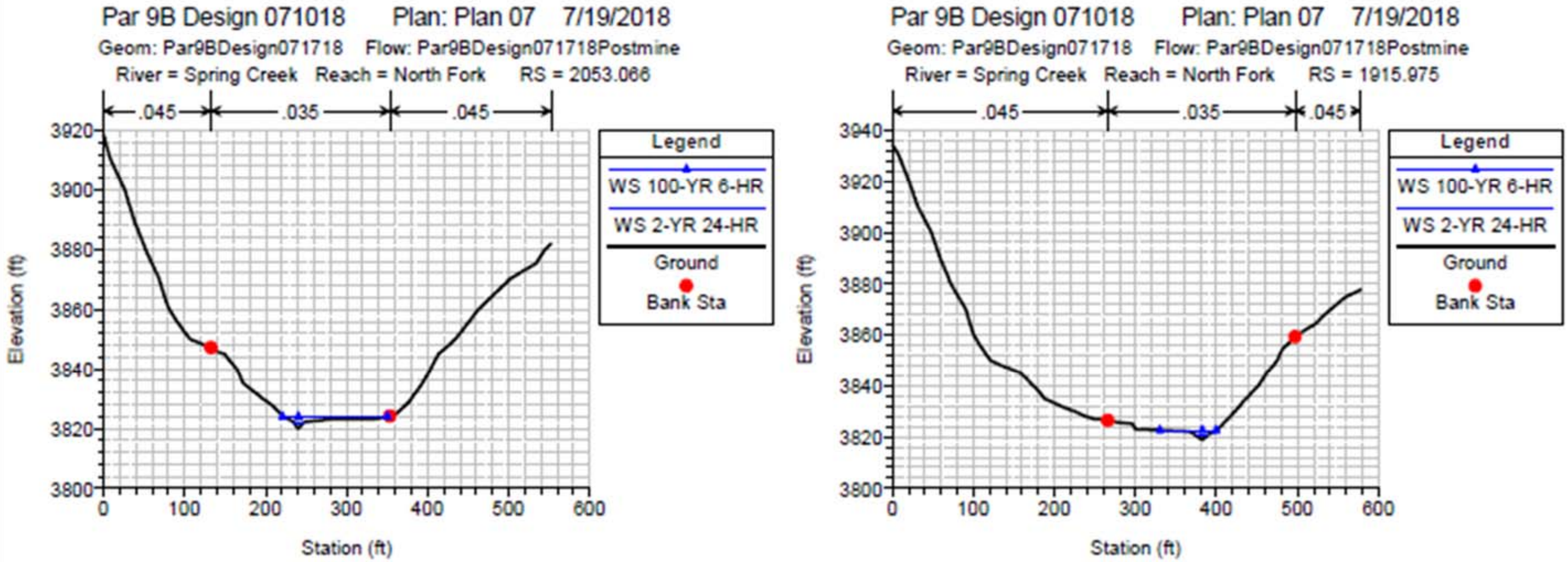


Figure 6. PAR 9B North Fork Spring Creek channel design segment HEC-RAS cross-sections

Channel Stability

The HEC-RAS software was used to ensure the final channel design would safely pass the 100-year 6-hour and the 2-year 24 hour storm event. Table 4 compares HEC-RAS model flow data for the most relevant pre-mine cross-sections with the five cross-sections inside the designed PAR 9B stream segment for the 100-year 6-hour storm event. Table 5 compares HEC-RAS model flow data for the pre-mine cross-sections to the five cross-sections within the PAR 9B boundary for the 2-year 24 hour storm event.

Note the runoff rate for the pre-mine condition is from Appendix I, Volume 2, Attachment I-5, Page I-5-4 from TR1, and the runoff rate for the post-mine condition is from Appendix J, Volume 2, Attachment J-2, Pages J-2-5 and J-2-6 from TR1. Note the post-mine TR1 runoff rate was used for designing the channel and floodplain within PAR 9B instead of the pre-mine TR1 runoff rate as the design is to hold the runoff after all the disturbed land has been reclaimed. The post-mine topography differs from the pre-mine topography, resulting in an insignificantly lower runoff rate (0.9 cfs for the 100-year 6-hour and 0.1 cfs for the 2-year 24-hour storm event) for each condition.

The design channel's longitudinal flood plain slope is steeper than the pre-mine condition as the approved profile of North Fork Spring Creek in Appendix J, Volume 1, Plate J-5, has a slope of 0.0091 ft/ft while the pre-mine location had a longitudinal slope of 0.007 ft/ft as shown in Appendix I, Volume 4, Plate J-6.The longitudinal slope of the native flood plain above PAR 9B as surveyed is 0.005 ft/ft. The slope differences are within the range of natural variability on major channels (in their native condition) at the Spring Creek Mine.

With respect to channel length, a direct comparison of approved post-mine (889 feet) to design post-mine (891 feet) for the low-flow channel was performed, showing the two lengths to be close in magnitude.

Table 4 shows the post-mine channel will be stable with a Froude number at or below 1.0 (indicating subcritical or slow/tranquil flow) using the modeled runoff flows from Appendix J in TR1.

Table 4. Comparison of HEC-RAS analysis for pre-mine and post-mine cross-sections in PAR 9B for a 100-year 6-hour storm event

Cross-section		Q Total	Min Ch. El	W.S. Elev.	Critical W.S.	E.G. Elev.	E.G. Slope	Vel. Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq. ft)	(ft)	
Pre-mine	7	435.0	3822.1	3825.7	3825.7	3826.4	0.0093	6.78	79.2	81.3	0.8
Pre-mine	6	435.0	3819.4	3821.1	3820.0	3821.2	0.0010	1.69	304.2	189	0.3
Pre-mine	5	435.0	3815.7	3820.3	3820.1	3820.6	0.0057	5.51	136.8	179	0.6
Design	25+56.6	434.1	3824.1	3828.9		3829.1	0.0052	3.32	141.4	170.8	0.5
Design	24+60.0	434.1	3823.2	3828.3	3827.8	3828.5	0.0074	3.82	113.7	104.7	0.7
Design	22+18.5	434.1	3821.2	3825.4	3825.4	3826.0	0.0186	6.44	67.4	55.9	1.0
Design	20+53.1	434.1	3820.0	3823.9	3823.4	3824.0	0.0038	2.89	150.0	129.4	0.5
Design	19+16.0	434.1	3818.7	3822.5	3822.5	3823.1	0.0186	5.93	73.2	69.6	1.0

Table 5 shows the post-mine channel invert (low-flow channel) will be stable with a Froude number at or below 1.0 using the modeled runoff rates from Appendix J in TR1.

Table 5. Comparison of HEC-RAS analysis for pre-mine and post-mine cross-sections in PAR 9B for a 2-year 24-hour storm event

Cross-section		Q Total (cfs)	Min Ch. El (ft)	W.S. Elev. (ft)	Critical W.S. (ft)	E.G. Elev. (ft)	E.G. Slope (ft/ft)	Vel. Chnl (ft/s)	Flow Area (sq. ft)	Top Width (ft)	Froude # Chl
Pre-mine	7	40.5	3822.1	3823.5	3823.5	3823.8	0.0216	4.73	8.56	12.7	1.0
Pre-mine	6	40.5	3819.4	3820.0	3820.0	3820.0	0.0004	0.73	96.2	177.1	0.1
Pre-mine	5	40.5	3815.7	3818.2	3817.4	3818.3	0.0029	2.50	16.2	23.3	0.4
Design	25+56.6	40.4	3824.1	3826.5		3826.8	0.0153	4.81	8.4	8.1	0.8
Design	24+60.0	40.4	3823.2	3825.5	3825.1	3825.8	0.0091	4.10	9.8	8.4	0.7
Design	22+18.5	40.4	3821.2	3823.1		3823.4	0.0123	4.61	8.8	8.1	0.8
Design	20+53.1	40.4	3820.0	3821.8	3821.4	3822.0	0.0073	3.58	11.3	10.9	0.6
Design	19+16.0	40.4	3818.7	3820.1	3820.1	3820.5	0.0212	4.91	8.2	11.3	1.0

As another comparison, Table 6 shows two of the designed cross-sections located within PAR 9B that correlate with conceptual post-mine cross-sections. The conceptual post-mine runoff rates and the design post-mine runoff rates are from Appendix J. The conceptual post-mine cross-section locations are shown in Figure 3, and the design post-mine cross-section locations are shown in Figure 4. Conceptual post-mine cross-section 16 correlates with design cross-section 25+56.6; conceptual post-mine cross-section 15 correlates with design cross-section 20+53.1.

Table 6. Comparison of HEC-RAS analysis for conceptual post-mine and the designed post-mine cross-sections in PAR 9B

Cross-section		Q Total (cfs)	Min Ch. El (ft)	W.S. Elev. (ft)	Critical W.S. (ft)	E.G. Elev. (ft)	E.G. Slope (ft/ft)	Vel. Chnl (ft/s)	Flow Area (sq. ft)	Top Width (ft)	Froude # Chl
2-Year 24-Hour											
Conceptual	16	40.4	3829.8	3831.0	3830.7	3831.1	0.003	2.27	31.6	117.7	0.4
Design	25+56.6	40.4	3824.1	3826.5		3826.8	0.0153	4.81	8.4	8.1	0.8
Conceptual	15	40.4	3826.7	3827.6	3827.6	3827.9	0.017	4.30	9.4	13.7	0.9
Design	20+53.1	40.4	3820.0	3821.8	3821.4	3822.0	0.0073	3.58	11.3	10.9	0.6
100-Year 6-Hour											
Conceptual	16	434.1	3829.8	3831.8		3832.0	0.007	5.19	137.9	134.6	0.7
Design	25+56.6	434.1	3824.1	3828.9		3829.1	0.0052	3.32	141.4	170.8	0.5
Conceptual	15	434.1	3826.7	3828.7	3828.5	3828.9	0.008	5.25	136.4	134.4	0.7
Design	20+53.1	434.1	3820.0	3823.9	3823.4	3824.0	0.0038	2.89	150.0	129.4	0.5

Channel Function

Additional upland features and an additional drainage feeding into North Fork Spring Creek were added to improve topographic diversity. The cover page figure shows a three dimensional rendering of the PAR 9B area with the stream centerline traced in red.

Channel Construction and Topsoil Plan

The North Fork Spring Creek channel will be constructed to the lines and grades depicted on Figure 4. Following overburden grading (and after receiving topsoil laydown approval), the channel and reclamation area will be topsoiled in accordance with Section 313 of SMP C1979012 (specifically Table 313-2a). Alluvial topsoil will be placed in the floodplain areas to a depth of 2.0 feet and general topsoil in all other places.

Comparison of PAR 9B Segment Design to Minor Tributary Design Methodology

While the minor tributary design methodology does not necessarily apply to the design of major stream channel segments at Spring Creek Mine, it does serve as a useful comparison. Furthermore, the regression equation that is used in the minor tributary methodology can be used to approximate floodplain widths for drainages as large as 450 square miles (for Type C streams, see Table J-9 of Appendix J in SMP C1979012) (MDEQ 2002). Therefore, a brief comparison is constructive.

Using a drainage area of approximately 4,300 acres (6.72 square miles) and a Type C channel slope of 0.5%-1.0%, the calculated belt width of the PAR 9B channel segment (using the Table J-9 regression equation) results in a calculated belt width of 127 to 170 feet and a calculated low-flow (or pilot channel) top width of 10.6 feet. The calculated low-flow channel width of 10.6 feet compares remarkably close to the actual low-flow top width (8 to 10 feet) of the designed cross-sections located inside PAR 9B as shown in Figure 4. The designed PAR 9B channel segment floodplain width varies considerably but generally conforms to the calculated belt width using the minor tributary methodology.

References

Montana Department of Environmental Quality (MDEQ), 2002. Guideline for Reclamation of Drainage Basins and Channels Disturbed by Surface Coal Mining. September.