ATTACHMENT J-5

POSTMINE PAR 9A SC MAJOR CHANNEL DESIGN

Appendix J Volume 2 Attachment J-5

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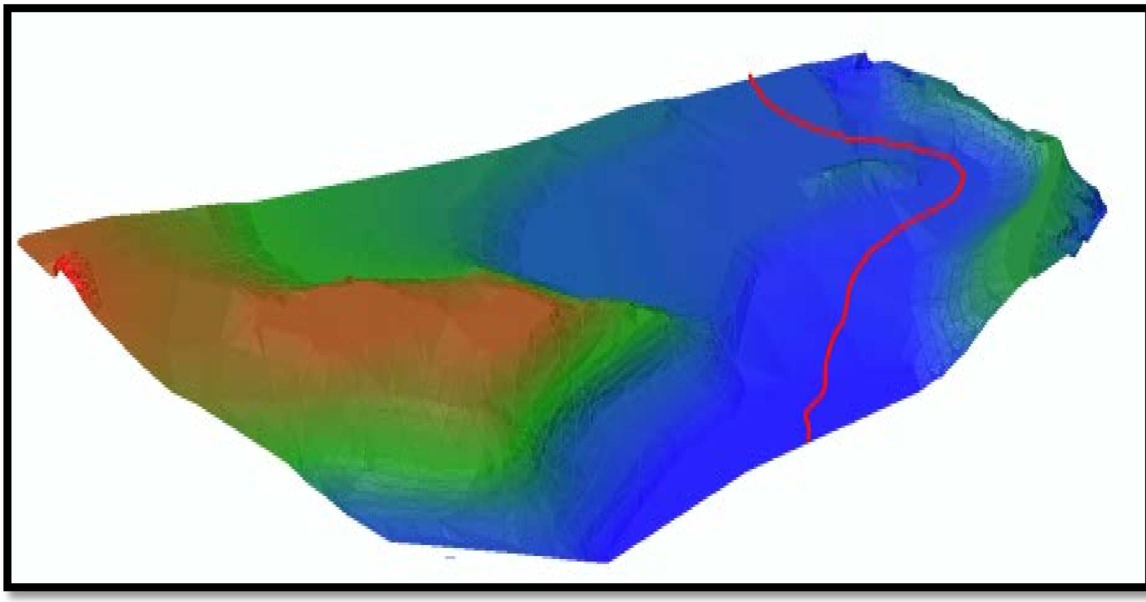
Spring Creek Channel Segment Design for PAR 9A (MR233)
September 27, 2017



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 Spring Creek) will be submitted to Montana DEQ for review and approval. This document details the PAR 9A Spring Creek channel design.

PAR 9A Setting

The designed stream segment that is the subject of this document is located in a reclaimed area known as PAR 9A and contains a segment of Spring Creek. Spring Creek is an ephemeral stream, flowing only in response to precipitation and/or snow melt events. The PAR 9A reclaimed area is approximately 8 acres and the reclaimed segment (as designed) of Spring Creek is approximately 660 feet long. The contributing drainage basin area to PAR 9A is approximately 5,700 acres (8.9 square miles). PAR 9A 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 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.

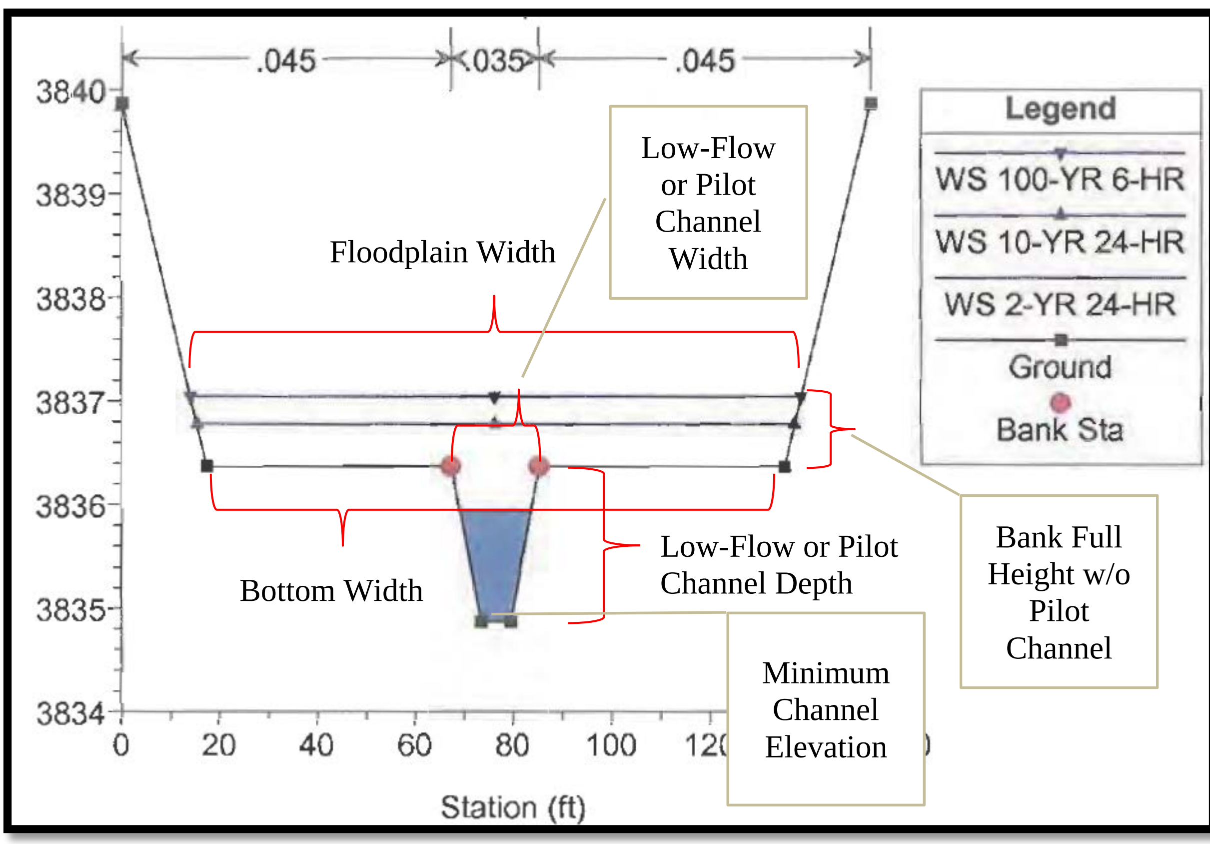


Figure 1. Stream Channel Cross-section Terms.

Spring Creek Characteristics (Pre-mine)

Detailed studies of the form and function of 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 9A is located.

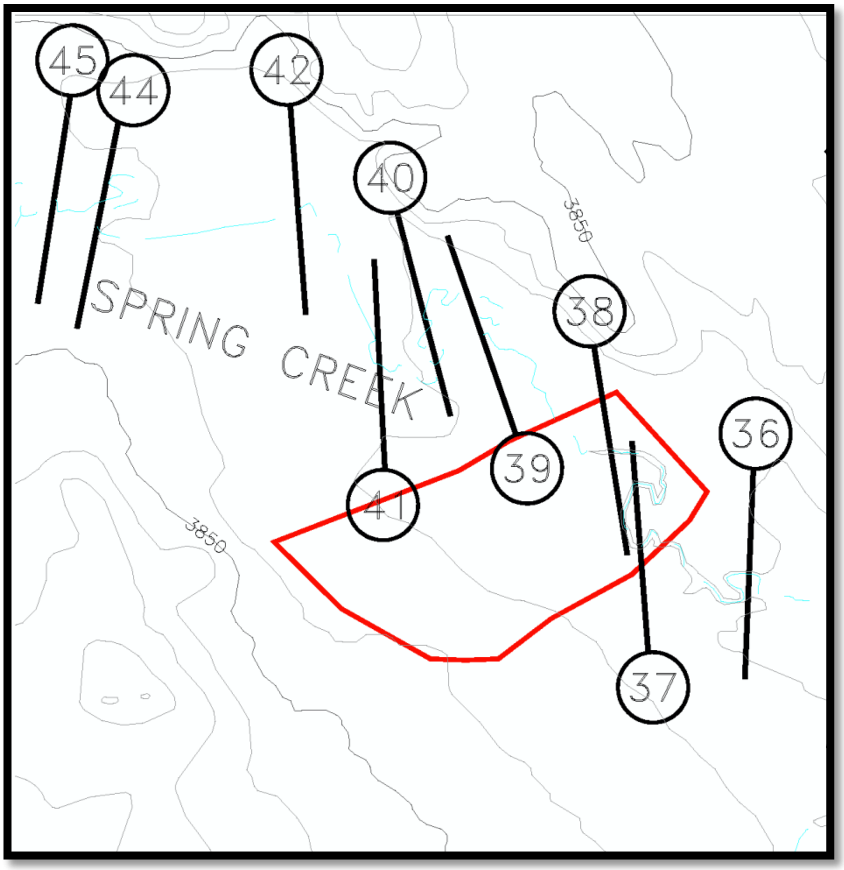


Figure 2. From Plate I-5, pre-mining HEC-RAS cross-section locations with PAR 9A boundary in red.

Table 1 below summarizes the modeled flow data of the six most-relevant pre-mine stations from Appendix I Volume 2, Attachment I-5, page I-5-2. 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)
41	605.9	3.87	183.0	455.2	1.0	3831.3	3830.6
40	605.9	2.86	212.0	204.0	0.5	3827.1	3825.2
39	605.9	4.73	134.8	69.2	0.5	3824.9	3822.0
38	605.9	4.72	128.3	117.7	0.7	3822.3	3819.6
37	605.9	3.11	356.9	269.4	0.3	3821.3	3816.9
36	605.9	7.39	82.0	48.4	1.0	3818.9	3815.5
Average	**605.9**	**4.45**	**182.8**	**194.0**	Slope = 0.005 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 maintains a similar longitudinal slope as 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 9A is located. Actual cross-sections depicting flow elevations are contained in Appendix J, Volume 2, Attachment J-2 of SMP C1979012.

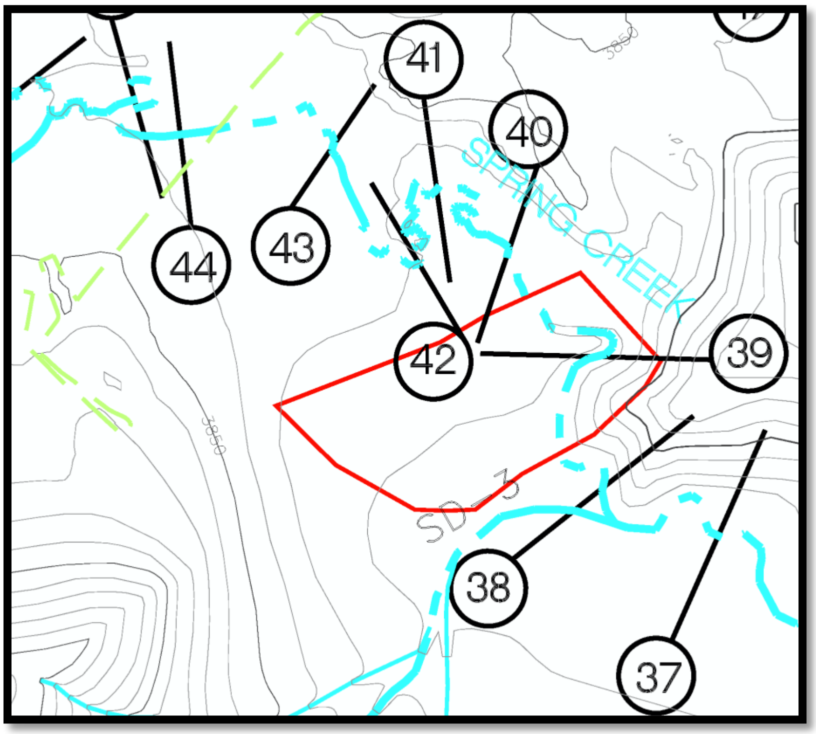


Figure 3. From Plate J-4, conceptual post-mining HEC-RAS cross-section locations with PAR 9A boundary in red.

Table 2 below summarizes the design flow data of the five most-relevant stations from Appendix J Volume 2, Attachment J-2, pages J-2-2 and J-2-4. Note that these data represent modeled flows on a **<u>conceptual</u>** 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)
42	605.9	2.42	250.7	221.8	0.4	3832.9	3830.8
41	605.9	5.20	120.5	63.9	0.6	3830.7	3828.0
40	605.9	6.74	148.1	109.5	0.8	3827.6	3825.2
39	605.9	4.99	227.3	253.5	0.6	3824.8	3822.4
38	605.9	5.49	209.0	250.6	0.7	3822.0	3819.6
Average	**605.9**	**4.97**	**191.1**	**179.9**	Slope = 0.006 ft/ft		

PAR 9A Spring Creek Channel Design

Figure 4 depicts the design finish grade topography for the reclaimed lands inside PAR 9A, including the segment of 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.

In keeping with the concept of allowing the low-flow (or 2-year) channel form naturally within the flood plain, no low-flow channel was included in the channel design or HEC-RAS modeling. Only the primary flood plain will be constructed and this will be capable of handling the flow from a 100-year, 6-hour runoff event. To demonstrate this, four cross-sections were developed for the Spring Creek channel segment inside PAR 9A. Surface topography and runoff data were then modeled using the HEC-RAS hydrology model. Note that cross-section 6+62.5 is actually located completely on undisturbed land immediately upgradient of PAR 9A as depicted in Figure 4. Also note that no low-flow or pilot channel was modeled in the PAR 9A stream segment; this feature will be allowed to develop naturally (and is consistent with the successful minor tributary methodology Spring Creek Mine uses in more upland environments). As the 2-year low-flow pilot channel forms over time, eroded sediment will be captured and re-used via the mine's sediment control structure network.

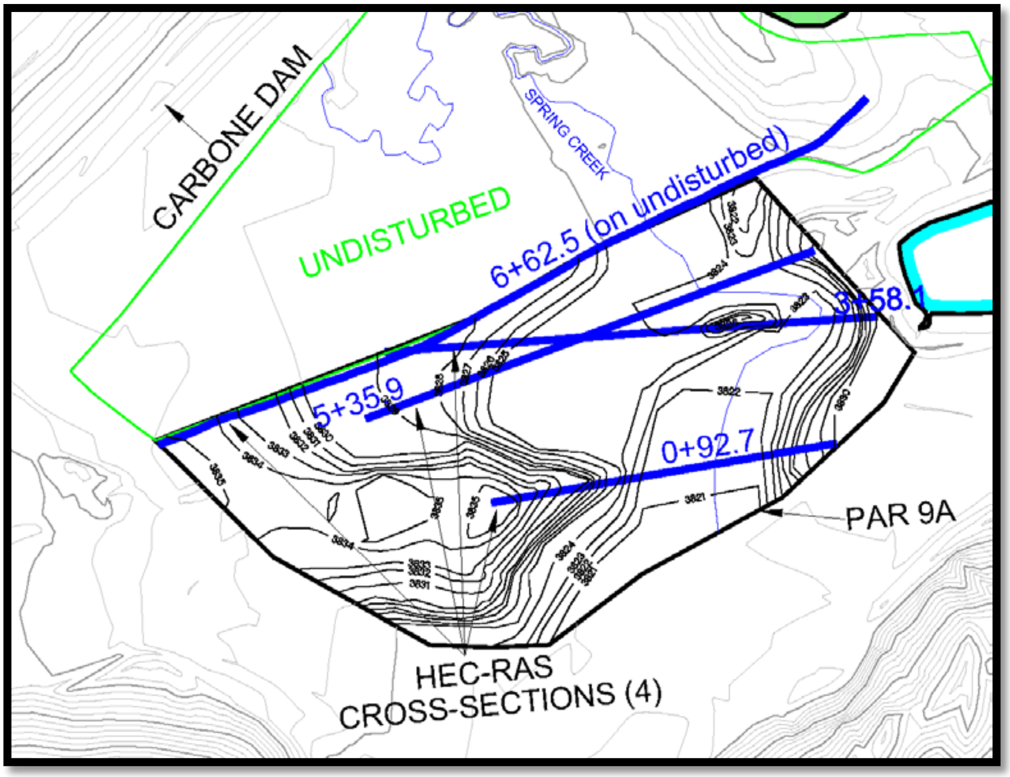


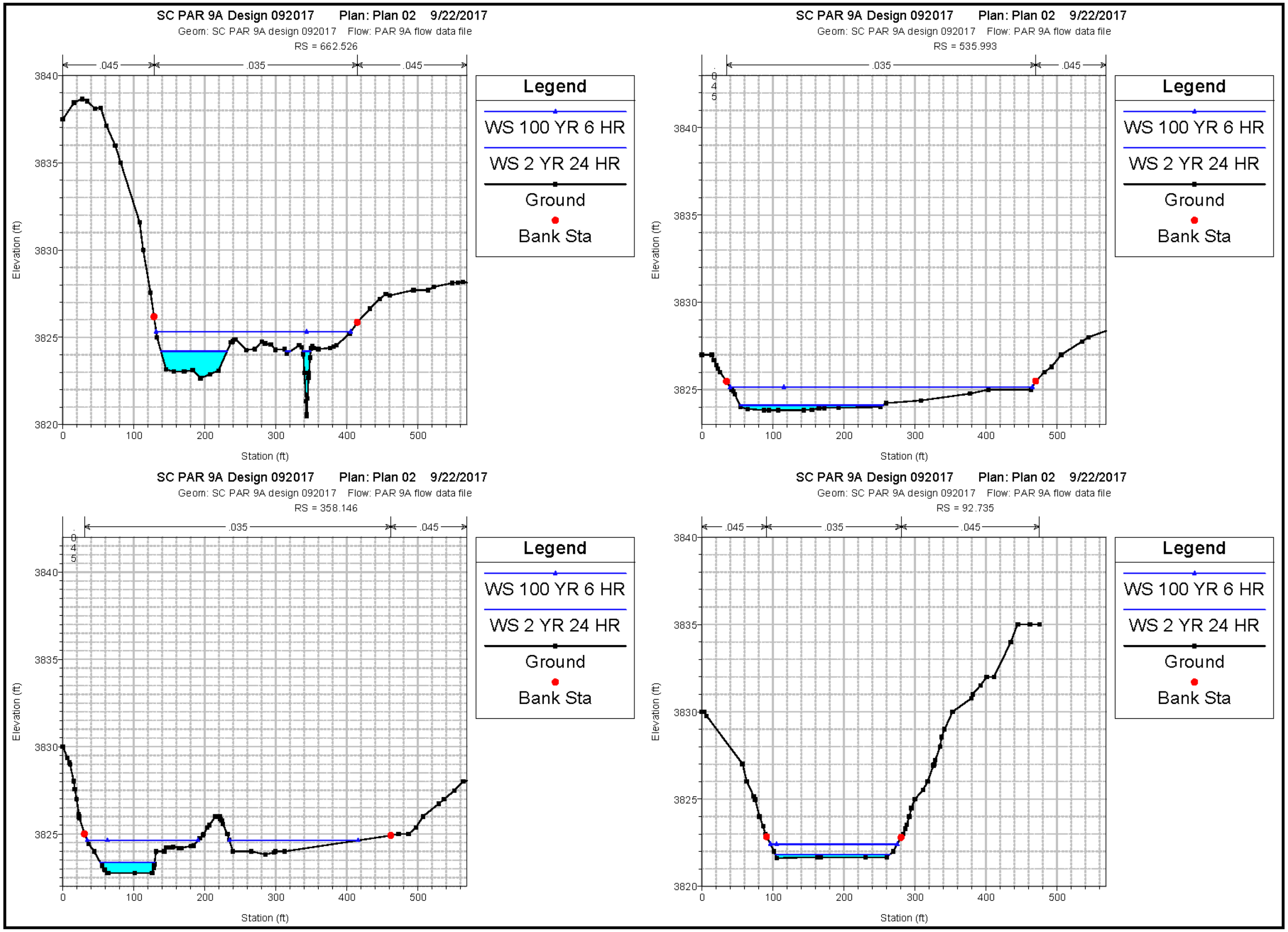
Figure 4. PAR 9A design topography with HEC-RAS cross-section locations in blue. Contour interval is one foot inside PAR 9A boundary and five foot outside the PAR 9A boundary.

Table 3 below summarizes the modeled flow data of four cross-sections using the runoff rates expected from the 100-year, 6-hour event. Also note the stations do not correlate exactly with the pre-mining condition stations. Figure 5 depicts 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 9A 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)
6+62.5	605.9	1.63	372.2	273.9	0.3	3825.3	3820.5
5+35.9	605.9	1.72	351.8	425.6	0.3	3825.1	*3823.8
3+58.1	605.9	2.32	260.7	337.5	0.5	3824.6	*3822.8
0+92.7	605.9	4.80	126.3	178.6	1.0	3822.4	*3821.6
Average	**605.9**	**2.62**	**277.8**	**303.9**	Slope = 0.005 ft/ft		

Notes:
* - Minimum channel elevation is necessarily higher in elevation than the elevation in upstream (native) cross-section 6+62.5 because the 2-year channel is not being constructed in the reclaimed environment; this channel will be allowed to develop naturally within the 100-year, 6-hour floodplain, as described more fully in Appendix J.



1 in Horiz. = 200 ft 1 in Vert. = 8.138352 ft

Figure 5. PAR 9A 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 storm event. Table 4 compares HEC-RAS model flow data for the most relevant pre-mine cross-sections with the three cross-sections inside the designed PAR 9A stream segment. It is important to note that there is no low-flow channel in the reclaimed channel segment and this is the reason for minimum channel elevations in the reclaimed channel greater than pre-mine.

The design channel's flood plain longitudinal slope is the same slope as the pre-mine condition and ensures channel concavity in the longitudinal direction. With respect to channel length, a direct comparison of pre-mine (783 feet) to post-mine (664 feet) is considered tenuous because the pre-mine channel centerline is based on the low-flow channel, while the post-mine channel is based on the centerline of the flood plain. As the low-flow channel develops over time, the channel length within PAR 9A is expected to approximate the pre-mine length as the channel erodes and deposits sediment naturally. Through this process, the low-flow channel will meander within the flood plain similar to stream segments found upstream of the mine. This is the same process that Spring Creek Mine uses in successfully constructing minor stream tributaries in upland environments.

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 I.

Table 4. Comparison of HEC-RAS analysis for pre-mine and post-mine cross-sections in PAR 9A

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	38	605.9	3819.6	3822.3	3821.9	3822.6	0.0078	4.7	128.3	117.7	0.7
Pre-mine	37	605.9	3816.9	3821.3	3820.6	3821.3	0.0016	3.1	356.9	269.4	0.3
Design	5+35	605.9	3823.8	3825.1		3825.2	0.0021	1.7	351.8	425.6	0.3
Design	3+58	605.9	3822.8	3824.6		3824.7	0.0042	2.3	260.7	337.5	0.5
Design	0+92	605.9	3821.6	3822.4	3822.4	3822.8	0.0202	4.8	126.3	178.6	1.0

Channel Function
A potential risk in constructing a low slope stream channel with a wide flat bottom width is the stream channel can take the shortest route; which reduces the stream length. The flat bottom width of the flood plain has flow direction variations to encourage the low-flow channel to meander within the greater flood plain. One island was added to provide topographic diversity and to direct the stream channel. Additional upland features were also added to improve topographic diversity. The cover page figure shows a three dimensional rendering of the PAR 9A area with the stream centerline traced in red.

Channel Construction and Topsoil Plan
The 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 9A 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 5,700 acres and a Type C channel slope of 0.5%, the calculated belt width of the PAR 9A channel segment (using the Table J-9 regression equation) results in a calculated belt width of 138 to 185 feet and a calculated low-flow (or pilot channel) top width of 11.6 feet. The calculated low-flow channel width of 11.6 feet compares remarkably close to the actual low-flow top width (~11 feet) of cross-section 6+62.5 (in native land just upgradient of PAR 9A) used in the HEC-RAS model. The designed PAR 9A 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.