Preliminary Analyses of the Critical Discharge for Streambed Mobilization – Currys Fork Watershed

Prepared for Oldham Co. Fiscal Court
By Sustainable Streams
June 2020

The purpose of this memorandum is to document the methodology and results of the preliminary analyses of estimates of the critical discharge for streambed mobilization ($Q_{critical}$). These preliminary estimates of the threshold discharge for streambed erosion can help to inform stormwater design targets for both new development and retrofits of existing stormwater control measures within the Currys Fork Watershed.

Introduction

The critical discharge for stream bed/bank erosion is known as $Q_{critical}$. Flows greater than this threshold will entrain bed particles, moving them downstream. While some bed disturbance is natural, developed watersheds tend to have flow regimes that cause more frequent disturbance to the bed, resulting in excess erosion in the stream system (Hawley and Vietz, 2016). To mitigate this excess erosion, $Q_{critical}$ can be used as a target flow for stormwater management. With enough implemented stormwater management measures designed for channel stability, a transition from Stage 3 of the Channel Evolution Model (Figure 1) to Stages 4 and 5 could occur. In this transition, the toe of the bank is sequentially protected by bar development that is ultimately colonized by more permanently protective vegetation (i.e. similar to the pilot study conducted by Sustainable Streams, US EPA, and other partners, Hawley *et al.* (2017)).

Figure 1: Channel evolution model (adapted from Schumm et al.*, 1984)*

Methods

The $Q_{critical}$ value was informed by six sites within the Currys Fork Watershed (Figure 2, Appendix A). Data for each site consisted of a longitudinal profile, a cross section at a riffle, and a 100-particle (minimum) pebble count using a gravelometer. For simplicity and budgetary constraints, GIS contours were used for cross-section and profile data. The Ballard Court and Moody Lane sites used pebble counts collected in 2013 as part of the stream stabilization project in those locations. The additional four sites were included in the *Currys Fork Stream Restoration Projects: BMP 30, BMP 18, and BMPs 19 & 58* conceptual design effort in 2019, and pebble counts were collected for these as part of this effort.

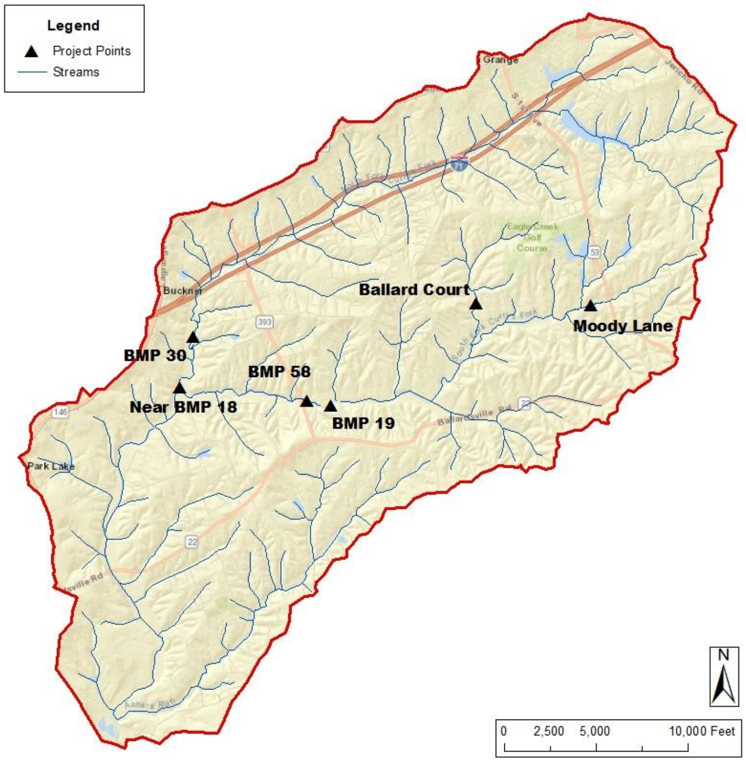


Figure 2: Currys Fork Watershed with six analysis sites identified

The watershed area for each location was determined using USGS Kentucky StreamStats software. Using the Hodgkins and Martin (2003) Region 1 equation, the 2-year undeveloped flow rate at each site was determined.

$Q_{critical}$ estimates were determined using inputs from stream geometry, streambed particle distributions, drainage areas, and representative slopes at each site according to standard methods of river mechanics (Hawley and Vietz, 2016). A range of Manning's n and critical Shields values after Hawley *et al.* (2012b) were evaluated.

Results

The six sites range in drainage area size from ~0.4 square miles to over ten square miles (imperviousness ranging from ~0.5% to ~9%). Representative stream slopes across the sites range from ~0.2% to ~1.1%. Cross-section, profile, and pebble count data for each of the six sites has been included in Appendix B.

Data from the six sites suggest that $Q_{critical}$ in representative streams typically ranges from ~40 to 50% of the undeveloped Q_2, which is consistent with the $Q_{critical}$ range from a similar study in Northern Kentucky that incorporated many more sites than this Oldham County study (e.g. Sustainable Streams, 2012, 2014, 2018). The full range of $Q_{critical}$ estimates ranged from 35 to 69% of Q_2; however, the site with the highest estimate, BMP 19, was likely skewed by the shallow bedrock. The average $Q_{critical}$ estimate for this study was 49% of Q_2 when including all six sites and 45% of Q_2 when excluding BMP 19. Both averages fall within the commonly used range of ~40-50% of Q_2 from this eco-region.

Conclusion

Our cursory analysis on $Q_{critical}$ for the Currys Fork Watershed resulted in a range of ~40 to 50% of the undeveloped Q_2. Incorporating this threshold into stormwater control design, where the 2-year design rate is released at a rate that is less than $Q_{critical}$ will throttle back the flows in the small, frequent storms that often cause excess erosion in the system. Implementation of this threshold across the watershed can improve stream stability relative to conventional stormwater management approaches. Managing stormwater in ways that facilitate geomorphic equilibrium can also improve water quality, habitat, and biotic integrity (e.g. Hawley et al., 2016, 2020).

References

Hawley R.J., Goodrich, J.A., Korth, N.L., Rust, C.J., Fet, E.V., Frye, C., MacMannis, K.R., Wooten, M.S., Jacobs, M., and Sinha, R. 2017. Detention outlet retrofit device improves the functionality of existing detention basins by reducing erosive flows in receiving channels. *Journal of the American Water Resources Association,* 53(5): 1032-1047.

Hawley R.J., MacMannis, K.R., and M.S. Wooten. 2013. Bed coarsening, riffle shortening, and channel enlargement in urbanizing watersheds, northern Kentucky, USA. Geomorphology 201: 111-126.

Hawley R.J., MacMannis, K.R., Wooten, M.S., Fet, E.V., and Korth, N.L. 2020. Suburban stream erosion rates in northern Kentucky exceed reference channels by an order of magnitude and follow predictable trajectories of channel evolution. Geomorphology, 352: 106998.

Hawley R.J. and G.J. Vietz. 2016. Addressing the urban stream disturbance regime. Freshwater Science, 35(1): 278-292.

Hawley R.J., Wooten, M.S., MacMannis, K.R., and E.V. Fet. 2016. When do macroinvertebrate communities of reference streams resemble urban streams? The biological relevance of Qcritical. Freshwater Science, 35(3): 778-794.

Hawley, R.J., Wooten, M.S., Vatter, B.C., Onderak, E., Lachniet, M .J., Schade, T., Grant, G., Groh, B., and J. DelVerne. 2012b. Integrating stormwater controls designed for channel protection, water quality, and inflow/infiltration mitigation in two pilot watersheds to restore a more natural flow regime in urban streams. Watershed Science Bulletin. 3(1), 25-37.

Hodgkins, G.A. and Martin, G.R., 2003. Estimating the Magnitude of Peak Flows for Streams in Kentucky for Selected Recurrence Intervals. Water-Resources Investigations Report 03-4180. U.S. Department of the Interior and U.S. Geological Survey; Louisville, Kentucky.

Schumm, S.A., Harvey, M.D. and Watson, C.C., 1984. Incised channels: Morphology, Dynamics, and Control. Water Resources Publications, Littleton, Colorado.

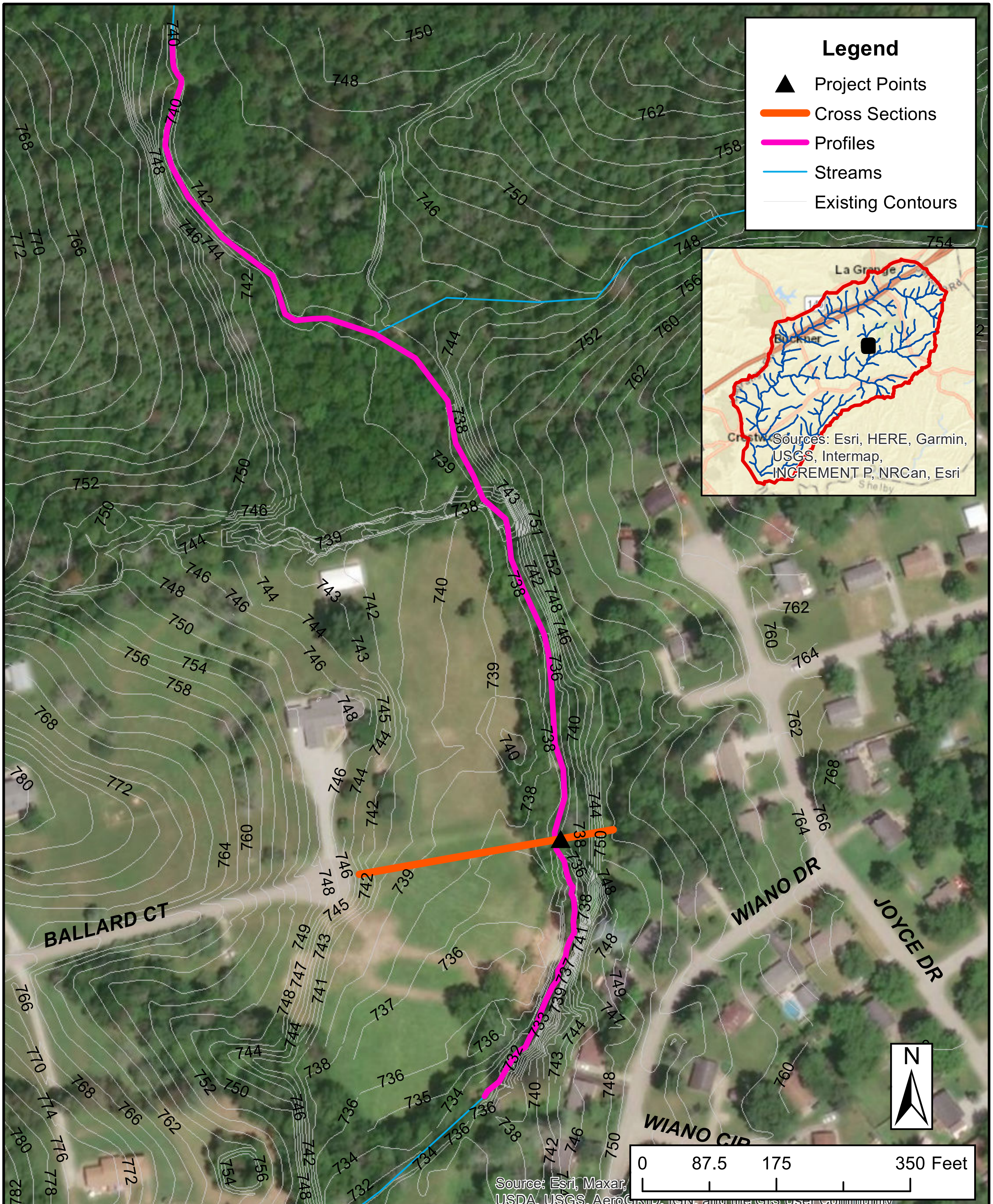
Sustainable Streams. 2012. Summary of Regional USGS Flow Gage Data in Support of $Q_{critical}$ Development for Storm Water Management, SD1 of Northern Kentucky. March 2012.

Sustainable Streams. 2014. Storm Water Management for Stream Stability in Northern Kentucky: Sediment Transport Modeling (Continuous Simulation) vs. $Q_{critical}$ Design, SD1 of Northern Kentucky. April 2014.

Sustainable Streams. 2018. Northern Kentucky $Q_{critical}$ Validation, SD1 of Northern Kentucky. June, 2018.

APPENDIX A

Site Location Maps



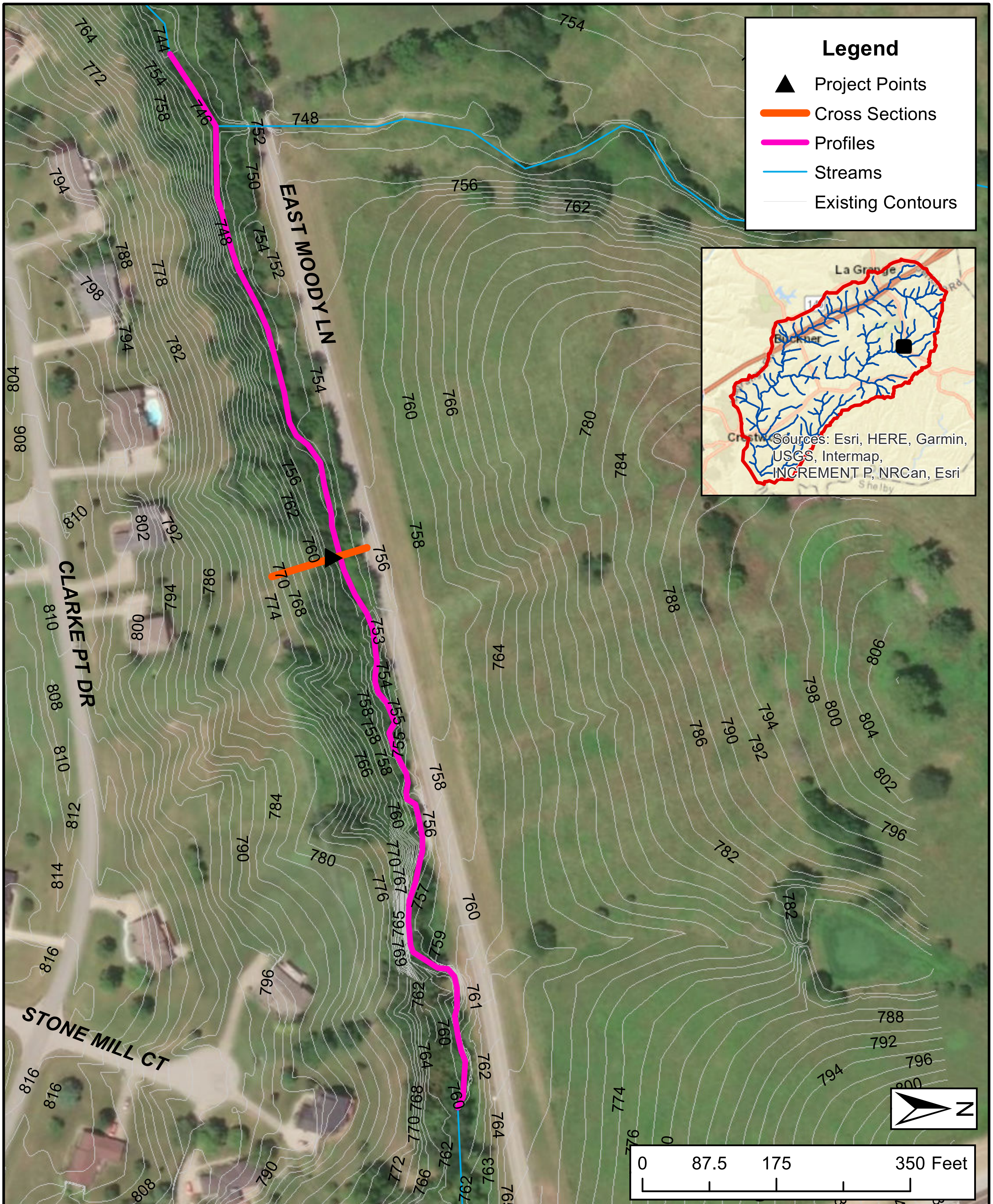
BALLARD COURT LOCATION

QCRITICAL ANALYSIS

OLDHAM COUNTY FISCAL COURT

Sustainable Streams LLC

Last Updated On: Wednesday, June 24, 2020



MOODY LANE LOCATION

QCRITICAL ANALYSIS
OLDHAM COUNTY FISCAL COURT

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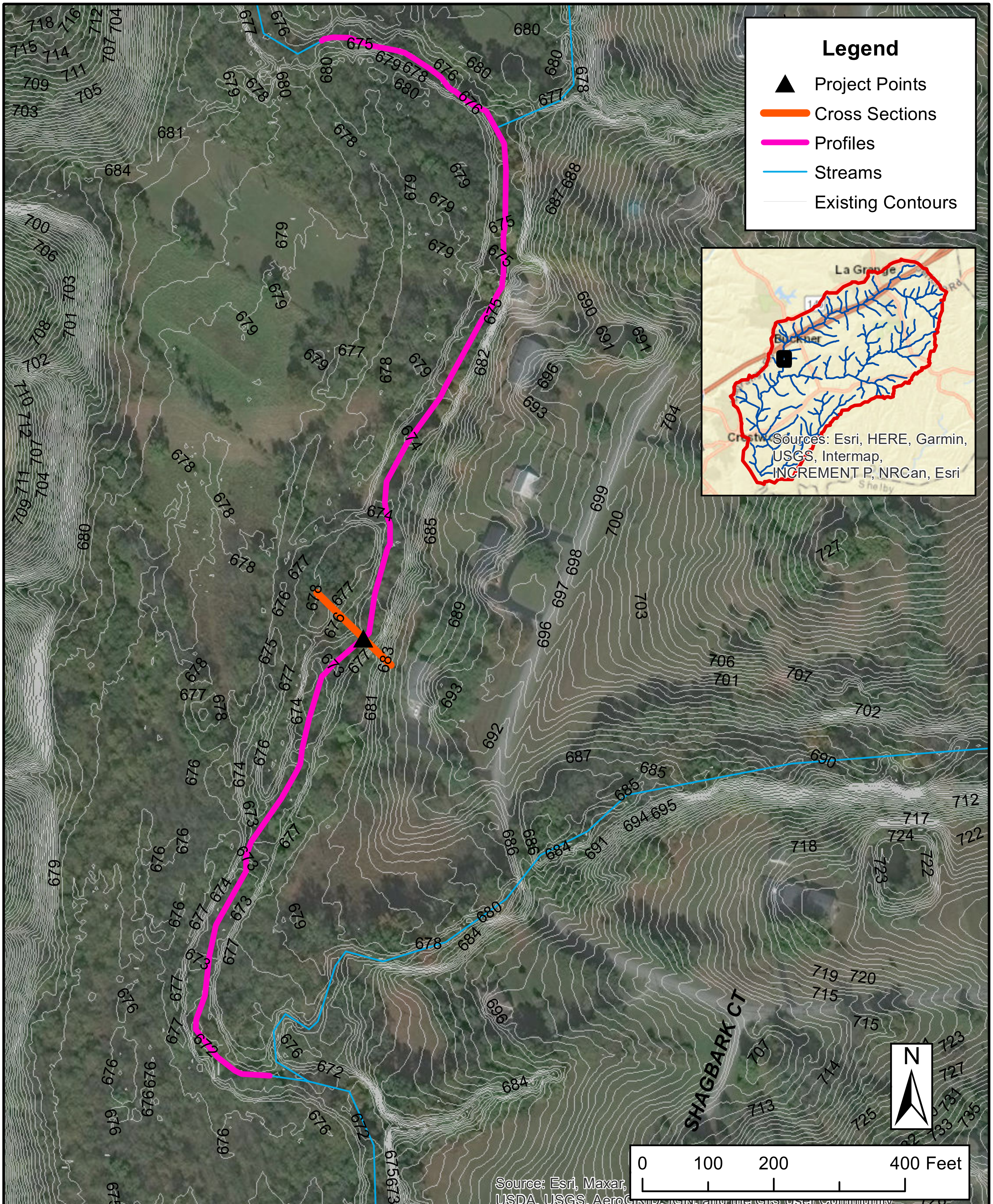

BMP 30 LOCATION

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OLDHAM COUNTY FISCAL COURT

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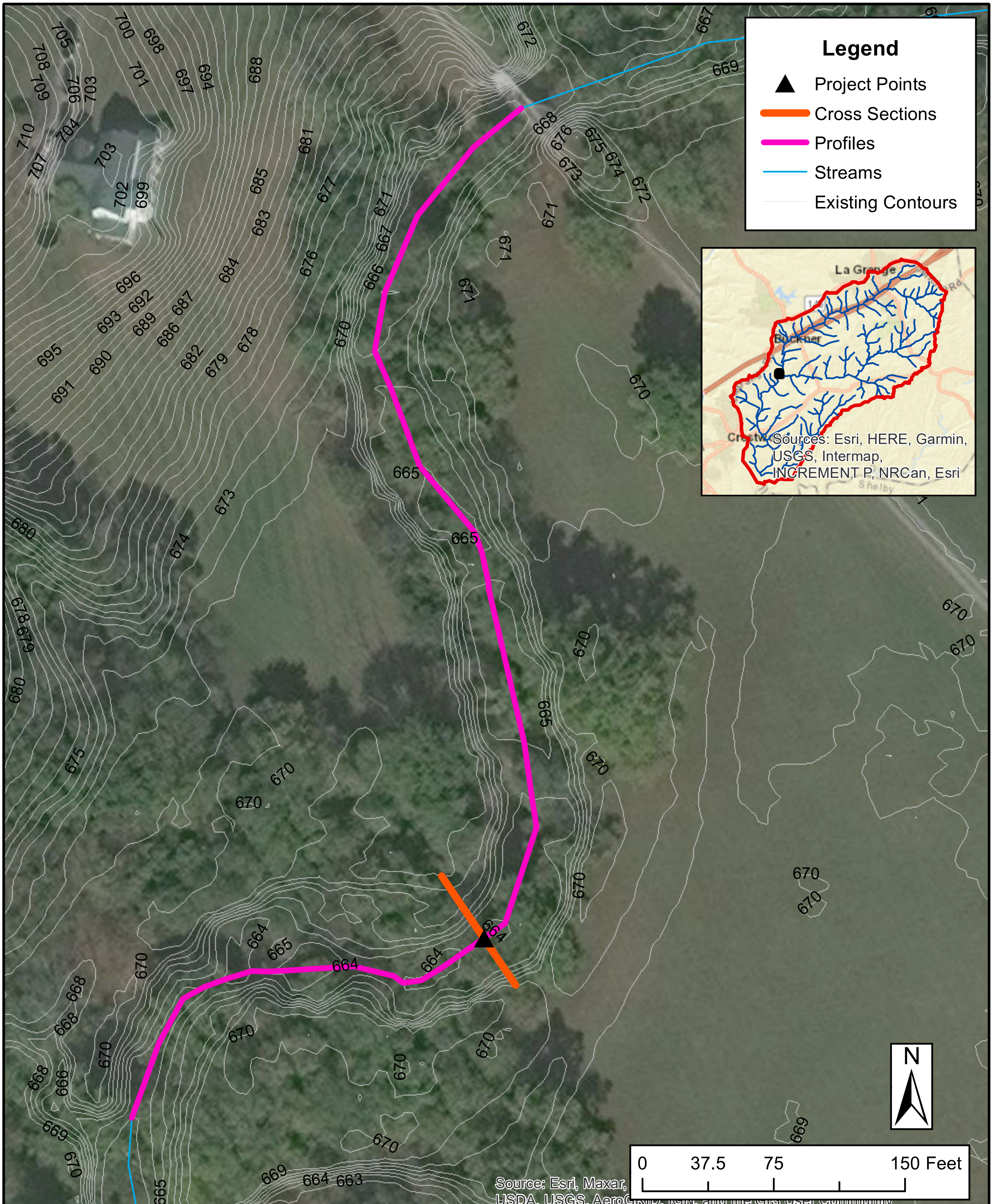

NEAR BMP 18 LOCATION

QCRITICAL ANALYSIS

OLDHAM COUNTY FISCAL COURT

Sustainable Streams LLC

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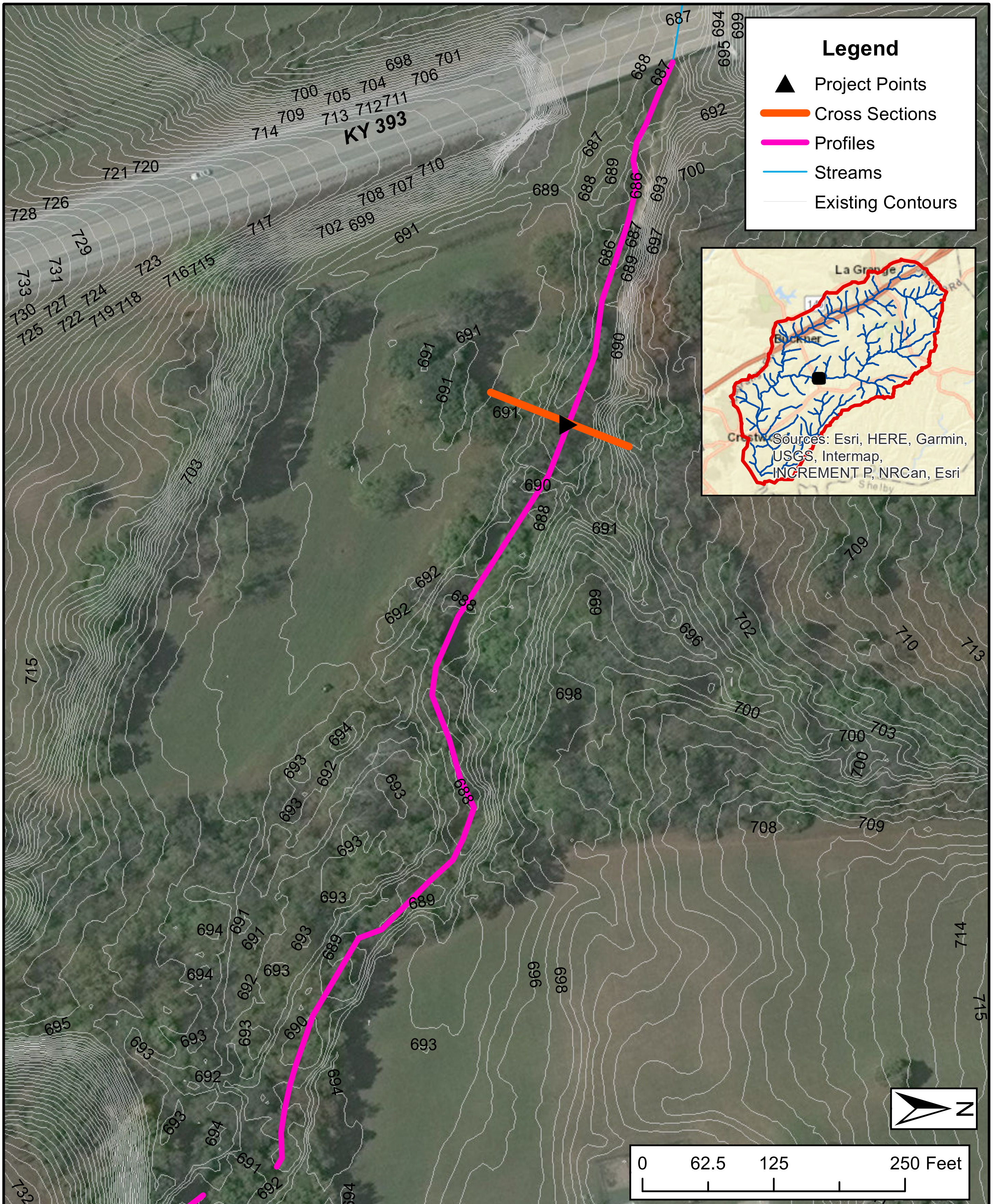

BMP 58 LOCATION

QCRITICAL ANALYSIS

OLDHAM COUNTY FISCAL COURT

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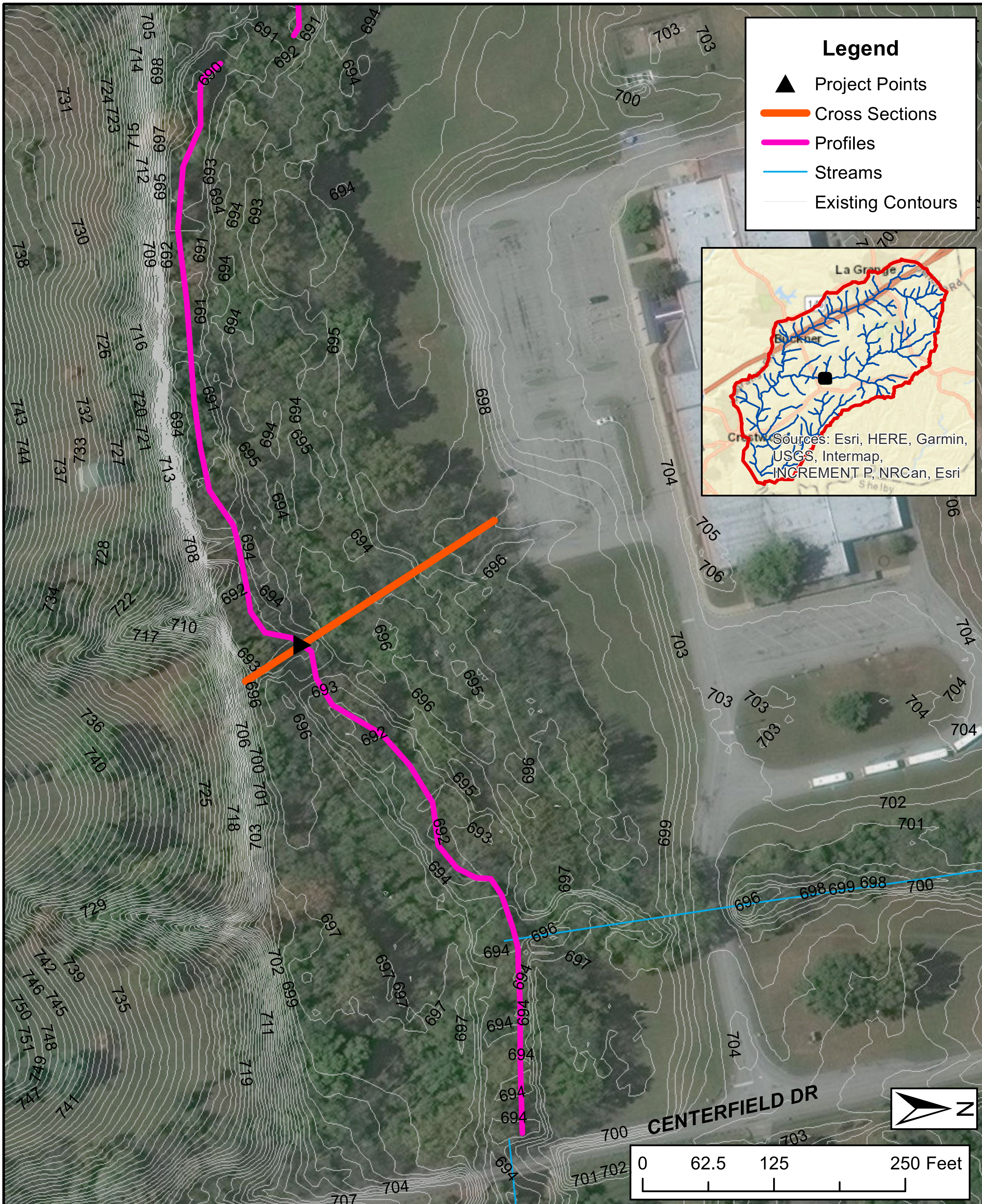

BMP 19 LOCATION

QCRITICAL ANALYSIS

OLDHAM COUNTY FISCAL COURT

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APPENDIX B

Hydrogeomorphic Data

Site: **Ballard Court**

DA: 1.01 mi^2 (per StreamStats)

Imp: 0.48% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
0.66	8.22	0.0067	29.9	62.1

Figure B1: Looking downstream at cross section location

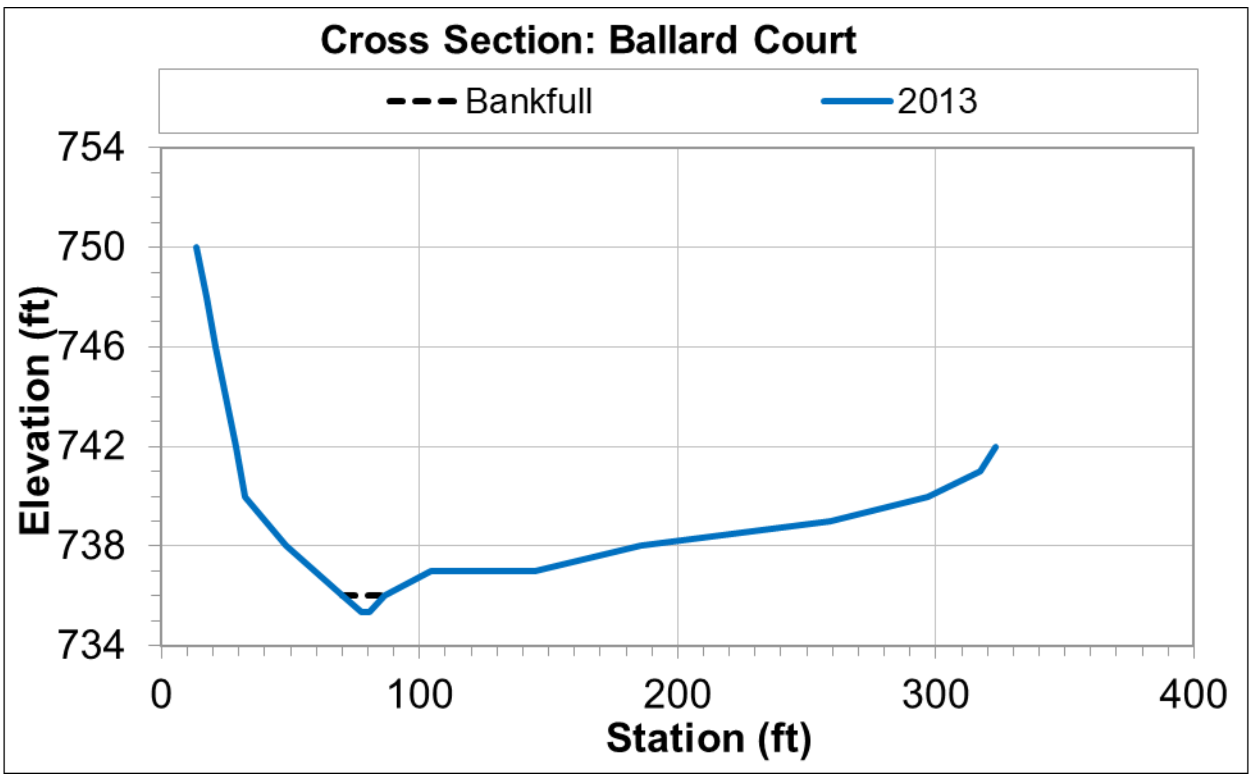

Figure B2: Cross section at site, looking downstream

Site: **Ballard Court** (continued)

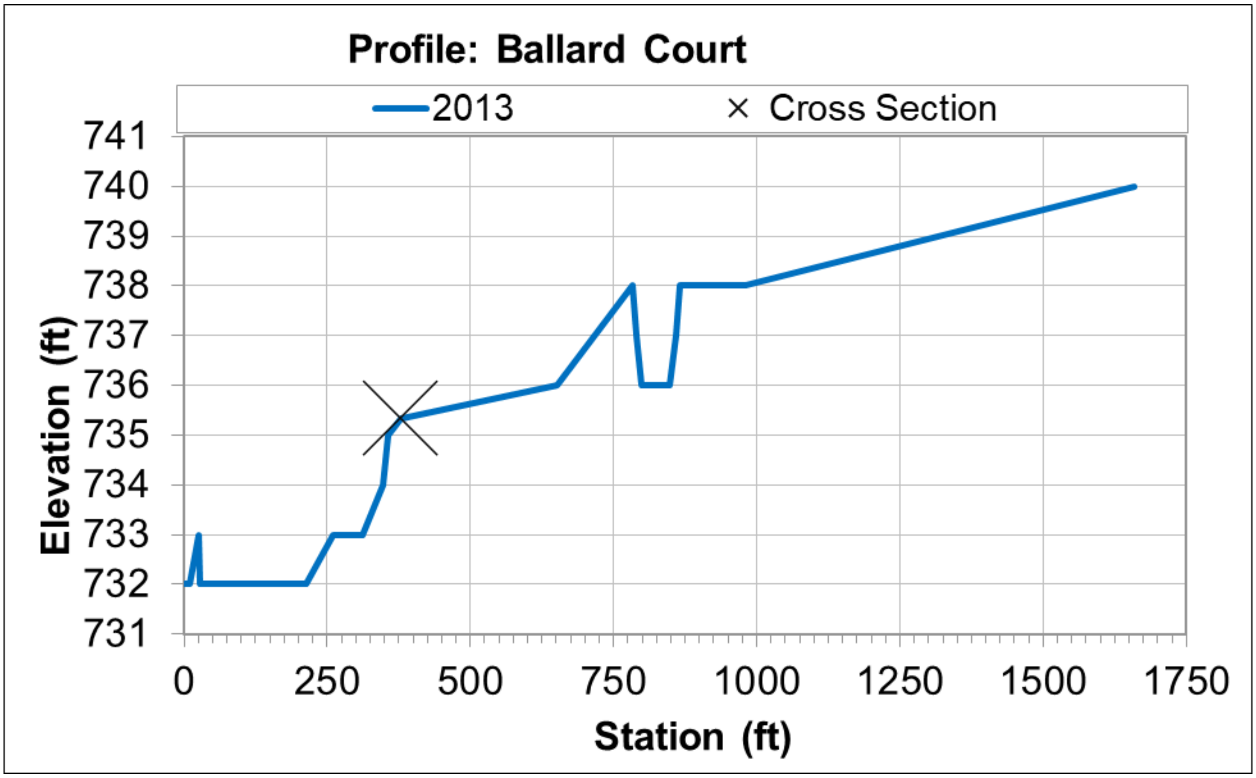

Figure B3: Profile at site

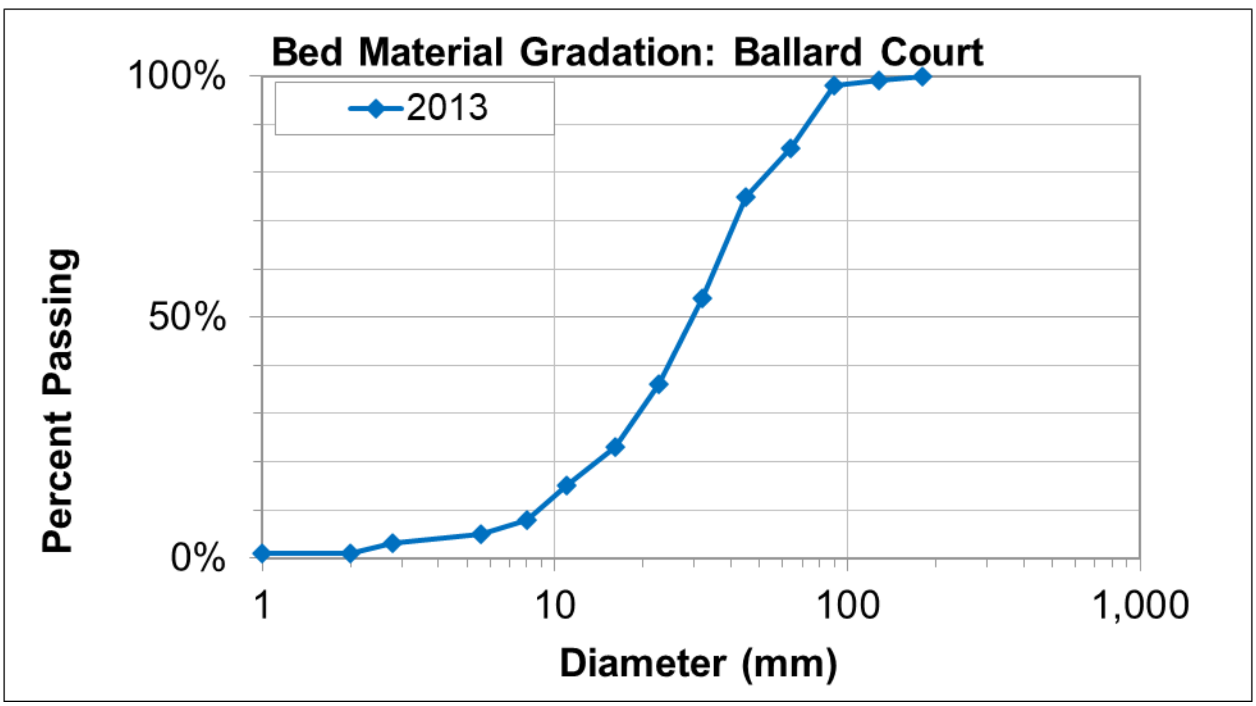

Figure B4: Bed material gradation at site

Site: **Moody Lane**

DA: 0.41 mi^2 (per StreamStats)

Imp: 1.8% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
0.55	2.55	0.0107	39.8	86.3

Figure B5: Looking upstream at cross section location

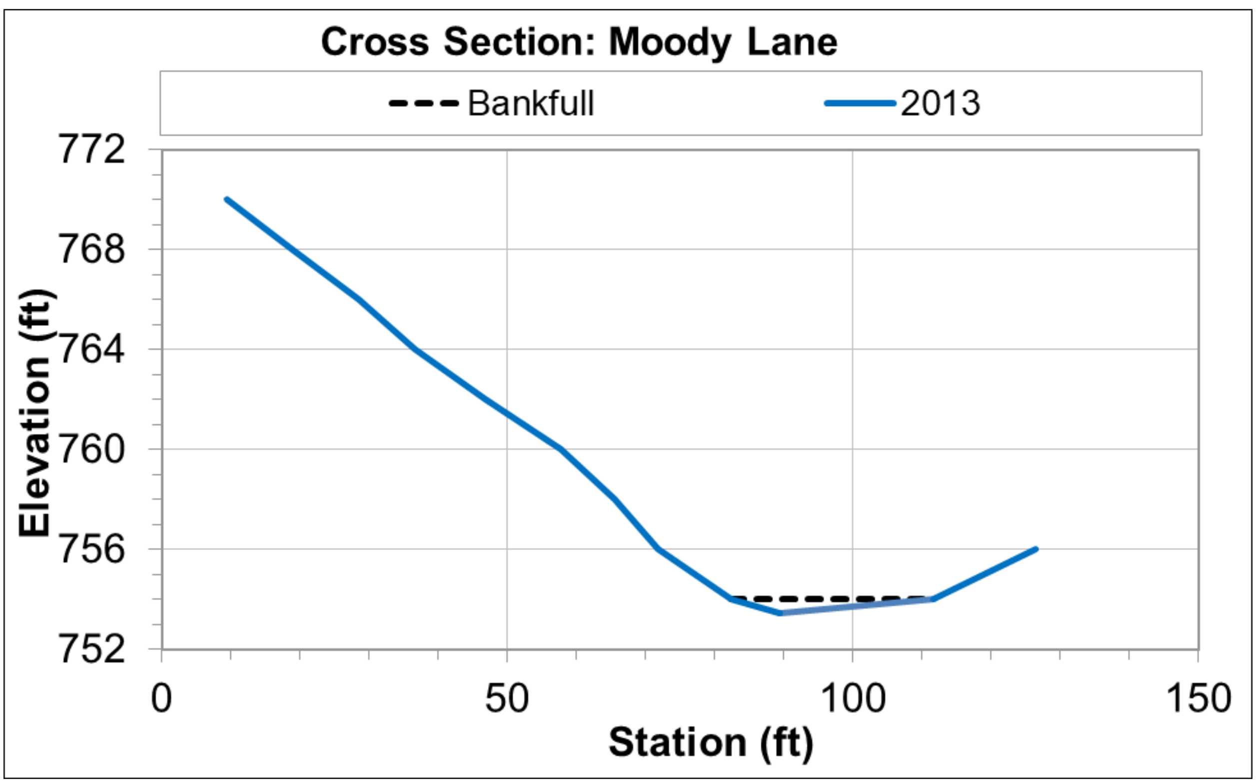

Figure B6: Cross section at site, looking downstream

Site: **Moody Lane** (continued)

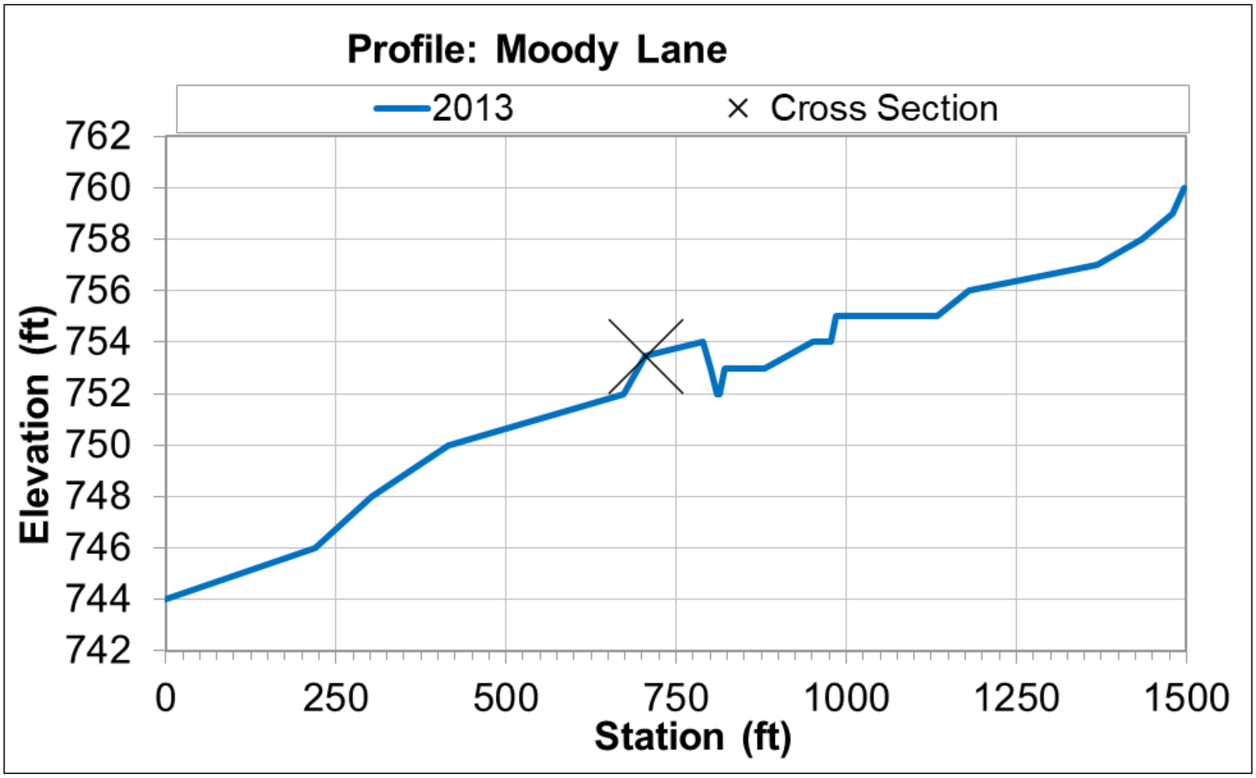

Figure B7: Profile at site

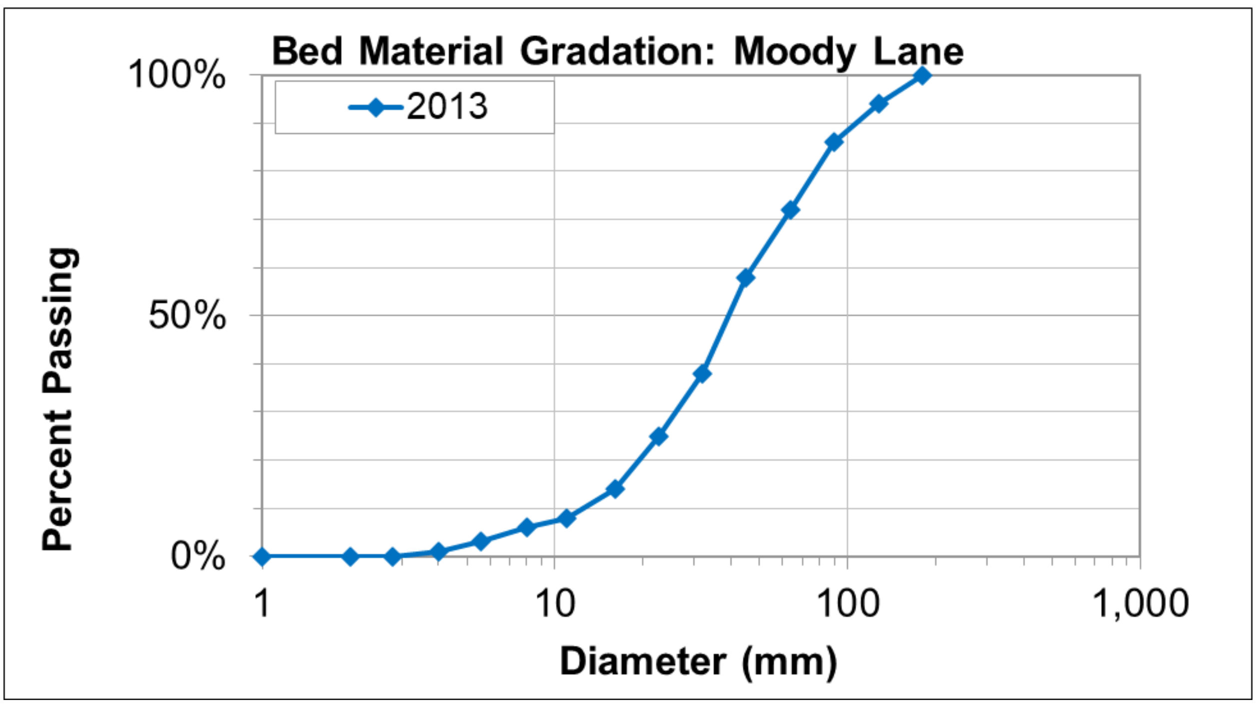

Figure B8: Bed material gradation at site

Site: **BMP 30**

DA: 9.63 mi^2 (per StreamStats)

Imp: 7.85% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
1.00	4.00	0.0024	32.0	83.5

Figure B9: Looking downstream towards cross section location

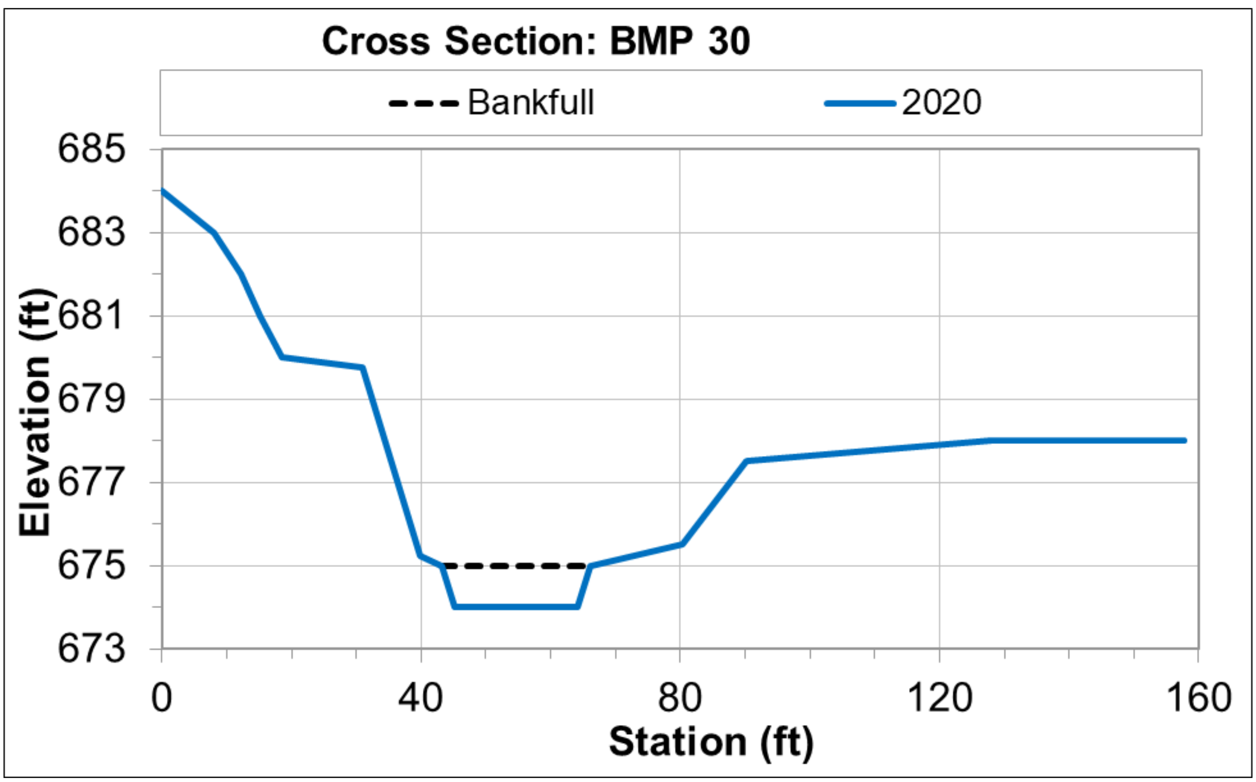

Figure B10: Cross section at site, looking downstream

Site: **BMP 30** (continued)

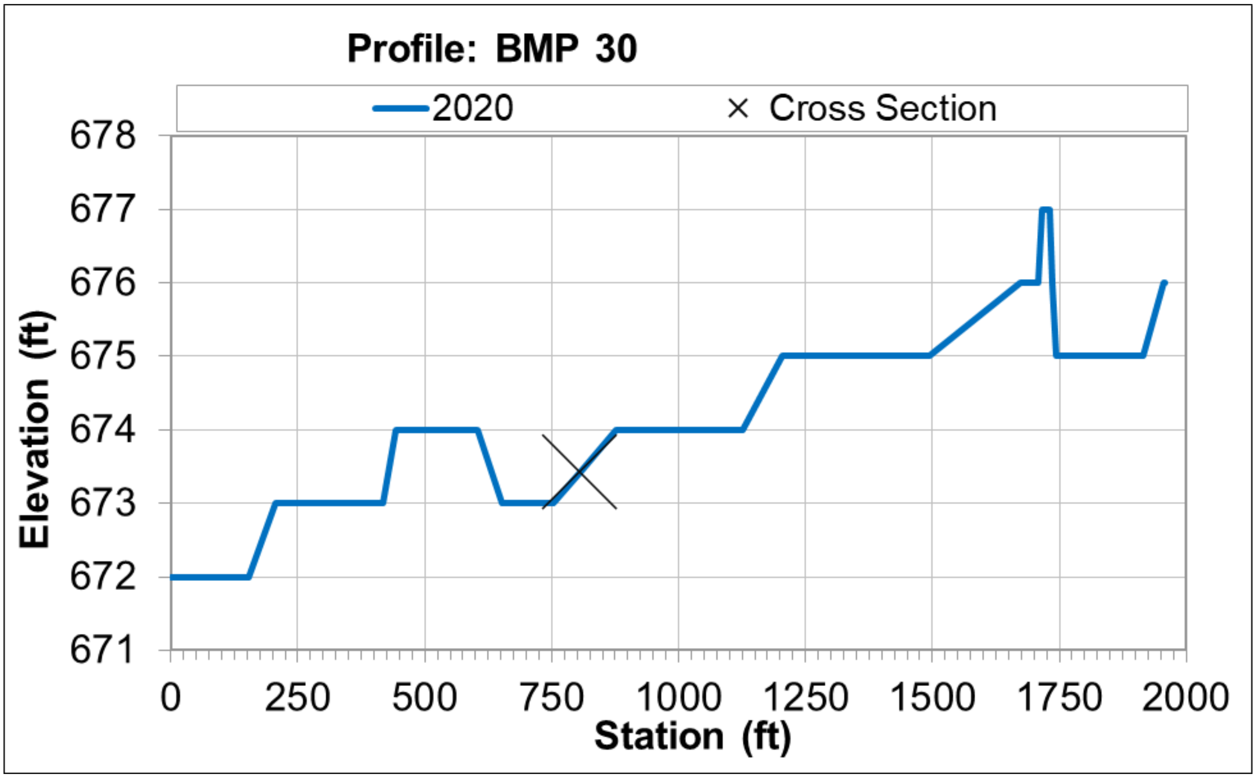

Figure B11: Profile at site

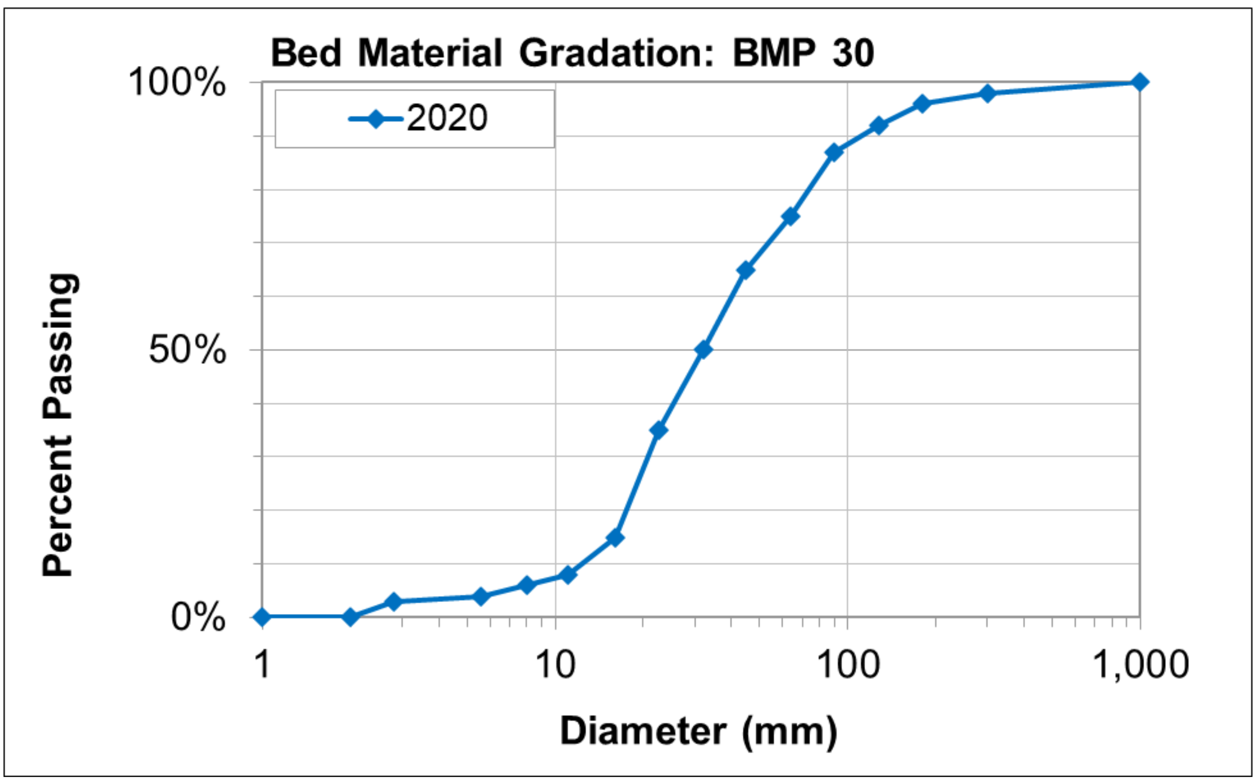

Figure B12: Bed material gradation at site

Site: **Near BMP 18**

DA: 10.10 mi^2 (per StreamStats)

Imp: 7.6% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
5.00	5.00	0.0039	52.3	114.0

Figure B13: Looking upstream at cross section location

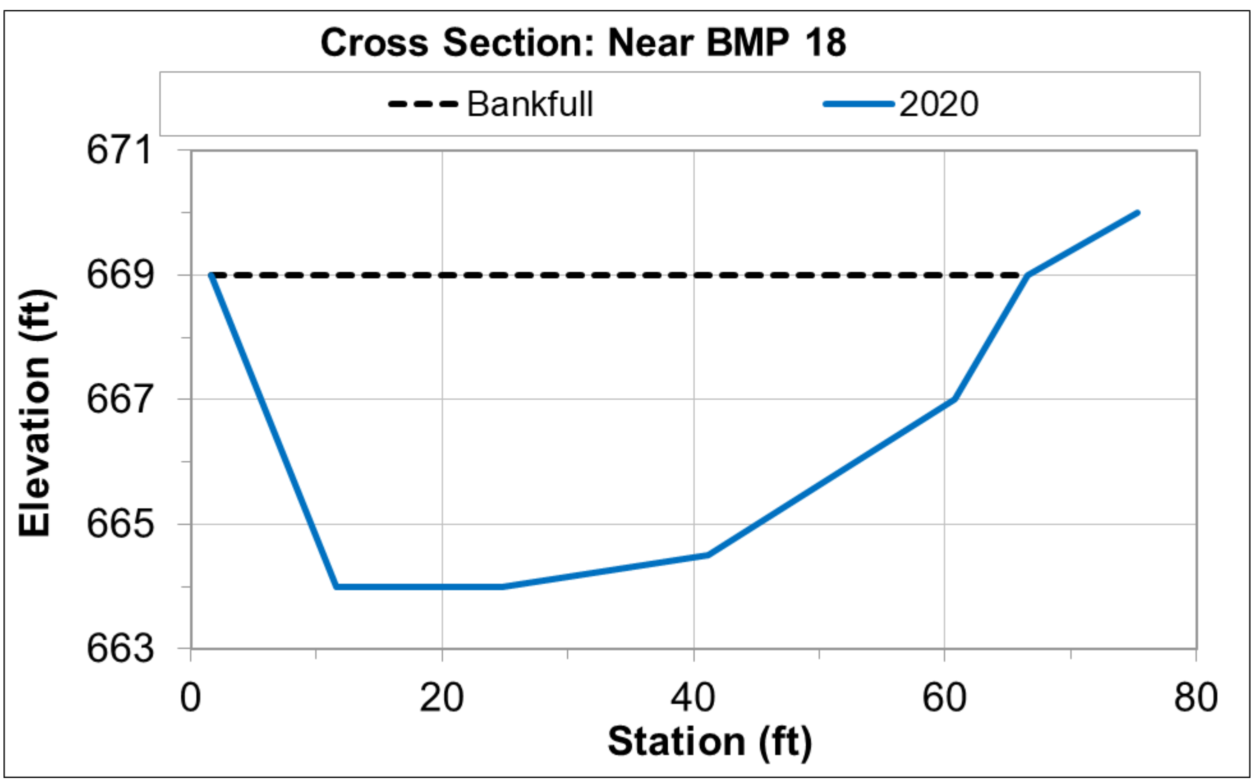

Figure B14: Cross section at site, looking downstream

Site: **Near BMP 18** (continued)

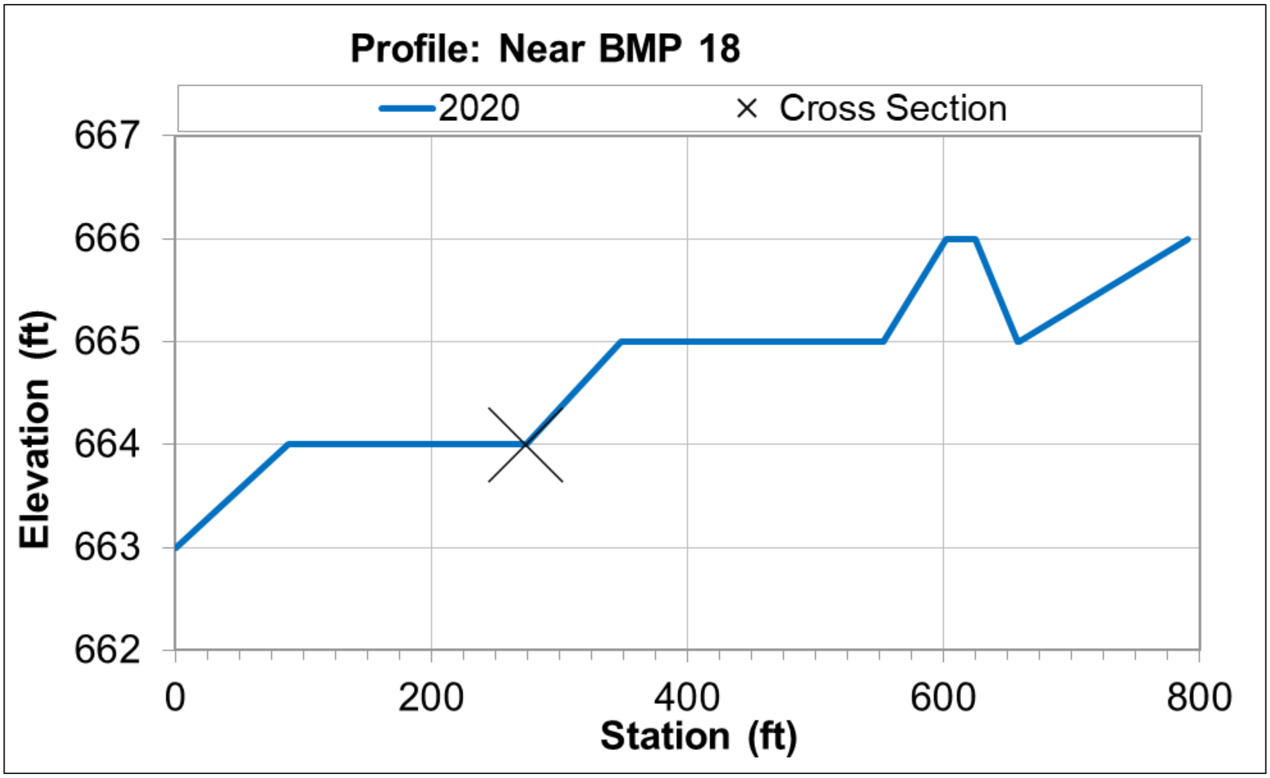

Figure B15: Profile at site

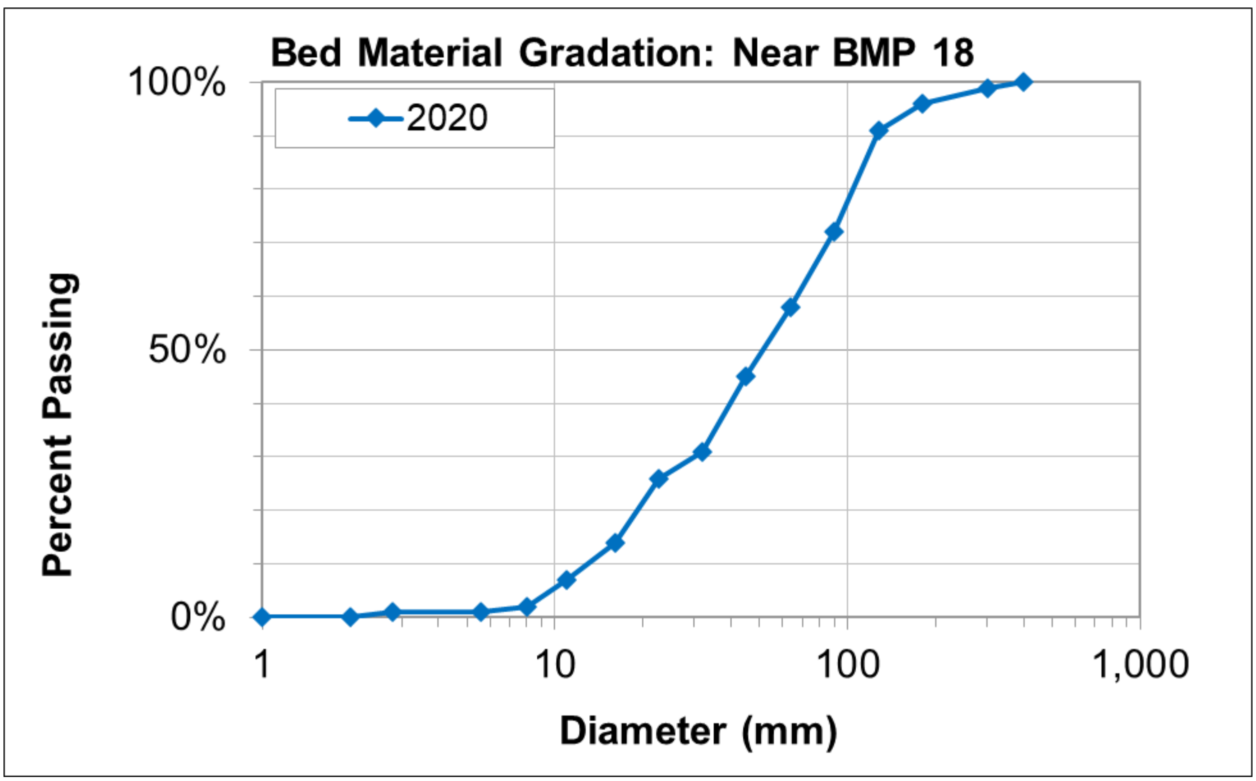

Figure B16: Bed material gradation at site

Site: **BMP 58**

DA: 7.85 mi^2 (per StreamStats)

Imp: 2.27% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
3.67	3.67	0.0022	61.8	121.1

Figure B17: Looking downstream towards cross section location

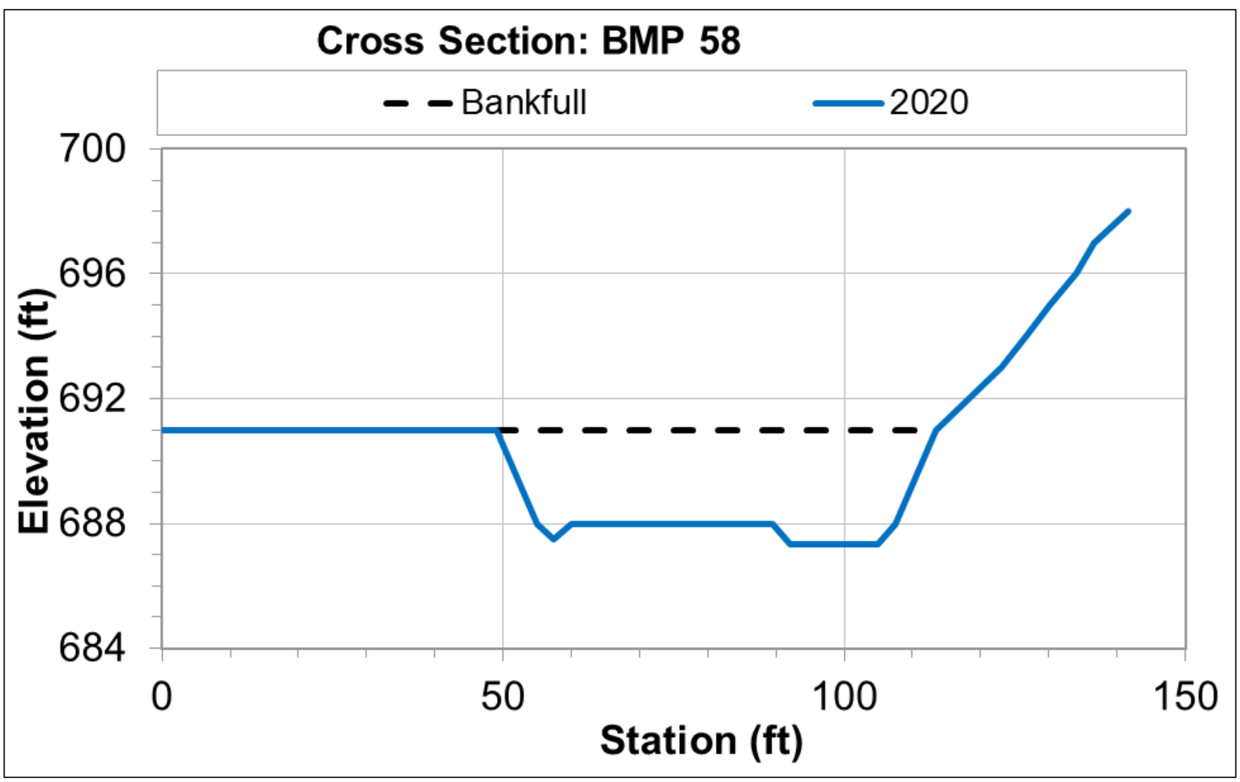

Figure B18: Cross section at site, looking downstream

Site: **BMP 58** (continued)

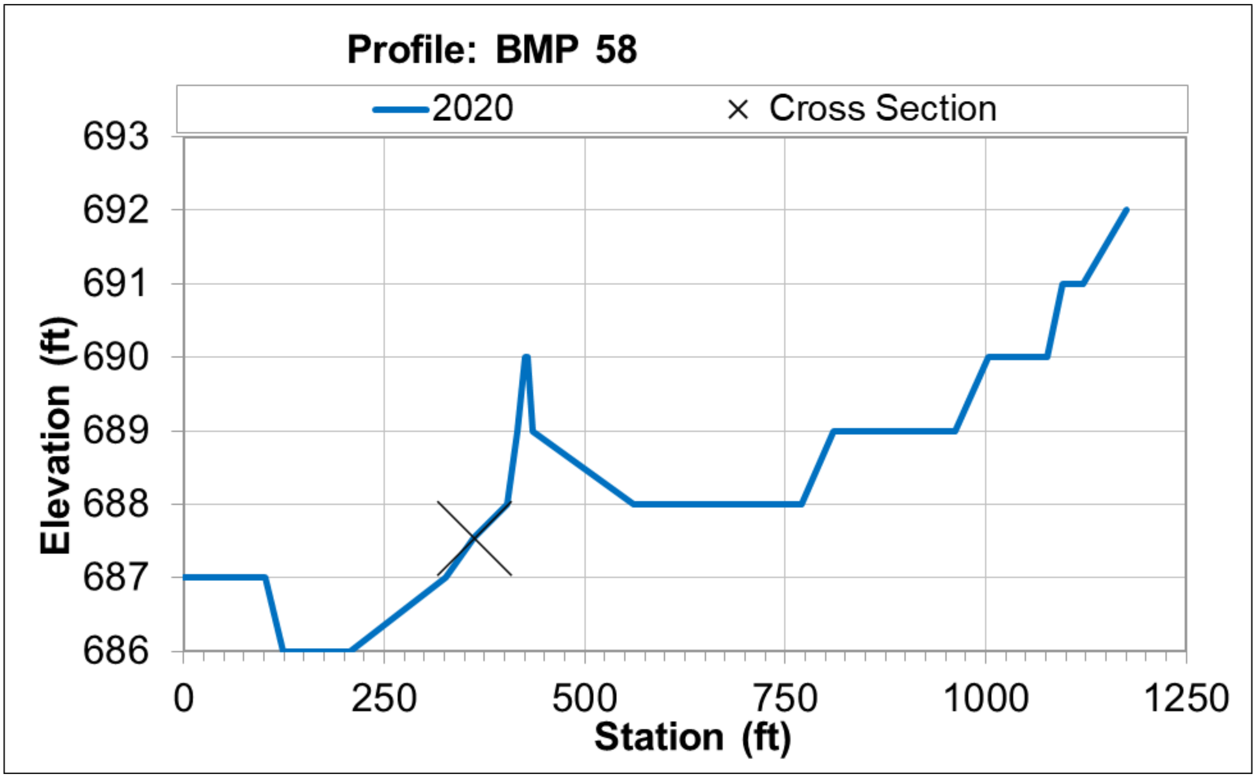

Figure B19: Profile at site

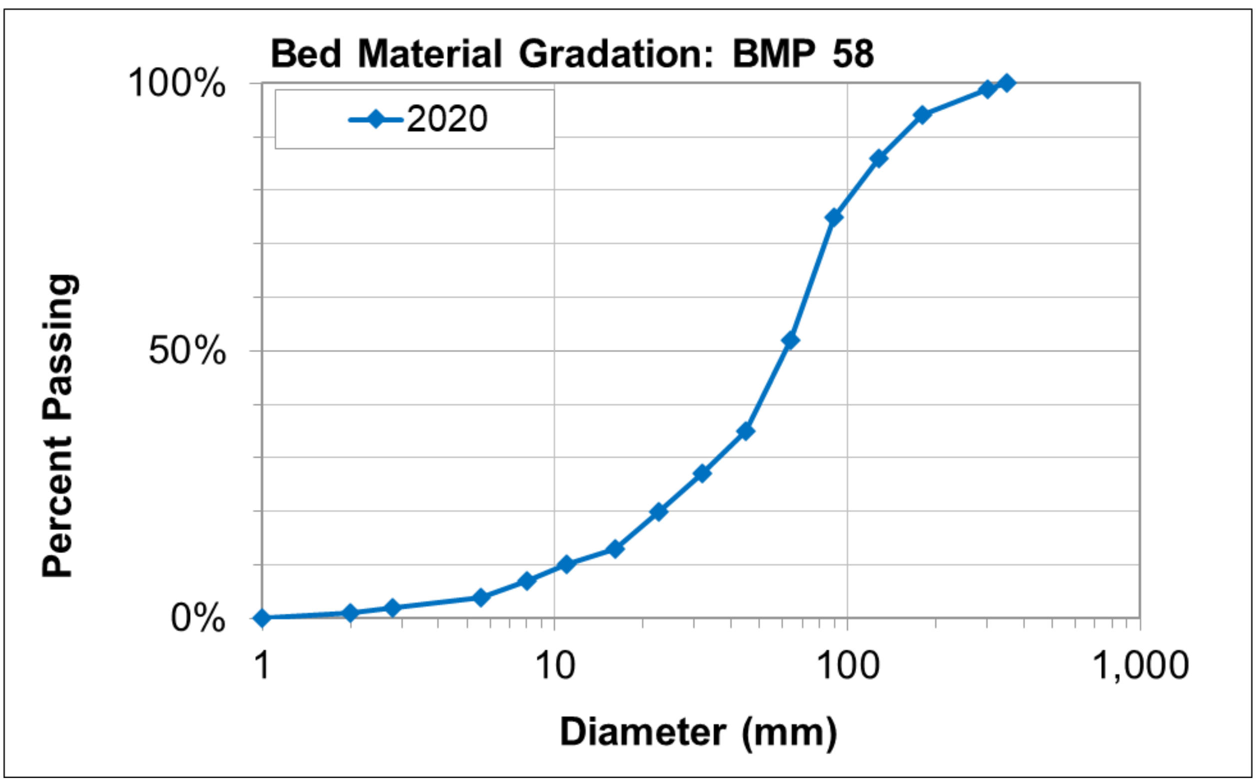

Figure B20: Bed material gradation at site

Site: **BMP 19**

DA: 7.65 mi^2 (per StreamStats)

Imp: 2.23% (approximate, based on StreamStats/NLCD 2011 impervious dataset)

Bankfull Depth (ft)	Maximum Depth (ft)	Representative $Q_{critical}$ Slope at Site (ft/ft)	d50 (mm)	d84 (mm)
1.25	4.87	0.0070	22.1	77.0

Figure B21: Looking upstream towards cross section location

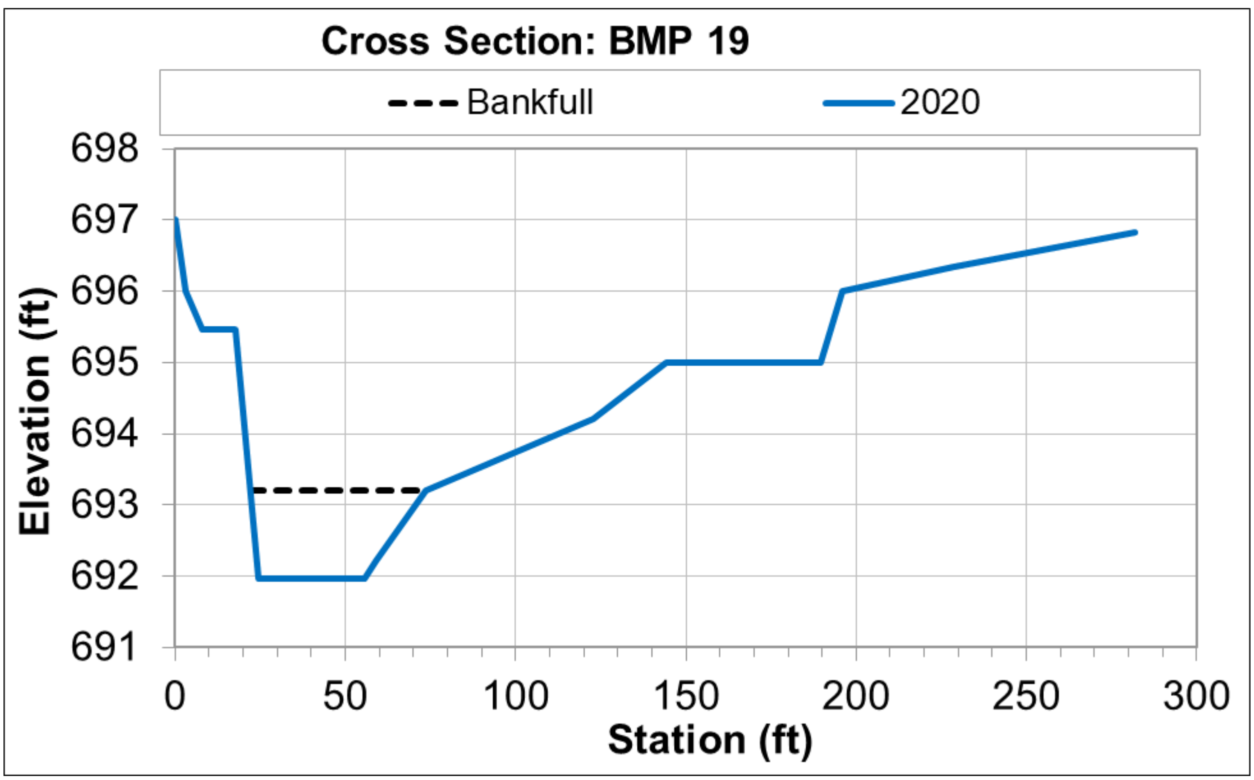

Figure B22: Cross section at site, looking downstream

Site: **BMP 19** (continued)

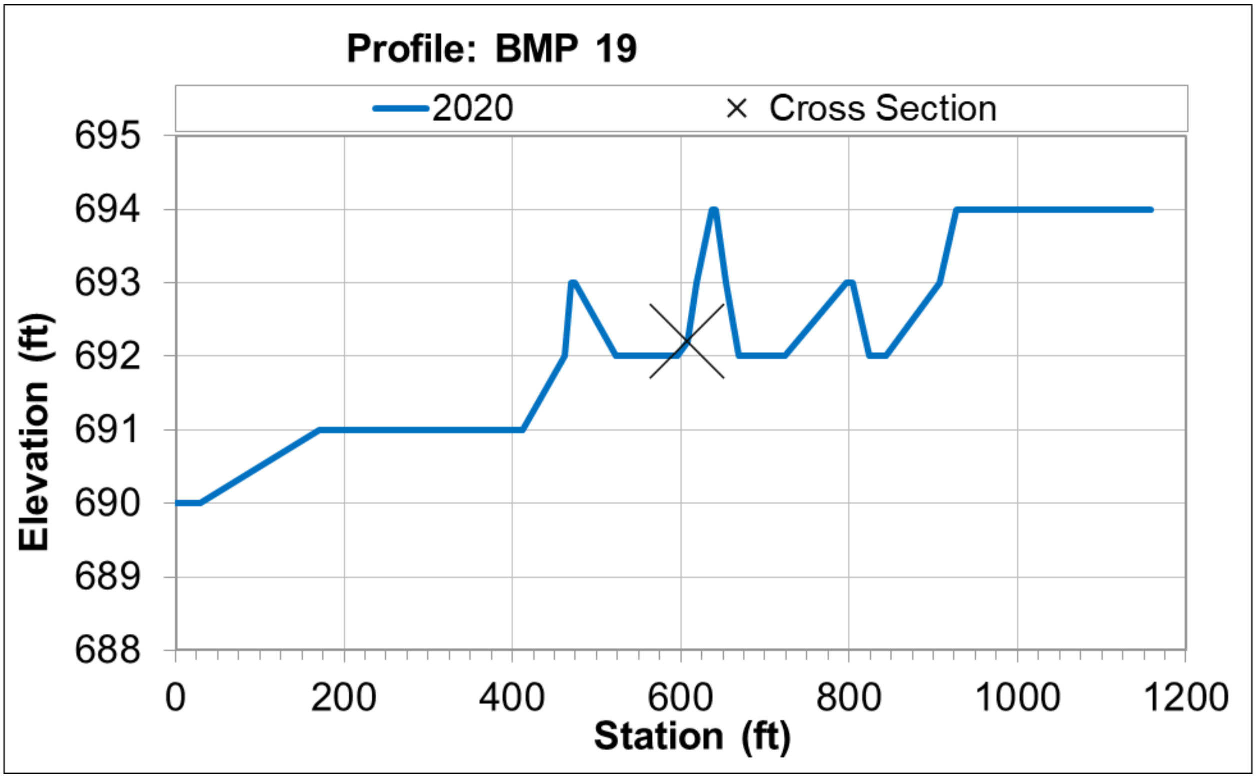

Figure B23: Profile at site

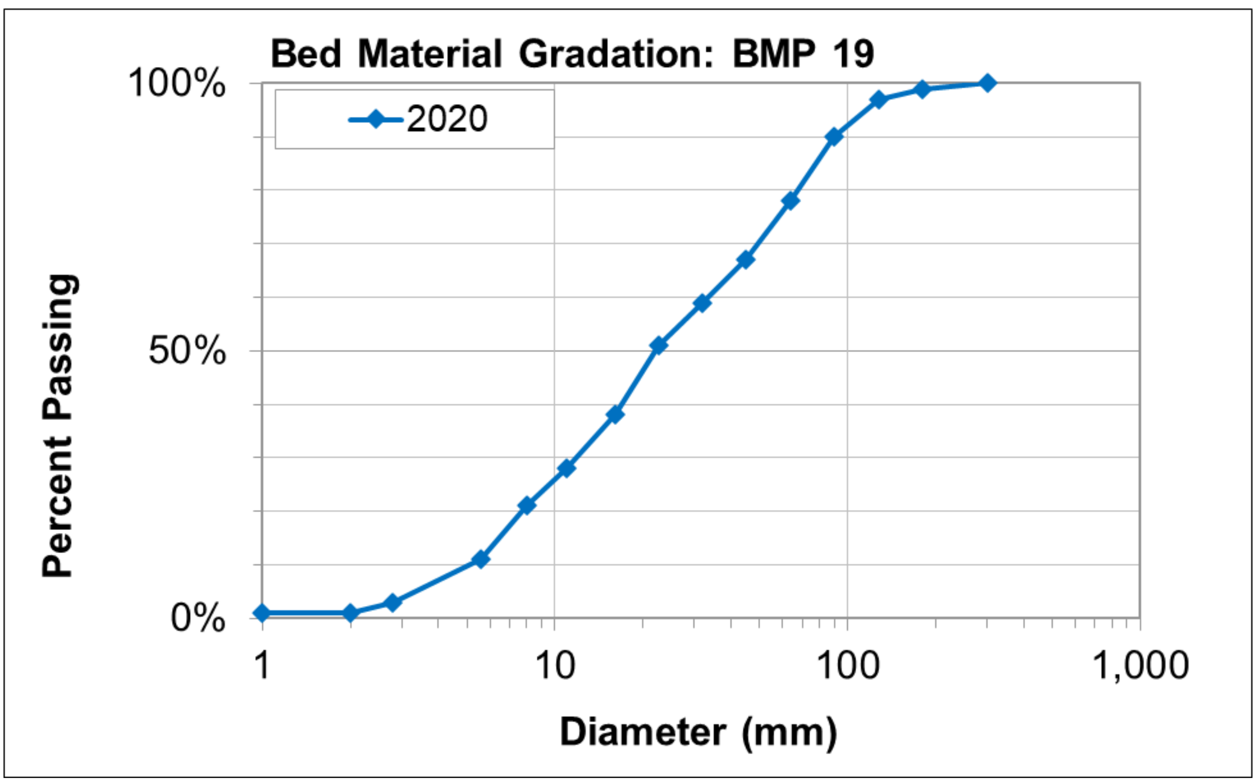

Figure B24: Bed material gradation at site