MEMORANDUM

Project: Sherwood Forest Improvement Project

To: Town of Blue River, Board of Trustees

From: Whitney Guerin, P.E./Muller Engineering Company

Date: July 7, 2023

Subject: Drainage Memorandum

INTRODUCTION

This memorandum documents a stormwater drainage evaluation associated with the Sherwood Forest Maintenance Project, located within the Sherwood Forest Subdivision of the Town of Blue River, Colorado (the Town). The maintenance project extends from south of the intersection of Sherwood Lane and Starlit Lane to a point approximately 550 feet to the north along Blue Grouse Trail. The purpose of the maintenance project is to address the poor drainage conditions that exist at the intersection of Sherwood Lane and Starlit Lane by conveying snowmelt and nuisance storm flows (minor and recurring storm runoff that is less than the 2-year event) off the road in a roadside ditch system, improving the functionality of the roadway for the neighborhood, and reducing the expense and effort required for reoccurring maintenance.

EXISTING CONDITIONS

The intersection of Sherwood Lane and Starlit Lane in the Town of Blue River currently experiences drainage issues during spring runoff and intermittently through the winter season. These issues are reported from town staff and local residents as: cross culverts freezing and not draining, standing and frozen water in roadside ditches, and flat roadway grade, which all result in recurring damage to the existing roadway.

There is an existing 12-inch plastic culvert at the intersection of Sherwood Lane and Starlit Lane. Site photos indicate that the downstream end of the culvert is damaged and does not drain properly. Further, the water in the culvert tends to freeze during the winter months, making it even less functional during the months of snowmelt.

On May 9th, 2023, Muller Engineering met onsite with town staff and residents to discuss current drainage problems which resulted in the identification of a maintenance project to be completed during the fall of 2023 to improve the condition of the intersection. The following drainage conditions were observed in the field and have been noted by the town:

- The lots north of Sherwood Lane drain to a perennial stream that continues northeast of the project area
- The east side of Starlit Lane drains either through the lots to the Blue River or toward the roadway corridor and continues around the corner and down the south side of Sherwood Lane.

- For the area to the south side of Sherwood and the west side of Starlit, runoff combines at a low point in front of Lot 60 and either flows through the existing culvert or spills over the roadway (Figures 1-4).
- Runoff generally follows the roadway corridor towards Blue Grouse Trail. Existing runoff spills across the roadway at the intersection of Blue Grouse Trail and Sherwood Lane creating a reoccurring flow path across Sherwood Lane (Figures 5-8).
- Nuisance runoff pools at a low point at Lot 101/102 along Blue Grouse Trail, which is directly adjacent to a hill down to the Blue River (Figures 9 and 10).

DRAINAGE BASINS

Drainage basins flowing toward the project area were delineated based on LiDAR survey information, a field topographic survey, and multiple field visits to understand the local drainage patterns. The topographic survey of the area inside the access easements for roadways was completed by Baseline Surveys, LLC, dated September 2nd, 2015. The topographic survey was completed several years prior to the current maintenance project and the soft surface neighborhood roads have been maintained several times since then. Due to the nature of the project being to maintain and improve the existing condition, no additional topographic data was acquired per the direction of the Town. It was assumed that slight adjustments to roadway grade were not considered impactful enough to alter the drainage patterns through the neighborhood, and therefore the survey was taken as the existing condition with some field fit adjustments anticipated during construction. Basin delineation outside of the roadway access easement was based on the most recent, publicly available LiDAR data:

- U.S. Geological Survey, 20180328, USGS Lidar Point Cloud CO Central-Western 2016 LD28441575 LAS 2018: U.S. Geological Survey.

Four on-site basins were delineated that drain toward the roadway corridor and towards the Blue River. Basin map is included in Appendix A. The following is a summary of each of the basins:

- Basin 1 collects the flows running northeast between State Highway (SH) 9 and Starlit Lane. The flows are directed to the intersection of Red Mountain Trail and Starlit Lane. There is no current drainage facility to relieve the flows from this point, so ponding occurs before the flow overtops the roadway and continues into Basin 2.
- Basin 2 collects flows between SH 9 and Starlit Lane, and flows from Basin 1. Concentrated flow begins at the north side of Red Mountain Trail and flows north to the intersection of Sherwood Lane and Starlit Lane (Design Point 2), where it then crosses under Sherwood Lane via a cross culvert and continues north. Flow is conveyed along the side of the roadway in a small, flat informal ditch which is intended to help convey stormwater.
- Basin 3 collects flows that are directed towards the roadway from the north side of Sherwood Lane at SH 9 to Blue Grouse Trail. It also collects the flow that exits Basin 2 through the cross culvert at the Sherwood and Starlit Lane intersection. The runoff flows northeast to the intersection of Sherwood Lane and Blue Grouse Trail (Design Point 3) where it then overtops the road to continue flowing northeast.
- Basin 4 collects flows along the east side of Sherwood Lane that are directed towards the roadway between Starlit Lane and Blue Grouse Trail. Flows from Basin 3 are added to Basin 4 at the intersection of Sherwood Land and Blue Grouse Trail. The flows are conveyed in an unformalized roadside ditch until they eventually flow offsite and towards Blue River (Design Point 4). Site

observations indicate that snowmelt and nuisance flows generally pond at a local depression on Lot 101/102.

Three offsite basins were also delineated in the vicinity of the project area but were not considered to contribute to the maintenance project area, and therefore named as *offsite*. Offsite Basin #1 collects flow on the east side of Starlit Lane that flow towards the road but ultimately turns and makes its way to Blue River before any major crossings. Offsite Basin #2 captures flow from the east side of SH 9 that drains towards Sherwood Lane. The flows then continue into Offsite Basin #3 via an existing cross culvert under Sherwood Lane. Offsite Basin #3 runs adjacent and to the north of Basin 3 and continues to the northeast. These flows then reach an existing culvert that crosses under Sherwood Lane and allows the water to continue to the north side of Blue Grouse Trail and away from the project area. An existing culvert that crosses underneath SH 9 conveys a perennial stream through Offsite Basin 3 and eventually through the existing culvert that exits the project area to the north of Blue Grouse Trail. The quantity of flow for this stream is unknown and was not determined with the scope of this maintenance project.

Existing drainage basins and flow patterns through the neighborhood are expected to be maintained with the maintenance project. No separate basin delineation or calculations were performed for the proposed condition due to this reason.

RUNOFF ESTIMATES

The Rational Method was used to estimate flow rates for a range of design storms. Since the Town of Blue River will be maintaining the streets and they currently have no drainage criteria, this method was selected using engineering judgement and prior experience from similar projects in the Town. Rational Method spreadsheet calculations are included in Appendix B. The NOAA atlas was consulted to determine rainfall data for Sherwood Forest, and the National Resources Conservation Service (NRCS) soil survey was used to collect soil data within the project area. Data from these sources are also found in Appendix B.

The following table summarizes the calculated flow rates at each outfall for the 2-year, 10-year, 25-year and 100-year storm events. These flow rates are considered approximate and are indicative of the potential magnitude of flows during a range of events. Runoff from snowmelt tends to create the most frequent nuisance drainage problems but was not quantified for this memo.

Basin ID	2-year flow, CFS	10-year flow, CFS	25-year flow, CFS	100-year flow, CFS
1	1.8	4.3	8.0	14.6
2	0.5	1.3	2.5	4.6
3	0.5	1.3	2.4	4.4
4	0.4	0.9	1.8	3.2

PROPOSED IMPROVEMENTS

Ditch improvements and cross culverts were not sized to carry a specific design storm; rather, facilities were designed to be no larger than necessary to convey nuisance flows, accommodate driveway and cross culverts of a size that would facilitate maintenance activities and include freeboard to allow for less frequency of maintenance operations. Based on historical input from the Town, a minimum cross culvert size of 18 inches and driveway culvert size of 12 inches was selected for maintainability throughout the Town; this tends to be the minimum pipe size for storm drainage facilities for most jurisdictions. The associated ditch section is proposed as a V shaped ditch that is 2 feet deep with 2:1 side slopes. Due to the maintenance nature of the current project, some variations of this ditch section are expected to avoid conflicts with existing features such as septic systems, leach fields, and utilities during construction.

Proposed improvements are intended to increase the capacity of the existing drainage facilities to maintain existing drainage patterns, but contain flows off of the roadway surface along Starlit Lane, Sherwood Lane, and Blue Grouse Trail. The proposed plan provides cross-culverts on Sherwood Lane to generally maintain the existing flow paths while reducing road overtopping from nuisance flows. An enlarged cross culvert is proposed at the intersection of Sherwood Lane and Starlit Lane (Design Point 2) and a new cross culvert is proposed at the intersection of Sherwood Lane and Blue Grouse Trail (Design Point 3).

The proposed culvert at Sherwood Lane and Blue Grouse Trail will outfall on the southeast side of Blue Grouse Trail, where flows continue to the northeast. Muller Engineering recommends continuing the standard ditch section described above along Blue Grouse Trail, but as directed by the Town, a formal roadside ditch is not preferred along Blue Grouse Trail and was not included in the proposed maintenance project improvements. Alternatively, as directed by the town, a flowpath from the proposed culvert to the project outfall will be provided in the construction plans and will be graded to maintain positive drainage.

At the end of the project improvements (Lot 101/102) there is a localized low point where nuisance flows collect (Figures 9-10). Adjacent to this localized low point is a large hill with flat vegetated grades at the bottom and the Blue River (Figure 11). A rock lined rundown is recommended to convey runoff down the hill while protecting the slope from erosion due to the concentrated flows from along Blue Grouse Trail. This rundown is intended to eliminate the low point where nuisance flows pond and provide stormwater conveyance to the Blue River.

Driveway culverts will not be evaluated for capacity; rather, a standard pipe size of 12 inches was selected for all driveways. The culvert at the intersection of Sherwood Lane and Starlit Lane was designed to have a 3% slope, and the culvert at the intersection of Sherwood Lane and Blue Grouse Trail was designed to have a 2% slope. The cross-culverts have been analyzed in HY-8 to evaluate culvert capacity. Culvert capacity is summarized in the table below and is shown in more detail in Appendix C.

Cross Culvert Location	Pipe Capacity (CFS)	Design Storm Conveyed
Sherwood Lane & Starlit Lane	6.3	10-year
Sherwood Lane & Blue Grouse Trail	10.9	10-year

Roadside ditch capacity was analyzed in FlowMaster using the typical ditch section and varying longitudinal slope. Ditch slope is proposed to match the existing adjacent roadway longitudinal slope. The minimum representative slope that was analyzed is 1% and the maximum slope that was analyzed is 5.5%. Based on these slopes, the ditches can convey between 36 and 86 CFS (Appendix C). This capacity is greater than the calculated 100-year design storm flow. The ditch section that was selected for this maintenance project is typical for roadside ditches through the Town and are sized for constructability associated with the installation depth of cross and driveway culverts and with the intention of allowing them to fill in with material from road grading operations and continue to function, thus reducing the frequency of maintenance required for the ditch. Culvert capacity is the limiting factor in how much water can be conveyed in a ditch at any time. During infrequent events that may reach peak flows greater than a culvert can pass, runoff will overtop roadways and driveways in sheet flow patterns that are similar to current conditions.

COMPARISON TO EXISTING CONDITIONS

Without the proposed ditch and culvert system, existing flow paths in the informal "ditches" and depressions along Starlit Lane, Sherwood Lane and Blue Grouse Trail are conveyed along the roadside and contribute to drainage issues and poor road surface quality in the project area for both the roads and adjacent properties. The proposed drainage improvements follow existing flow paths and have a capacity of approximately 6 to 11 CFS as limited by the 18-inch culverts.

SUMMARY

The drainage for the Sherwood Forest Maintenance Project has been designed to follow historic flow paths. Conveyances are generally designed to convey nuisance flows up to the capacity of the 18" culverts being installed throughout the project. The design is based on continued coordination with the Town to finalize the detailed layout of the project outfall from the public access easement to the Blue River to the east.

PHOTO LOG

Figure 1. Sherwood Lane and Starlit Lane. Looking south toward Starlit Lane.

Figure 2. Upstream side of existing cross culvert at Sherwood Lane and Starlit Lane. Looking south toward Starlit Lane.

Figure 3. Downstream side of existing cross culvert at Sherwood Lane and Starlit Lane. Looking east along Sherwood Lane.

Figure 4. Downstream side of existing cross culvert at Sherwood Lane and Starlit Lane. Poor drainage from culvert was observed.

Figure 5. Sherwood Lane. Looking west at the intersection with Sherwood Lane and Starlit Lane. Drainage along the existing roadway corridor was observed.

Figure 6. Sherwood Lane. Looking east. Drainage along the existing roadway corridor was observed.

Figure 7. Sherwood Lane. Looking east. Drainage along the existing roadway corridor was observed.

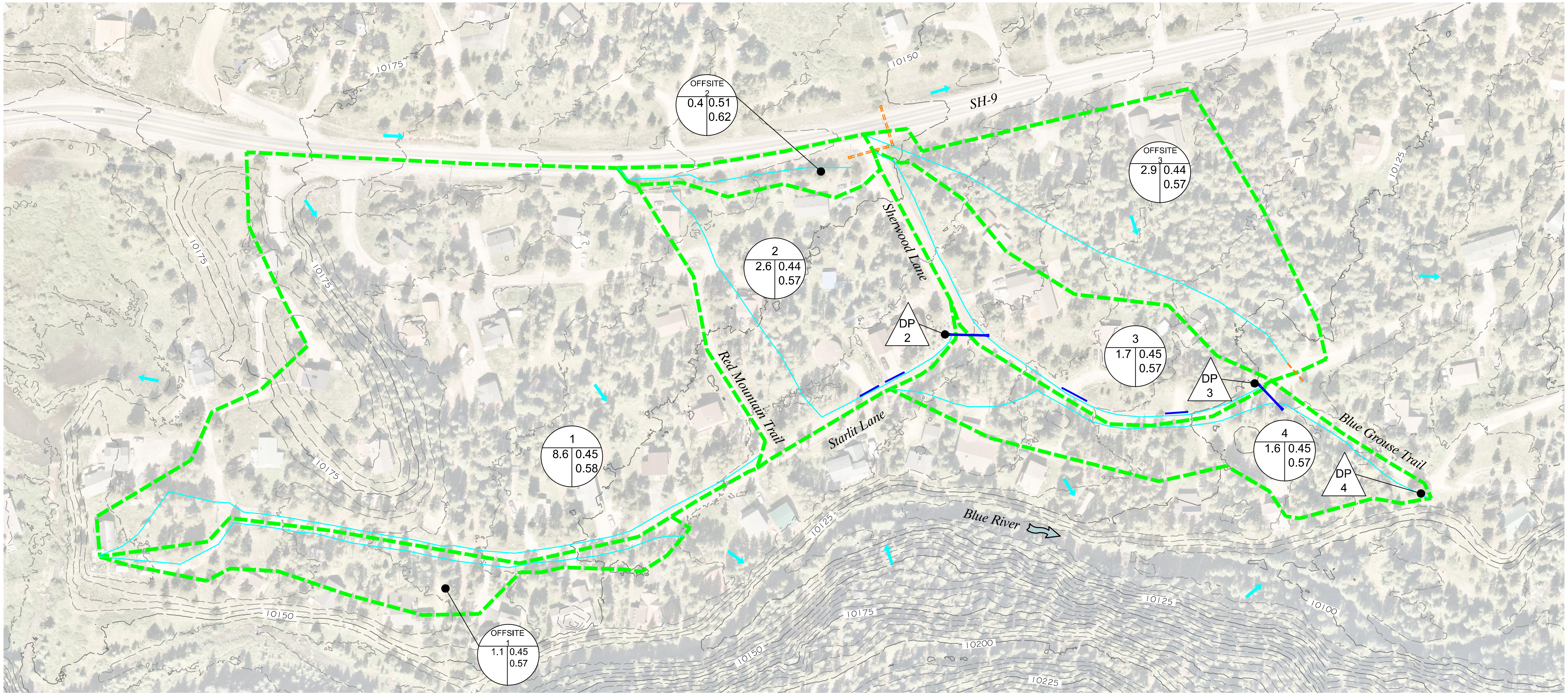
Figure 8. Intersection of Sherwood Lane and Blue Grouse Trail. Looking east down Blue Grouse Trail. Nuisance flows overtopping Sherwood Lane and continuing along Blue Grouse Trail were observed.

Figure 9. Looking west along Blue Grouse Trail. Nuisance flow ponding at lot 101/102 was observed.

Figure 10. Ponding from nuisance flows at lot 101/102 was observed .

Figure 11. Location of proposed rundown at lot 101/102 to the Blue River. Photo taken from side of road.

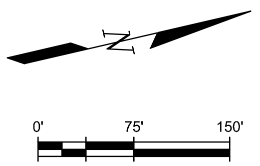
APPENDIX A:
DRAINAGE BASIN MAP



LEGEND:

ID / AREA (ac) / C25 / C100	ID = BASIN NAME AREA = AREA OF BASIN C25 = 25 YR BASIN COEFFICIENT C100 = 100 YR BASIN COEFFICIENT
△ DP #	DESIGN POINT
🟩	BASIN BOUNDARY
—	FLOW PATH
→	FLOW ARROW
=====	EXISTING CULVERT
═══	PROPOSED CULVERT

DESIGN POINT	C_{25}	C_{100}	Q_{25}	Q_{100}
DP 2	0.45	0.58	10.3	18.9
DP 3	0.45	0.57	11.9	21.8
DP 4	0.45	0.57	13.4	24.6



PLOTTED: 7/6/2023 10:24:41 AM
NAME: P:\11-008.22 SHERWOOD FOREST MAINTENANCE - TOWN OF BLUE RIVER\CADD\DRAWINGS\11-008.22_BASIN MAP.DWG

PREPARED UNDER THE SUPERVISION OF

DESIGNED: ELW
DRAWN: BTG
CHECKED: WMG

PROJECT NO. 11-008.22

SHEET REVISIONS

NO.	DATE	DESCRIPTION	BY

MULLER ENGINEERING COMPANY

TOWN OF BLUE RIVER

SHERWOOD FOREST MAINTENANCE

BASIN MAP

DATE 06/28/2023
DRAWING NO. B-1
SHEET NO. 1 OF 1

APPENDIX B:
HYDROLOGIC CALCULATIONS

RATIONAL METHOD CALCULATIONS

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

Land Use Types	Percent Impervious
STREETS: PAVED	100
STREETS: GRAVEL (PACKED)	40
RESIDENTIAL: 0.25 - 0.75 ACRES	30

Land Use Types and Imperviousness Values from USDCM Volume 1 Table 6-3

PERCENT IMPERVIOUS VALUES

STATION/ ALT ID	BASIN ID	TOTAL AREA	STREETS: PAVED		STREETS: GRAVEL (PACKED)		RESIDENTIAL: 0.25 - 0.75 ACRES		WEIGHTED PERCENT IMPERVIOUS	WEIGHTED PERCENT PERVIOUS
		(acre)	(acre)	% of Basin ^{2}	(acre)	% of Basin ^{2}	(acre)	% of Basin ^{2}		
	1	8.56	0.12	**1**	0.77	**9**	7.67	**90**	32	68
	2	2.56	0.00	**0**	0.25	**10**	2.31	**90**	31	69
	3	1.73	0.00	**0**	0.22	**13**	1.51	**87**	31	69
	4	1.63	0.00	**0**	0.24	**15**	1.39	**85**	31	69
	Offsite 1	1.10	0.00	**0**	0.17	**15**	0.93	**85**	32	68
	Offsite 2	0.40	0.06	**15**	0.02	**5**	0.32	**80**	41	59
	Offsite 3	2.88	0.00	**0**	0.02	**1**	2.86	**99**	30	70

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RUNOFF COEFFIECIENTS FOR 2, 5, 10, AND 100 YEAR STORM EVENTS

STATION/ ALT ID	BASIN ID	NRCS HYDROLOGIC SOIL GROUP[1]										C_2	C_5	C_{10}	C_{25}	C_{50}	C_{100}
		SOIL GROUP (%)[1]			SOIL GROUP B												
		A	B	C/D	C_2	C_5	C_{10}	C_{25}	C_{50}	C_{100}	%						
00+00	1		100		0.22	0.25	0.32	0.45	0.51	0.58	100	0.22	0.25	0.32	0.45	0.51	0.58
00+00	2		100		0.21	0.24	0.31	0.44	0.50	0.57	100	0.21	0.24	0.31	0.44	0.50	0.57
00+00	3		100		0.22	0.24	0.31	0.45	0.50	0.57	100	0.22	0.24	0.31	0.45	0.50	0.57
00+00	4		100		0.22	0.24	0.31	0.45	0.50	0.57	100	0.22	0.24	0.31	0.45	0.50	0.57
00+00	Offsite 1		100		0.22	0.25	0.31	0.45	0.50	0.57	100	0.22	0.25	0.31	0.45	0.50	0.57
00+00	Offsite 2		100		0.30	0.33	0.39	0.51	0.56	0.62	100	0.30	0.33	0.39	0.51	0.56	0.62
00+00	Offsite 3		100		0.21	0.23	0.30	0.44	0.50	0.57	100	0.21	0.23	0.30	0.44	0.50	0.57

Notes:

[1] Soil Group based on NRCS Soil Classification Map

[2] C Values obtained from USDCM Manual, March 2017, Chpt 6, Sec 2.5.1, Table 6-4

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STATION/ ALT ID	TIME OF CONCENTRATION																					REMARKS
	BASIN DATA				INITIAL/OVERLAND TIME (T_i)					CHANNELIZED (TRAVEL) TIME (T_t)								TOTAL t_c	T_c CHECK (Urbanized Basins)		FINAL t_c	
	BASIN ID	AREA (acre)	C_5	Basin Type	LENGTH L_i (ft)	ELEV. START (ft)	ELEV. END (ft)	OVERLAND SLOPE (S_i) (ft/ft)	t_i (min)[1]	LENGTH L_t (ft)	ELEV. START (ft)	ELEV. END (ft)	CHANNELIZED SLOPE (S_t) (ft/ft)	CONVEYANCE COEFFICIENT		Velocity V_t (ft/sec)	t_t (min)[2]	$t_i + t_t$ (min.)	First Design Point	Maximum t_c (min)[3]	$t_{minimum}$= 5 (Urban) $t_{minimum}$= 10 (Non-Urban)	
														Type	K							
00+00	1	8.56	0.25	Non-Urban	252	10172.00	10166.00	0.024	18.3	785	10166.00	10143.00	0.029	SP	7	1.2	10.9	29.2	No	N/A	29.2	
00+00	2	2.56	0.24	Non-Urban	405	10163.00	10142.00	0.052	18.1	226	10142.00	10141.00	0.004	SP	7	0.5	8.1	26.2	No	N/A	26.2	
00+00	3	1.73	0.24	Non-Urban	36	10153.00	10150.00	0.084	4.6	722	10150.00	10122.00	0.039	SP	7	1.4	8.7	13.3	No	N/A	13.3	
00+00	4	1.63	0.24	Non-Urban	220	10142.00	10133.00	0.041	14.4	597	10133.00	10113.00	0.034	SP	7	1.3	7.8	22.2	No	N/A	22.2	
00+00	Offsite 1	1.10	0.25	Urban	249	10172.00	10166.00	0.024	18.2	627	10166.00	10145.00	0.033	SP	7	1.3	8.2	26.4	No	N/A	26.4	
00+00	Offsite 2	0.40	0.33	Urban	22	10162.50	10162.00	0.023	5.0	326	10162.00	10150.50	0.035	SP	7	1.3	4.1	9.1	No	N/A	9.1	
00+00	Offsite 3	2.88	0.23	Non-Urban	378	10154.00	10136.00	0.048	18.2	325	10136.00	10121.00	0.046	SP	7	1.5	3.6	21.8	No	N/A	21.8	

Notes:

[1] $t_i = \frac{0.395(1.1 - C_5)\sqrt{L_i}}{{S_o}^{0.33}}$ USDCM Equation 6-3, August 2018

[2] $t_t = \frac{Length}{60 * V_t}$ Where $V_t = K * S^{0.5}$ and K = 2.5 (Heavy Meadows), 5 (Tillage / Field), 7 (Short Pasture / Lawns), 10 (Nearly Bare Ground), 15, (Grassed Waterway), 20 (Paved) - USDCM Equation 6-4 August 2018

[3] $t_c = (26 - 17i) + \frac{L_t}{60(14i + 9)}$ USDCM Equation 6-5 August 2018

Sherwood Forest Maintenance
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Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

Point Precipitation Frequency Estimates

Storm Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
One-Hour Point Rainfall Values (P1) (inches)	0.59	0.79	0.99	1.30	1.56	1.86

NOAA Atlas 14, Volume 8, Version 2

RATIONAL FLOWS

STATION/ ALT ID	BASIN ID	AREA (acre)	C_2	C_5	C_{10}	C_{25}	C_{50}	C_{100}	I_2 (in/hr)	I_5 (in/hr)	I_{10} (in/hr)	I_{25} (in/hr)	I_{50} (in/hr)	I_{100} (in/hr)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)	Q_{25} (cfs)	Q_{50} (cfs)	Q_{100} (cfs)
00+00	1	8.56	0.22	0.25	0.32	0.45	0.51	0.58	0.93	1.26	1.58	2.07	2.48	2.96	1.8	2.7	4.3	8.0	10.8	14.6
00+00	2	2.56	0.21	0.24	0.31	0.44	0.50	0.57	1.00	1.35	1.68	2.21	2.65	3.16	0.5	0.8	1.3	2.5	3.4	4.6
00+00	3	1.73	0.22	0.24	0.31	0.45	0.50	0.57	1.41	1.90	2.37	3.12	3.74	4.46	0.5	0.8	1.3	2.4	3.3	4.4
00+00	4	1.63	0.22	0.24	0.31	0.45	0.50	0.57	1.09	1.48	1.84	2.42	2.91	3.46	0.4	0.6	0.9	1.8	2.4	3.2
00+00	Offsite 1	1.10	0.22	0.25	0.31	0.45	0.50	0.57	0.99	1.34	1.67	2.20	2.64	3.15	0.2	0.4	0.6	1.1	1.5	2.0
00+00	Offsite 2	0.40	0.30	0.33	0.39	0.51	0.56	0.62	1.64	2.22	2.77	3.64	4.37	5.21	0.2	0.3	0.4	0.7	1.0	1.3
00+00	Offsite 3	2.88	0.21	0.23	0.30	0.44	0.50	0.57	1.10	1.49	1.86	2.44	2.93	3.50	0.7	1.0	1.6	3.1	4.2	5.7

Notes:

[1] $I = \frac{28.5 * P1}{(10 + T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where $T_d = T_c$ USDCM Chapter 6 Section 2.5 (August 2018)

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

STATION/ ALT ID	STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE) 2-YEAR STORM EVENT												
	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA (acres)	C_2	CA (acres)	T_c (min)	I_2 (in/hr)	Q (cfs)	T_c (min)	Effective CA_2	I_2 (in/hr)	Q (cfs)	
00+00		1	8.56	0.22	1.89	29.24	0.93	1.8					
00+00		2	2.56	0.21	0.55	26.22	1.00	0.5					
	DP 2								29.2	2.44	0.93	2.3	
00+00		3	1.73	0.22	0.37	13.31	1.41	0.5					
#N/A		DP 2	11.12	#N/A	2.44	29.20	0.93	2.3					
	DP 3								29.2	2.81	0.93	2.6	
00+00		4	1.63	0.22	0.35	22.16	1.09	0.4					
#N/A		DP 3	12.85	#N/A	2.81	29.20	0.93	2.6					
	DP 4								29.2	3.16	0.93	2.9	

Notes:

[1] $I = \frac{28.5 * P1}{(10 * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

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STATION/ ALT ID	STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE) 5-YEAR STORM EVENT												
	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA	C_5	CA	T_c	I_5	Q	T_c	Effective CA_5	I_5	Q	
			(acres)		(acres)	(min)	(in/hr)	(cfs)	(min)		(in/hr)	(cfs)	
#N/A		1	8.56	0.25	2.12	29.24	1.26	2.7					
#N/A		2	2.56	0.24	0.62	26.22	1.35	0.8					
	DP 2								29.2	2.74	1.26	3.5	
#N/A		3	1.73	0.24	0.42	13.31	1.90	0.8					
#N/A		DP 2	11.12	#N/A	2.74	29.20	1.26	3.5					
	DP 3								29.2	3.16	1.26	4.0	
#N/A		4	1.63	0.24	0.40	22.16	1.48	0.6					
#N/A		DP 3	12.85	#N/A	3.16	29.20	1.26	4.0					
	DP 4								29.2	3.56	1.26	4.5	

Notes:

[1] $I = \frac{28.5 * P1}{(10\ * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

STATION/ ALT ID	STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE) 10-YEAR STORM EVENT												
	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA	C_{10}	CA	T_c	I_{10}	Q	T_c	Effective CA_{10}	I_{10}	Q	
			(acres)		(acres)	(min)	(in/hr)	(cfs)	(min)		(in/hr)	(cfs)	
00+00		1	8.56	0.32	2.70	29.24	1.58	4.3					
00+00		2	2.56	0.31	0.79	26.22	1.68	1.3					
	DP 2								29.2	3.49	1.58	5.5	
00+00		3	1.73	0.31	0.54	13.31	2.37	1.3					
#N/A		DP 2	11.12	#N/A	3.49	29.20	1.58	5.5					
	DP 3								29.2	4.03	1.58	6.4	
00+00		4	1.63	0.31	0.51	22.16	1.84	0.9					
#N/A		DP 3	12.85	#N/A	4.03	29.20	1.58	6.4					
	DP 4								29.2	4.54	1.58	7.2	

Notes:

[1] $I = \frac{28.5 * P1}{(10 \ * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE)
25-YEAR STORM EVENT

STATION/ ALT ID	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA (acres)	C_{25}	CA (acres)	T_c (min)	I_{25} (in/hr)	Q (cfs)	T_c (min)	Effective CA_{25}	I_{25} (in/hr)	Q (cfs)	
00+00		1	8.56	0.45	3.85	29.24	2.07	8.0					
00+00		2	2.56	0.44	1.14	26.22	2.21	2.5					
	DP 2								29.2	4.99	2.07	10.3	
00+00		3	1.73	0.45	0.77	13.31	3.12	2.4					
#N/A		DP 2	11.12	#N/A	4.99	29.20	2.07	10.3					
	DP 3								29.2	5.76	2.07	11.9	
00+00		4	1.63	0.45	0.73	22.16	2.42	1.8					
#N/A		DP 3	12.85	#N/A	5.76	29.20	2.07	11.9					
	DP 4								29.2	6.49	2.07	13.4	

Notes:

[1] $I = \frac{28.5 * P1}{(10 * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE)
50-YEAR STORM EVENT

STATION/ ALT ID	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA (acres)	C_{50}	CA (acres)	T_c (min)	I_{50} (in/hr)	Q (cfs)	T_c (min)	Effective CA_{50}	I_{50} (in/hr)	Q (cfs)	
00+00		1	8.56	0.51	4.34	29.24	2.48	10.8					
00+00		2	2.56	0.50	1.28	26.22	2.65	3.4					
	DP 2								29.2	5.62	2.48	14.0	
00+00		3	1.73	0.50	0.87	13.31	3.74	3.3					
#N/A		DP 2	11.12	#N/A	5.62	29.20	2.48	13.9					
	DP 3								29.2	6.49	2.48	16.1	
00+00		4	1.63	0.50	0.82	22.16	2.91	2.4					
#N/A		DP 3	12.85	#N/A	6.49	29.20	2.48	16.1					
	DP 4								29.2	7.31	2.48	18.1	

Notes:

[1] $I = \frac{28.5 * P1}{(10 * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

Sherwood Forest Maintenance
Basin Calculations - Rational Method
Muller Engineering Company, Inc.
CDOT Project Number: N/A
Muller Project Number: 11-008.22

Originator ELW
Date: 6/21/2023
Checker: WMG
Date: 7/5/2023

STORM DRAINAGE SYSTEM DESIGN (RATIONAL METHOD PROCEDURE)
100-YEAR STORM EVENT

STATION/ ALT ID	DESIGN POINT	DIRECT RUNOFF FROM BASIN							TOTAL RUNOFF				DESCRIPTION
		BASIN ID	AREA (acres)	C_{100}	CA (acres)	T_c (min)	I_{100} (in/hr)	Q (cfs)	T_c (min)	Effective CA_{100}	I_{100} (in/hr)	Q (cfs)	
00+00		1	8.56	0.58	4.93	29.24	2.96	14.6					
00+00		2	2.56	0.57	1.46	26.22	3.16	4.6					
	DP 2								29.2	6.39	2.96	18.9	
00+00		3	1.73	0.57	0.99	13.31	4.46	4.4					
#N/A		DP 2	11.12	#N/A	6.39	29.20	2.96	18.9					
	DP 3								29.2	7.38	2.96	21.8	
00+00		4	1.63	0.57	0.94	22.16	3.46	3.2					
#N/A		DP 3	12.85	#N/A	7.38	29.20	2.96	21.8					
	DP 4								29.2	8.32	2.96	24.6	

Notes:

[1] $I = \frac{28.5 * P1}{(10 * T_d)^{0.786}}$ USDCM Equation 5-1, (March 2017) where P Values come from NOAA Atlas 2, Volume 8, Version 2 and Td = Tc USDCM Chapter 6 Section 2.5 (August 2018)

[2] $Q_{tot} = I_{min}\left[\sum_{i=0}^{n}(CA)_i\right]$ Where: I_{min} = Minimum Intensity and CA = Effective CA

NOAA POINT PRECIPITATION DATA

NOAA Atlas 14, Volume 8, Version 2
Location name: Breckenridge, Colorado, USA*
Latitude: 39.4203°, Longitude: -106.0425°
Elevation: 10126 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.156 (0.120-0.203)	0.197 (0.152-0.257)	0.275 (0.211-0.359)	0.348 (0.265-0.457)	0.462 (0.348-0.653)	0.561 (0.410-0.801)	0.670 (0.473-0.985)	0.789 (0.536-1.20)	0.962 (0.629-1.51)	1.10 (0.699-1.74)
10-min	0.229 (0.176-0.298)	0.289 (0.223-0.377)	0.402 (0.308-0.525)	0.509 (0.389-0.669)	0.677 (0.509-0.956)	0.822 (0.601-1.17)	0.981 (0.693-1.44)	1.16 (0.785-1.76)	1.41 (0.921-2.21)	1.62 (1.02-2.55)
15-min	0.279 (0.215-0.363)	0.353 (0.271-0.459)	0.490 (0.376-0.641)	0.621 (0.474-0.816)	0.825 (0.621-1.17)	1.00 (0.732-1.43)	1.20 (0.845-1.76)	1.41 (0.957-2.14)	1.72 (1.12-2.70)	1.97 (1.25-3.11)
30-min	0.379 (0.292-0.493)	0.477 (0.367-0.621)	0.661 (0.507-0.864)	0.836 (0.637-1.10)	1.11 (0.834-1.57)	1.35 (0.984-1.92)	1.61 (1.13-2.36)	1.89 (1.28-2.87)	2.31 (1.51-3.62)	2.65 (1.68-4.18)
60-min	0.477 (0.368-0.621)	0.587 (0.451-0.764)	0.793 (0.608-1.04)	0.989 (0.755-1.30)	1.30 (0.976-1.83)	1.56 (1.14-2.23)	1.86 (1.31-2.73)	2.18 (1.48-3.31)	2.65 (1.73-4.16)	3.04 (1.92-4.80)
2-hr	0.575 (0.448-0.740)	0.696 (0.542-0.897)	0.925 (0.717-1.20)	1.14 (0.882-1.49)	1.49 (1.13-2.07)	1.78 (1.32-2.52)	2.11 (1.51-3.07)	2.47 (1.70-3.71)	3.00 (1.98-4.64)	3.43 (2.19-5.35)
3-hr	0.645 (0.506-0.825)	0.762 (0.597-0.975)	0.985 (0.768-1.26)	1.20 (0.931-1.55)	1.54 (1.18-2.13)	1.84 (1.37-2.57)	2.16 (1.56-3.13)	2.53 (1.75-3.77)	3.06 (2.03-4.72)	3.50 (2.25-5.43)
6-hr	0.794 (0.629-1.00)	0.917 (0.726-1.16)	1.15 (0.908-1.46)	1.38 (1.08-1.76)	1.73 (1.34-2.36)	2.04 (1.53-2.82)	2.38 (1.72-3.38)	2.75 (1.92-4.05)	3.30 (2.21-5.02)	3.75 (2.44-5.75)
12-hr	0.999 (0.800-1.25)	1.15 (0.917-1.43)	1.42 (1.13-1.78)	1.68 (1.34-2.12)	2.09 (1.63-2.81)	2.44 (1.85-3.33)	2.83 (2.07-3.97)	3.25 (2.29-4.73)	3.86 (2.62-5.81)	4.37 (2.87-6.63)
24-hr	1.25 (1.02-1.55)	1.43 (1.16-1.77)	1.76 (1.42-2.19)	2.08 (1.66-2.59)	2.55 (2.01-3.38)	2.96 (2.27-3.98)	3.41 (2.53-4.73)	3.90 (2.77-5.60)	4.60 (3.15-6.83)	5.18 (3.44-7.77)
2-day	1.56 (1.28-1.90)	1.78 (1.46-2.17)	2.17 (1.77-2.66)	2.54 (2.06-3.12)	3.09 (2.45-4.03)	3.56 (2.75-4.71)	4.06 (3.04-5.56)	4.61 (3.31-6.53)	5.40 (3.73-7.91)	6.04 (4.05-8.96)
3-day	1.78 (1.47-2.15)	2.03 (1.68-2.47)	2.49 (2.04-3.03)	2.90 (2.37-3.55)	3.52 (2.80-4.54)	4.03 (3.14-5.29)	4.58 (3.44-6.21)	5.17 (3.74-7.26)	6.01 (4.18-8.74)	6.69 (4.52-9.86)
4-day	1.97 (1.64-2.38)	2.26 (1.87-2.72)	2.75 (2.27-3.33)	3.20 (2.62-3.89)	3.86 (3.09-4.95)	4.40 (3.44-5.74)	4.98 (3.76-6.71)	5.60 (4.06-7.82)	6.47 (4.52-9.36)	7.17 (4.87-10.5)
7-day	2.48 (2.08-2.96)	2.81 (2.35-3.35)	3.37 (2.81-4.04)	3.86 (3.20-4.66)	4.59 (3.70-5.81)	5.18 (4.08-6.68)	5.80 (4.42-7.72)	6.47 (4.73-8.92)	7.39 (5.20-10.6)	8.12 (5.56-11.8)
10-day	2.91 (2.45-3.45)	3.26 (2.74-3.87)	3.87 (3.24-4.61)	4.40 (3.67-5.27)	5.18 (4.20-6.50)	5.81 (4.60-7.43)	6.47 (4.96-8.55)	7.17 (5.27-9.82)	8.14 (5.76-11.6)	8.92 (6.14-12.9)
20-day	4.04 (3.45-4.74)	4.49 (3.83-5.27)	5.26 (4.46-6.19)	5.93 (5.00-7.01)	6.88 (5.64-8.52)	7.66 (6.13-9.65)	8.46 (6.55-11.0)	9.30 (6.91-12.6)	10.5 (7.48-14.7)	11.4 (7.91-16.2)
30-day	5.00 (4.29-5.81)	5.56 (4.77-6.47)	6.50 (5.55-7.59)	7.30 (6.20-8.57)	8.42 (6.94-10.3)	9.32 (7.50-11.6)	10.2 (7.96-13.2)	11.2 (8.35-15.0)	12.5 (8.96-17.3)	13.5 (9.42-19.1)
45-day	6.25 (5.40-7.22)	6.99 (6.03-8.07)	8.18 (7.04-9.48)	9.17 (7.84-10.7)	10.5 (8.70-12.7)	11.6 (9.36-14.3)	12.6 (9.86-16.1)	13.6 (10.2-18.1)	15.0 (10.9-20.7)	16.1 (11.3-22.6)
60-day	7.36 (6.40-8.45)	8.26 (7.17-9.49)	9.70 (8.39-11.2)	10.9 (9.34-12.6)	12.4 (10.3-14.9)	13.6 (11.0-16.6)	14.7 (11.5-18.6)	15.8 (11.9-20.8)	17.2 (12.5-23.5)	18.2 (12.9-25.6)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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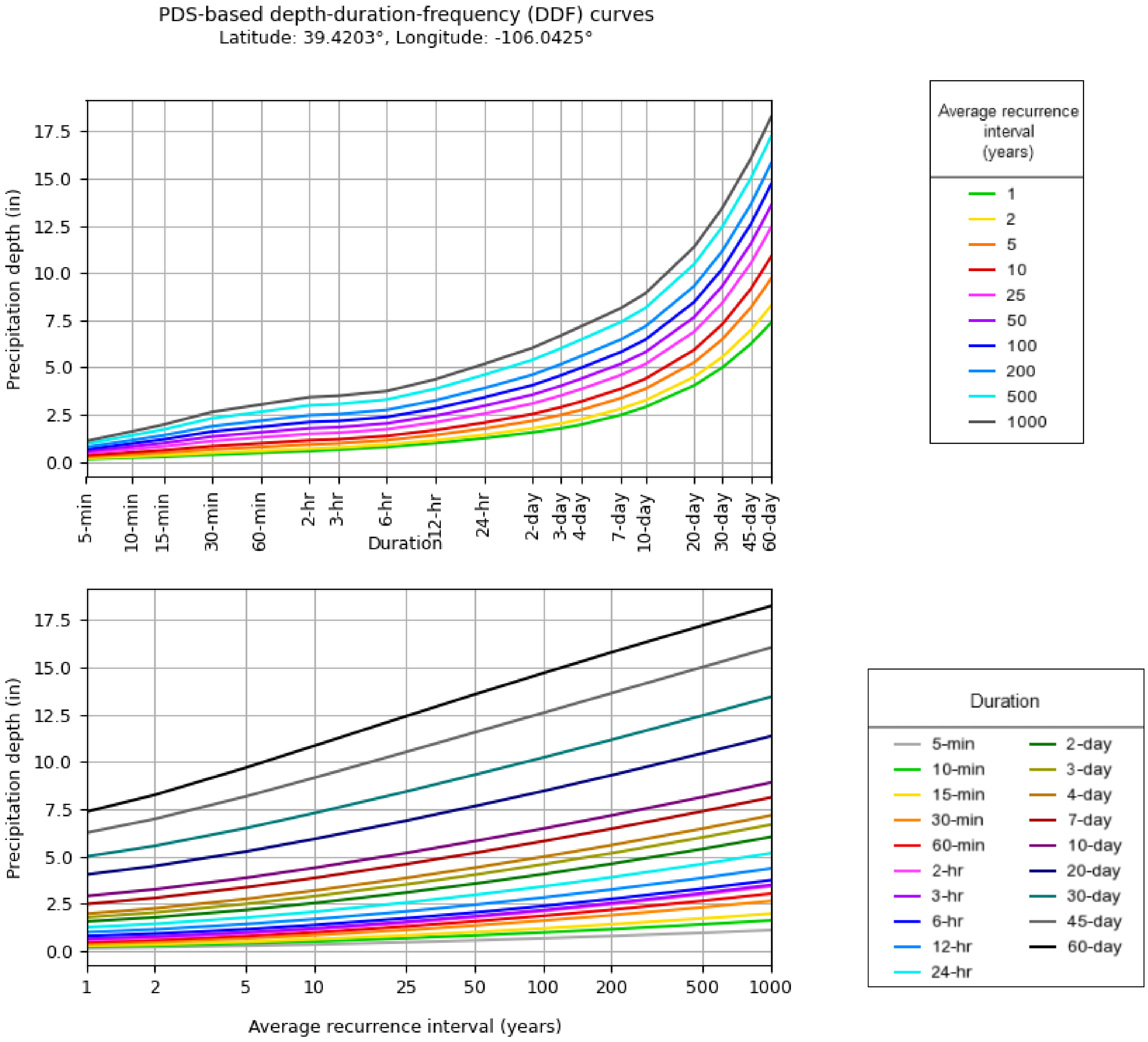
PF graphical



NOAA Atlas 14, Volume 8, Version 2

Created (GMT): Wed Jun 21 17:42:02 2023

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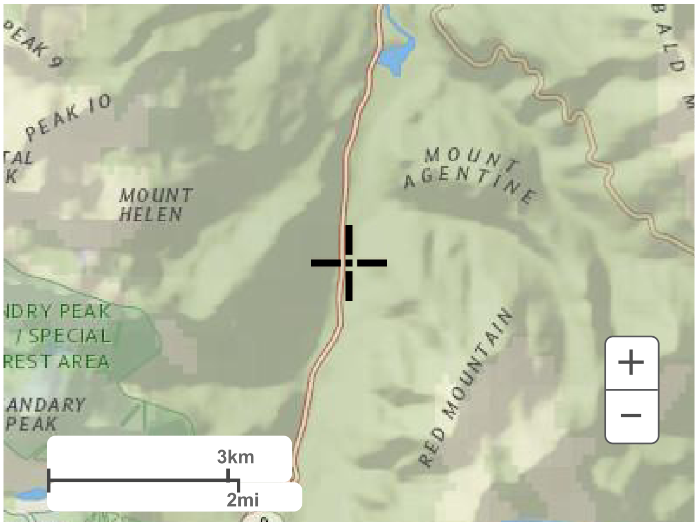
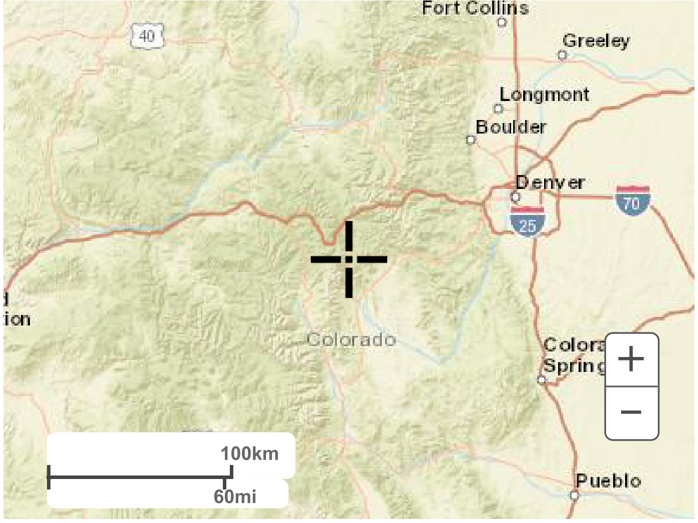
Maps & aerials

Small scale terrain

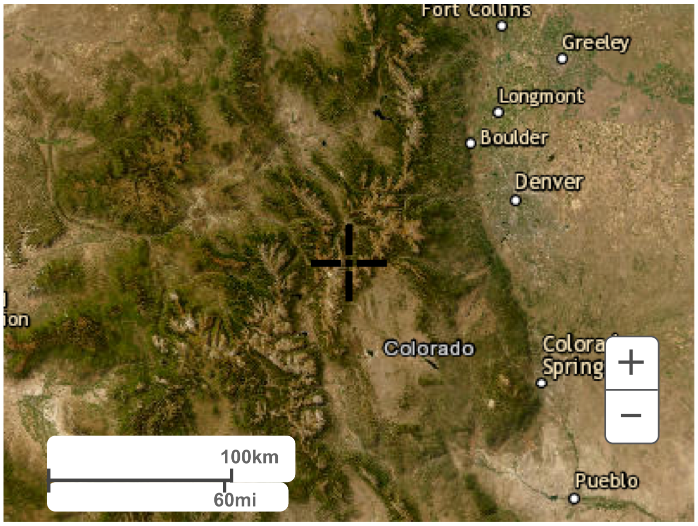


Large scale terrain

Large scale map



Large scale aerial



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Disclaimer

NRCS SOIL DATA

United States
Department of
Agriculture

NRCS

Natural
Resources
Conservation
Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Pike and San Isabel NF, Colorado, Northern Part, Parts of Chaffee, Clear Creek, Fremont, Jefferson, Lake, Park, and Saguache Counties; and Summit County Area, Colorado

June 21, 2023

Soil Information for All Uses

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

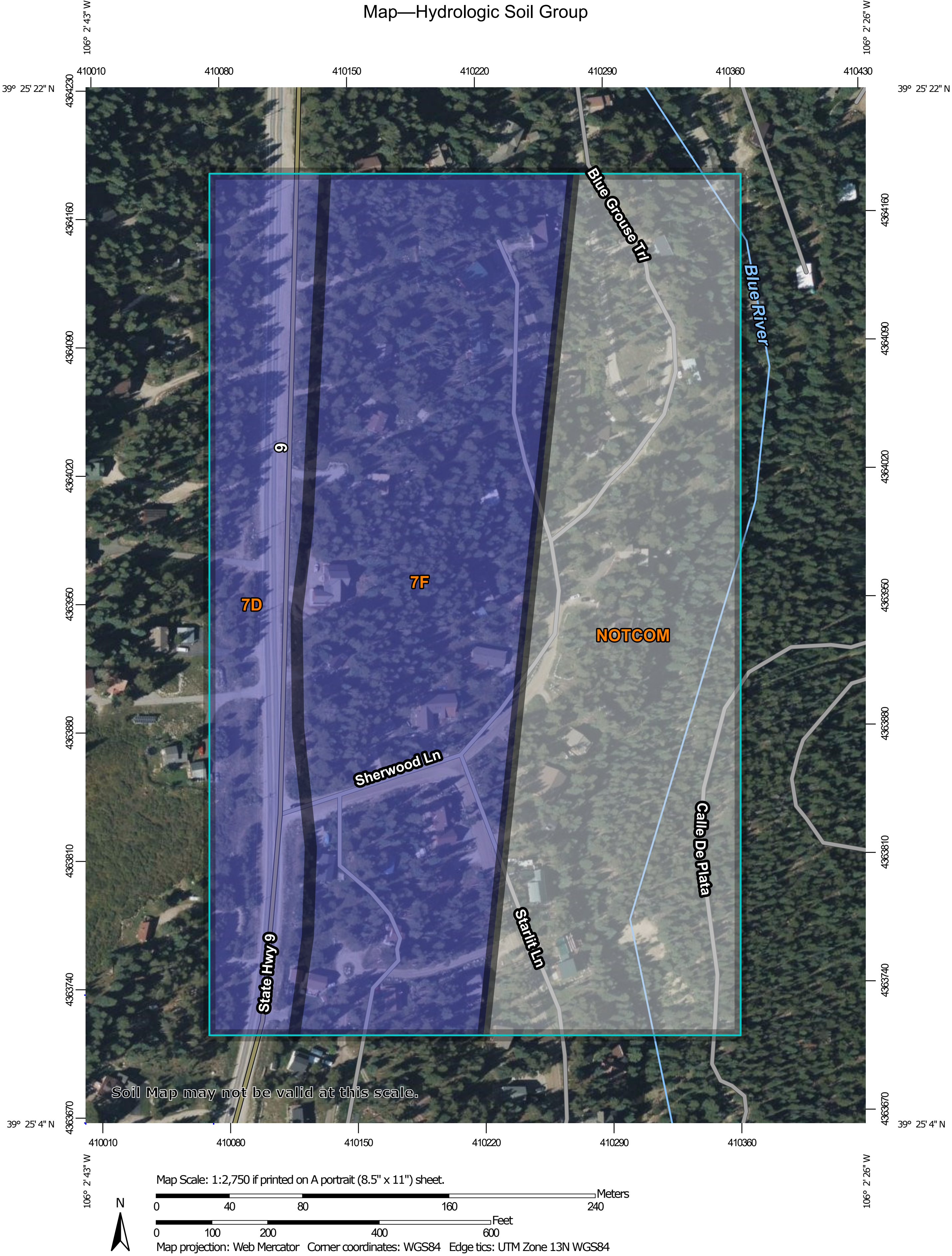
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Map—Hydrologic Soil Group



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Pike and San Isabel NF, Colorado, Northern Part, Parts of Chaffee, Clear Creek, Fremont, Jefferson, Lake, Park, and Saguache Counties
Survey Area Data: Version 4, Sep 7, 2022

Soil Survey Area: Summit County Area, Colorado
Survey Area Data: Version 14, Sep 6, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil

MAP LEGEND	MAP INFORMATION
	properties, and interpretations that do not completely agree across soil survey area boundaries. Soil map units are labeled (as space allows) for map scales 1:50,000 or larger. Date(s) aerial images were photographed: Sep 5, 2021—Sep 7, 2021 The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
NOTCOM	No Digital Data Available		13.5	39.9%
Subtotals for Soil Survey Area			**13.5**	**39.9%**
Totals for Area of Interest			**33.9**	**100.0%**

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
7D	Grenadier gravelly loam, 6 to 15 percent slopes	B	6.3	18.6%
7F	Grenadier gravelly loam, 15 to 55 percent slopes	B	14.1	41.5%
Subtotals for Soil Survey Area			**20.4**	**60.1%**
Totals for Area of Interest			**33.9**	**100.0%**

Rating Options—Hydrologic Soil Group

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

APPENDIX C:
HYDRAULIC CALCULATIONS

HY-8 CROSS CULVERT ANALYSIS RESULTS

Table 1 - Summary of Culvert Flows at Crossing: Sherwood Ln & Starlit Ln

Headwater Elevation (ft)	Total Discharge (cfs)	Sherwood Ln & Starlit Ln Cross Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
10139.28	2.30	2.30	0.00	1
10139.60	3.96	3.96	0.00	1
10139.86	5.50	5.50	0.00	1
10140.03	7.28	6.53	0.70	12
10140.07	8.94	6.75	2.15	5
10140.10	10.60	6.92	3.64	4
10140.13	12.26	7.07	5.17	4
10140.15	13.92	7.19	6.67	3
10140.17	15.58	7.31	8.22	3
10140.19	17.24	7.43	9.79	3
10140.21	18.90	7.53	11.35	3
10140.00	6.34	6.34	0.00	Overtopping

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 2.3 cfs

Design Flow: 5.5 cfs

Maximum Flow: 18.9 cfs

Table 2 - Culvert Summary Table: Sherwood Ln & Starlit Ln Cross Culvert

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.30	2.30	10139.28	0.782	0.0*	1-S2n	0.346	0.573	0.346	0.517	7.472	4.297
3.96	3.96	10139.60	1.104	0.0*	1-S2n	0.455	0.761	0.466	0.634	8.469	4.923
5.50	5.50	10139.86	1.360	0.0*	1-S2n	0.541	0.904	0.561	0.717	9.128	5.344
7.28	6.53	10140.03	1.534	0.0*	5-S2n	0.594	0.989	0.618	0.797	9.522	5.732
8.94	6.75	10140.07	1.572	0.0*	5-S2n	0.605	1.005	0.629	0.861	9.599	6.034
10.60	6.92	10140.10	1.602	0.0*	5-S2n	0.613	1.018	0.638	0.917	9.659	6.297
12.26	7.07	10140.13	1.628	0.0*	5-S2n	0.620	1.029	0.647	0.969	9.696	6.530
13.92	7.19	10140.15	1.650	0.0*	5-S2n	0.626	1.038	0.654	1.016	9.727	6.740
15.58	7.31	10140.17	1.673	0.0*	5-S2n	0.632	1.047	0.660	1.060	9.758	6.933
17.24	7.43	10140.19	1.694	0.018	5-S2n	0.637	1.056	0.667	1.101	9.787	7.111
18.90	7.53	10140.21	1.714	0.076	5-S2n	0.642	1.063	0.673	1.140	9.814	7.276

* Full Flow Headwater elevation is below inlet invert.

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                    ******************************************************************************
                                              Straight Culvert
                 Inlet Elevation (invert): 10138.50 ft,     Outlet Elevation (invert): 10136.76 ft
                         Culvert Length: 58.03 ft,     Culvert Slope: 0.0300
                    ******************************************************************************
```

Site Data - Sherwood Ln & Starlit Ln Cross Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 10138.50 ft

Outlet Station: 58.00 ft

Outlet Elevation: 10136.76 ft

Number of Barrels: 1

Culvert Data Summary - Sherwood Ln & Starlit Ln Cross Culvert

Barrel Shape: Circular

Barrel Diameter: 1.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Sherwood Ln & Starlit Ln)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.30	10137.28	0.52	4.30	1.71	1.49
3.96	10137.39	0.63	4.92	2.10	1.54
5.50	10137.48	0.72	5.34	2.37	1.57
7.28	10137.56	0.80	5.73	2.64	1.60
8.94	10137.62	0.86	6.03	2.85	1.62
10.60	10137.68	0.92	6.30	3.03	1.64
12.26	10137.73	0.97	6.53	3.20	1.65
13.92	10137.78	1.02	6.74	3.36	1.67
15.58	10137.82	1.06	6.93	3.51	1.68
17.24	10137.86	1.10	7.11	3.64	1.69
18.90	10137.90	1.14	7.28	3.77	1.70

Tailwater Channel Data - Sherwood Ln & Starlit Ln

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0530

Channel Manning's n: 0.0300

Channel Invert Elevation: 10136.76 ft

Roadway Data for Crossing: Sherwood Ln & Starlit Ln

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 50.00 ft

Crest Elevation: 10140.00 ft

Roadway Surface: Gravel

Roadway Top Width: 45.00 ft

Table 4 - Summary of Culvert Flows at Crossing: Sherwood Ln & Blue Grouse Trl

Headwater Elevation (ft)	Total Discharge (cfs)	Sherwood Ln & Blue Grouse Trl Cross Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
10120.35	2.60	2.60	0.00	1
10120.71	4.52	4.52	0.00	1
10121.02	6.40	6.40	0.00	1
10121.38	8.36	8.36	0.00	1
10121.83	10.28	10.28	0.00	1
10122.04	12.20	11.09	1.03	12
10122.09	14.12	11.24	2.84	5
10122.12	16.04	11.36	4.63	4
10122.15	17.96	11.46	6.48	4
10122.17	19.88	11.55	8.27	3
10122.20	21.80	11.63	10.13	3
10122.00	10.93	10.93	0.00	Overtopping

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 2.6 cfs

Design Flow: 6.4 cfs

Maximum Flow: 21.8 cfs

Table 5 - Culvert Summary Table: Sherwood Ln & Blue Grouse Trl Cross Culvert

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.60	2.60	10120.35	0.854	0.0*	1-S2n	0.407	0.611	0.413	0.657	6.563	3.016
4.52	4.52	10120.71	1.207	0.047	1-S2n	0.543	0.816	0.560	0.808	7.508	3.463
6.40	6.40	10121.02	1.518	0.441	5-S2n	0.657	0.978	0.684	0.920	8.148	3.778
8.36	8.36	10121.38	1.884	0.909	5-S2n	0.766	1.120	0.803	1.017	8.675	4.039
10.28	10.28	10121.83	2.326	1.561	5-S2n	0.870	1.234	0.916	1.099	9.096	4.253
12.20	11.09	10122.04	2.544	1.778	5-S2n	0.914	1.274	0.963	1.172	9.258	4.439
14.12	11.24	10122.09	2.586	1.819	5-S2n	0.922	1.281	0.971	1.238	9.287	4.604
16.04	11.36	10122.12	2.619	1.851	5-S2n	0.929	1.287	0.978	1.299	9.309	4.753
17.96	11.46	10122.15	2.648	1.880	5-S2n	0.934	1.291	0.984	1.355	9.329	4.890
19.88	11.55	10122.17	2.674	1.905	5-S2n	0.939	1.295	0.989	1.408	9.345	5.015
21.80	11.63	10122.20	2.698	1.928	5-S2n	0.944	1.299	0.994	1.457	9.361	5.132

* Full Flow Headwater elevation is below inlet invert.

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Straight Culvert

Inlet Elevation (invert): 10119.50 ft,   Outlet Elevation (invert): 10118.50 ft

Culvert Length: 50.01 ft,   Culvert Slope: 0.0200

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Site Data - Sherwood Ln & Blue Grouse Trl Cross Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 10119.50 ft

Outlet Station: 50.00 ft

Outlet Elevation: 10118.50 ft

Number of Barrels: 1

Culvert Data Summary - Sherwood Ln & Blue Grouse Trl Cross Culvert

Barrel Shape: Circular

Barrel Diameter: 1.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 6 - Downstream Channel Rating Curve (Crossing: Sherwood Ln & Blue Grouse Trl)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
2.60	1019.16	0.66	3.02	0.78	0.93
4.52	1019.31	0.81	3.46	0.96	0.96
6.40	1019.42	0.92	3.78	1.09	0.98
8.36	1019.52	1.02	4.04	1.21	1.00
10.28	1019.60	1.10	4.25	1.30	1.01
12.20	1019.67	1.17	4.44	1.39	1.02
14.12	1019.74	1.24	4.60	1.47	1.03
16.04	1019.80	1.30	4.75	1.54	1.04
17.96	1019.86	1.36	4.89	1.61	1.05
19.88	1019.91	1.41	5.02	1.67	1.05
21.80	1019.96	1.46	5.13	1.73	1.06

Tailwater Channel Data - Sherwood Ln & Blue Grouse Trl

Tailwater Channel Option: Triangular Channel

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0190

Channel Manning's n: 0.0300

Channel Invert Elevation: 1018.50 ft

Roadway Data for Crossing: Sherwood Ln & Blue Grouse Trl

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 50.00 ft

Crest Elevation: 10122.00 ft

Roadway Surface: Gravel

Roadway Top Width: 30.00 ft

FLOWMASTER DITCH CALCULATIONS

Ditch Calculations Report

Label	Roughness Coefficient	Channel Slope (ft/ft)	Normal Depth (ft)	Left Side Slope (ft/ft (H:V))	Right Side Slope (ft/ft (H:V))	Discharge (ft³/s)	Velocity (ft/s)
2.5% ditch slope	0.030	0.02500	2.00	2.00	2.00	58.16	7.27
3.5% ditch slope	0.030	0.03500	2.00	2.00	2.00	68.82	8.60
4.5% ditch slope	0.030	0.04500	2.00	2.00	2.00	78.03	9.75
5.5% ditch slope	0.030	0.05500	2.00	2.00	2.00	86.27	10.78
1% ditch slope	0.030	0.01000	2.00	2.00	2.00	36.78	4.60