APPENDIX C

UPDATED DRAINAGE ANALYSIS

November 12, 2018
Revised: November 15, 2019

DRAINAGE ANALYSIS
for
Tioga Inn Revised Specific Plan

This drainage letter is prepared for the Tioga Inn Revised Specific Plan (project), located in Lee Vining, Mono County, CA. The letter examines (1) the required retention facilities for the project's revision to include workforce housing; and (2) the effects of the project on the capacity of the existing culverts under US 395. The following pages are provided as a summary of the results of the attached calculations.

The analysis was prepared by Triad/Holmes Associates under the direction of:

Thomas A. Platz, PE

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1. **Retention**
    - Retention Requirements
    - Retention Facilities Sizing
    - Treatment Requirements
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    - Hydrologic Calculations
    - Existing Culvert Capacity

Please find attached to this document the following:

Appendix A - Retention
- Retention Facilities Sizing
- Precipitation Depth (NOAA)

Appendix B – Culverts Capacity
- Figures 1 and 2
- Precipitation Intensity (NOAA)
- Unit Hydrograph
- Supporting Tables and Figures

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1. Retention Analysis

Retention Requirements

Retention facilities are sized for the previously approved but yet to be constructed hotel and restaurant. The retention for the proposed hotel and workforce housing is based on the Town of Mammoth Lakes (TOML) 1984 Stormdrain Design Manual. The TOML requirement is retention of a 20-year 1-hour storm event or 1 inch of precipitation from the impervious surface. Since this site is located in Lee Vining and receives less precipitation than the Town of Mammoth Lakes, the Mono County permitted to use the NOAA precipitation data for the retention calculations. Based on the NOAA Atlas 14, the precipitation depth for the 20-year 1-hour event at the location of the site is 0.84 inches. Refer to attached NOAA precipitation chart.

Even though the hotel and restaurant have been approved under the current specific plan, the required retention volume for the hotel is 9,950 cf. The workforce housing and the restaurant combined required 11,246 cf. If the restaurant is constructed separate from the housing, a separate retention basin will be installed. Restaurant parking was constructed at the time of the existing Gas Mart. Table 1 below summarizes retention volume calculations.

Table 1: Retention Volume Calculations

Volume Required = Tributary Area * Average Runoff Coefficient * Rainfall Quantity

Rainfall Quantity	0.84 in	=	0.070 ft

	Workforce Housing and Restaurant			**Hotel**		
	Area		C	Area		C
Roof	62,879 sf	36%	0.95	38,277 sf	25%	0.95
AC/Concrete	109,699 sf	64%	0.92	114,936 sf	75%	0.92
Total Area	172,578 sf		**0.93**	153,213 sf		**0.93**

	Volume Required
Workforce Housing and Restaurant	**11,246 cf**
Hotel	**9,947 cf**

Retention Facilities Sizing

The retention facility was preliminary sized based on the storm water volume less storm water infiltration. Infiltration rates in the sandy soil found onsite are less than one minute per inch. A conservative rate of 5 min per inch was used to calculate retention volume.

Perforated storm drain pipes are proposed to retain the required stormwater volume. Based on the attached calculation, the hotel will require 3-48" pipes with the total basin length of 167 feet. Workforce housing site will also require 3-48" pipes with the total basin length of 188 feet. The proposed location for the retention systems are shown on Sheet C3 of the Tioga Inn Revised Specific Plan.

Treatment Requirements

Treatment will be provided by the bioswales located in the landscaped areas of the parking lot. Other means of treatment may include installation of the oil removal inserts into the inlets or a separate oil treatment unit.

2. Culvert Capacity Analysis

Hydrologic Calculations

Three primary categories of the hydrologic data are considered for this analysis including surface water runoff, precipitation, and drainage basin characteristics. Data was collected during the field investigations and using existing topographic maps. Rational method is used for hydrologic analysis. All hydrologic calculations are included in Appendix B.

There are two culverts (labeled Culverts A and B) located under US 395 northeast of the future project. Upon examination of the culverts' stormwater tributary area, future project improvements fall within these tributary areas as shown in Figures 1 and 2, Appendix B. Hydrologic analysis is performed to determine the amount of flow entering the culverts during pre- and post-project conditions.

Culvert A is a 30" corrugated metal pipe located north of the future hotel and restaurant. Culvert B is a 36" corrugated metal pipe located northwest of the future workforce housing. As shown in Figures 1 and 2, approximately 65 acres is tributary to Culvert A and 100 acres is tributary to Culvert B. Future hotel and restaurant are located within Area A and is labeled Area A1, totaling 3.7 ac of impervious area. Future workforce housing is located within Area B and is labeled Area B1. Area B1 encompasses 3.8 ac of impervious surface.

Runoff coefficients for each of the tributary area are determined using Caltrans Highway Design Manual (HDM) Tables 819.2A and 819.2B and shown in tables below:

Undeveloped Surface (based on HDM Figure 819.2A)

	C
Relief	0.20
Soil Infiltration	0.04
Vegetal Cover	0.06
Surface Storage	0.08
Average	**0.38**

Average Runoff Coefficient (Developed Surface based on HDM Table 819.2B)

		Roofs (C=0.95)	AC (C=0.90)	Undeveloped (C=0.38)	**Average C**
Area A	Existing Watershed	23,743 sf	128,503 sf	2,696,937 sf	**0.41**
Area B	Existing Watershed	00 sf	15,833 sf	4,339,410 sf	**0.38**
Area A1	Future Hotel/Rest.	45,123 sf	114,936 sf	00 sf	**0.91**
Area B1	Future Workforce	56,033 sf	109,699 sf	00 sf	**0.92**

Time of concentration is the time required for the storm runoff to travel from the most remote point of the drainage basin to the point of interest. Time of concentration, Tc, is the cumulative sum of sheet flow and shallow concentrated flow. In the areas where the travel time was calculated to be less than 5 minutes, Tc of 5 minutes was assumed.

Sheet Flow

$$T_t = \frac{0.42L^{4/5}n^{4/5}}{P_2^{1/2}s^{2/5}}$$

	Surface	L	n[1]	P_2[2]	S	T_t	$T_{t\ used}$
Area A	Natural	300 ft	0.4	2.17 in	0.2300	23.6 min	24 min
Area B	Natural	300 ft	0.4	2.17 in	0.1400	28.8 min	29 min
Area A1	Paved	100 ft	0.013	2.17 in	0.0200	1.7 min	5 min
Area B1	Paved	100 ft	0.013	2.17 in	0.0200	1.7 min	5 min

Shallow Concentrated Flow

$$T_t = L/60V$$

	Surface	S	V[4]	L	T_t	$T_{t\ used}$
Area A	Natural	0.14	6.0 ft/s	3272 ft	9.1 min	9 min
Area B	Natural	0.13	5.8 ft/s	4152 ft	11.9 min	12 min
Area A1	Paved	0.02	2.8 ft/s	340 ft	2.0 min	5 min
Area B1	Paved	0.02	2.8 ft/s	595 ft	3.5 min	5 min

Total Travel Time

	Sheet Flow	Shallow Flow	Total Tc
Area A	24 min	9 min	33 min
Area B	29 min	12 min	41 min
Area A1	5 min	5 min	10 min
Area B1	5 min	5 min	10 min

Precipitation Frequency Estimates are based upon the NOAA Atlas 14 results from the website, http://hdsc.nws.noaa.gov/hdsc/pfds/sa/sca_pfds.html. These results are from Lee Vining, at Latitude 37.9458° Longitude 119.1114° and an approximate elevation of 7013 feet. This location represents the average precipitation estimates for the tributary area under consideration. NOAA data is included in Appendix B. Flow rate calculations have been performed for the storm of 100-year intensities using the calculated Tc.

Rational method, Q=CiA, was used to calculate the quantity of the runoff tributary to each culvert during the 100-year intensity storm. Summary of the runoff rates calculations and input parameters are shown below:

		A	C	i_{100}[3]	Q_{100}
Area A	Existing	65.4 ac	0.41	1.76 in/hr	**47 cfs**
Area B	Existing	99.6 ac	0.38	1.60 in/hr	**61 cfs**
Area A1	Future Hotel/Rest.	3.7 ac	0.91	3.34 in/hr	**11 cfs**
Area B1	Future Workforce	3.8 ac	0.92	3.34 in/hr	**12 cfs**

Since retention systems are proposed to attenuate the flow due to the future hotel, restaurant, and workforce housing, a dimensionless hydrograph is used to determine whether the future project will add any additional flows to the culverts. Two retention systems are sized to handle a 20-year, 1 hr storm event, capable to store 11,246 cf and 9,947 cf each. Based on the unit hydrograph, at the Tc of 33 min (time of concentration for the peak 100-year flow), the volume of stormwater is 3,465 cf and 3,765 cf tributary to Culvert A and B, respectively. These volumes are significantly less than the capacity of the future retention system, and therefore, there will be no increase in flow during a design 100-year event from the future development. The 100-year storm event flows at the two culverts will actually be decreased once the site is developed and the retention system is installed. The existing and future project flows at each culvert are:

	Q_{100} (existing)	**Q_{100} (proposed)**
Culvert A	47 cfs	36 cfs
Culvert B	61 cfs	49 cfs

Appendix A – Retention

Hotel

PIPE DIAMETER		PIPE VOLUME	STONE VOID VOLUME	TOTAL RETENTION STORAGE	PERC VOLUME	RETENTION STORAGE W/ PERC	LENGTH OF TYPICAL CROSS SECTION	BASIN DIMENSIONS: TOTAL BASIN LENGTH	BASIN DIMENSIONS: CROSS SECTION WIDTH (TOTAL BASIN WIDTH)	BASIN DIMENSIONS: DEPTH OF STORAGE (NOT INCLUDING EARTH COVER)	LINEAR FEET OF PIPE REQ'D (INC HEADER)
in.	ft.	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft.	ft^3/cs-ft	ft.	ft.	ft.
12	1.00	2.36	2.71	5.07	3.33	8.40	1157	1161	7.00	1.50	3501
15	1.25	3.68	3.29	6.98	3.72	10.69	910	914	7.75	1.75	2759
18	1.50	5.30	3.90	9.20	4.10	13.30	731	736	8.50	2.00	2224
24	2.00	9.42	5.19	14.62	4.86	19.48	499	504	10.00	2.50	1528
30	2.50	14.73	8.59	23.32	6.46	29.78	327	332	13.50	3.00	1010
36	3.00	21.21	10.43	31.64	7.22	38.86	250	256	15.00	3.50	781
42	3.50	28.86	12.38	41.24	7.99	49.23	198	204	16.50	4.00	623
48	**4.00**	**37.70**	**14.43**	**52.13**	**8.75**	**60.88**	**160**	**167**	**18.00**	**4.50**	**509**
54	4.50	47.71	16.60	64.31	9.51	73.82	132	139	19.50	5.00	425
60	5.00	58.90	18.87	77.77	10.28	88.05	110	118	21.00	5.50	361

INPUT SIZE OF PIPES (ft):	**4.00**	
INPUT NUMBER OF ROWS OF PIPES:	**3**	**Header Length (ft) =** **15**
INPUT PERCOLATION RATE (ft/hr):	**0.42**	
INPUT REQ'D. STORAGE VOLUME (cf):	**9947**	
Less storage volume of header (cf)	222	
Cross-Sect STORAGE VOLUME (cf):	9725	(see table above for amount of pipe required)

Workforce Housing and Restaurant

PIPE DIAMETER		PIPE VOLUME	STONE VOID VOLUME	TOTAL RETENTION STORAGE	PERC VOLUME	RETENTION STORAGE W/ PERC	LENGTH OF TYPICAL CROSS SECTION	BASIN DIMENSIONS: TOTAL BASIN LENGTH	BASIN DIMENSIONS: CROSS SECTION WIDTH (TOTAL BASIN WIDTH)	BASIN DIMENSIONS: DEPTH OF STORAGE (NOT INCLUDING EARTH COVER)	LINEAR FEET OF PIPE REQ'D (INC HEADER)
in.	ft.	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft^3/cs-ft	ft.	ft^3/cs-ft	ft.	ft.	ft.
12	1.00	2.36	2.71	5.07	3.33	8.40	1312	1316	7.00	1.50	3965
15	1.25	3.68	3.29	6.98	3.72	10.69	1031	1035	7.75	1.75	3123
18	1.50	5.30	3.90	9.20	4.10	13.30	829	833	8.50	2.00	2517
24	2.00	9.42	5.19	14.62	4.86	19.48	566	571	10.00	2.50	1728
30	2.50	14.73	8.59	23.32	6.46	29.78	370	376	13.50	3.00	1141
36	3.00	21.21	10.43	31.64	7.22	38.86	284	290	15.00	3.50	881
42	3.50	28.86	12.38	41.24	7.99	49.23	224	230	16.50	4.00	702
48	**4.00**	**37.70**	**14.43**	**52.13**	**8.75**	**60.88**	**181**	**188**	**18.00**	**4.50**	**573**
54	4.50	47.71	16.60	64.31	9.51	73.82	149	157	19.50	5.00	478
60	5.00	58.90	18.87	77.77	10.28	88.05	125	133	21.00	5.50	406

INPUT SIZE OF PIPES (ft): **4.00**
INPUT NUMBER OF ROWS OF PIPES: **3** **Header Length (ft) =** **15**
INPUT PERCOLATION RATE (ft/hr): **0.42**
INPUT REQ'D. STORAGE VOLUME (cf): **11246**
Less storage volume of header (cf) 222
Cross-Sect STORAGE VOLUME (cf): 11024 (see table above for amount of pipe required)

NOAA Atlas 14, Volume 6, Version 2
Location name: Lee Vining, California, USA*
Latitude: 37.9477°, Longitude: -119.1105°
Elevation: 6935.44 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

20 year 1 hour = 0.84 inches
2-year 24 hour = 2.17 inches

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	0.109 (0.096-0.125)	0.141 (0.124-0.162)	0.186 (0.163-0.215)	0.226 (0.196-0.263)	0.285 (0.236-0.347)	0.334 (0.270-0.418)	0.388 (0.303-0.500)	0.447 (0.338-0.598)	0.536 (0.384-0.755)	0.611 (0.420-0.899)
10-min	0.156 (0.137-0.179)	0.202 (0.177-0.232)	0.267 (0.234-0.308)	0.324 (0.281-0.378)	0.408 (0.339-0.497)	0.479 (0.387-0.599)	0.556 (0.435-0.717)	0.641 (0.484-0.858)	0.768 (0.551-1.08)	0.876 (0.601-1.29)
15-min	0.188 (0.166-0.216)	0.244 (0.215-0.280)	0.323 (0.283-0.372)	0.392 (0.339-0.457)	0.494 (0.410-0.601)	0.579 (0.467-0.724)	0.672 (0.526-0.867)	0.776 (0.586-1.04)	0.929 (0.666-1.31)	1.06 (0.727-1.56)
30-min	0.254 (0.224-0.292)	0.329 (0.289-0.378)	0.435 (0.381-0.502)	0.528 (0.458-0.616)	0.666 (0.552-0.810)	0.780 (0.630-0.976)	0.906 (0.709-1.17)	1.05 (0.790-1.40)	1.25 (0.898-1.77)	1.43 (0.981-2.10)
60-min	0.344 (0.303-0.395)	0.446 (0.392-0.512)	0.590 (0.517-0.680)	0.716 (0.620-0.834)	0.902 (0.748-1.10)	1.06 (0.854-1.32)	1.23 (0.961-1.59)	1.42 (1.07-1.90)	1.70 (1.22-2.39)	1.94 (1.33-2.85)
2-hr	0.481 (0.423-0.552)	0.616 (0.541-0.708)	0.806 (0.706-0.930)	0.971 (0.842-1.13)	1.21 (1.01-1.48)	1.41 (1.14-1.77)	1.63 (1.27-2.10)	1.87 (1.41-2.49)	2.21 (1.58-3.11)	2.50 (1.71-3.67)
3-hr	0.588 (0.517-0.674)	0.750 (0.659-0.861)	0.976 (0.855-1.13)	1.17 (1.01-1.37)	1.45 (1.21-1.77)	1.69 (1.36-2.11)	1.93 (1.51-2.50)	2.20 (1.66-2.95)	2.59 (1.86-3.65)	2.91 (2.00-4.28)
6-hr	0.837 (0.737-0.960)	1.06 (0.935-1.22)	1.38 (1.21-1.59)	1.64 (1.42-1.91)	2.02 (1.68-2.46)	2.32 (1.88-2.91)	2.65 (2.07-3.42)	2.99 (2.26-4.00)	3.48 (2.49-4.90)	3.87 (2.66-5.70)
12-hr	1.19 (1.05-1.37)	1.53 (1.34-1.76)	1.99 (1.74-2.29)	2.37 (2.05-2.76)	2.90 (2.41-3.53)	3.33 (2.69-4.16)	3.77 (2.95-4.87)	4.24 (3.20-5.67)	4.89 (3.50-6.89)	5.40 (3.71-7.95)
24-hr	1.67 (1.49-1.92)	2.17 (1.93-2.49)	2.84 (2.51-3.27)	3.39 (2.98-3.93)	4.15 (3.52-4.99)	4.75 (3.95-5.83)	5.37 (4.35-6.76)	6.01 (4.74-7.80)	6.91 (5.21-9.34)	7.61 (5.54-10.7)
2-day	2.10 (1.87-2.41)	2.73 (2.42-3.13)	3.57 (3.16-4.11)	4.27 (3.75-4.96)	5.23 (4.44-6.28)	5.97 (4.96-7.34)	6.74 (5.46-8.49)	7.55 (5.94-9.78)	8.65 (6.52-11.7)	9.51 (6.93-13.3)
3-day	2.29 (2.04-2.62)	2.99 (2.65-3.43)	3.92 (3.48-4.52)	4.69 (4.12-5.45)	5.75 (4.88-6.91)	6.57 (5.46-8.07)	7.41 (6.01-9.34)	8.29 (6.53-10.7)	9.49 (7.16-12.8)	10.4 (7.59-14.6)
4-day	2.46 (2.19-2.83)	3.22 (2.86-3.70)	4.24 (3.76-4.88)	5.08 (4.46-5.90)	6.22 (5.28-7.48)	7.11 (5.91-8.73)	8.02 (6.50-10.1)	8.97 (7.06-11.6)	10.3 (7.74-13.9)	11.3 (8.21-15.8)
7-day	2.78 (2.47-3.18)	3.65 (3.24-4.19)	4.81 (4.26-5.54)	5.77 (5.07-6.71)	7.09 (6.02-8.52)	8.11 (6.74-9.96)	9.14 (7.41-11.5)	10.2 (8.04-13.2)	11.7 (8.80-15.8)	12.8 (9.31-17.9)
10-day	2.92 (2.60-3.35)	3.85 (3.42-4.43)	5.11 (4.53-5.89)	6.15 (5.40-7.14)	7.57 (6.42-9.10)	8.66 (7.19-10.6)	9.77 (7.91-12.3)	10.9 (8.58-14.1)	12.4 (9.39-16.8)	13.6 (9.92-19.1)
20-day	3.73 (3.32-4.28)	4.97 (4.42-5.71)	6.64 (5.88-7.64)	7.99 (7.02-9.28)	9.85 (8.37-11.8)	11.3 (9.37-13.9)	12.7 (10.3-16.0)	14.2 (11.2-18.4)	16.1 (12.2-21.8)	17.6 (12.8-24.7)
30-day	4.23 (3.76-4.85)	5.68 (5.04-6.52)	7.61 (6.74-8.76)	9.18 (8.07-10.7)	11.3 (9.63-13.6)	13.0 (10.8-15.9)	14.6 (11.8-18.4)	16.2 (12.8-21.1)	18.4 (13.9-24.9)	20.0 (14.5-28.0)
45-day	5.09 (4.53-5.84)	6.85 (6.09-7.87)	9.18 (8.14-10.6)	11.1 (9.73-12.9)	13.6 (11.6-16.4)	15.6 (13.0-19.2)	17.5 (14.2-22.1)	19.4 (15.3-25.2)	21.9 (16.5-29.6)	23.7 (17.3-33.2)
60-day	5.75 (5.12-6.60)	7.77 (6.90-8.92)	10.4 (9.23-12.0)	12.6 (11.0-14.6)	15.4 (13.1-18.6)	17.6 (14.6-21.6)	19.8 (16.0-24.9)	21.9 (17.2-28.4)	24.6 (18.5-33.2)	26.5 (19.3-37.1)

[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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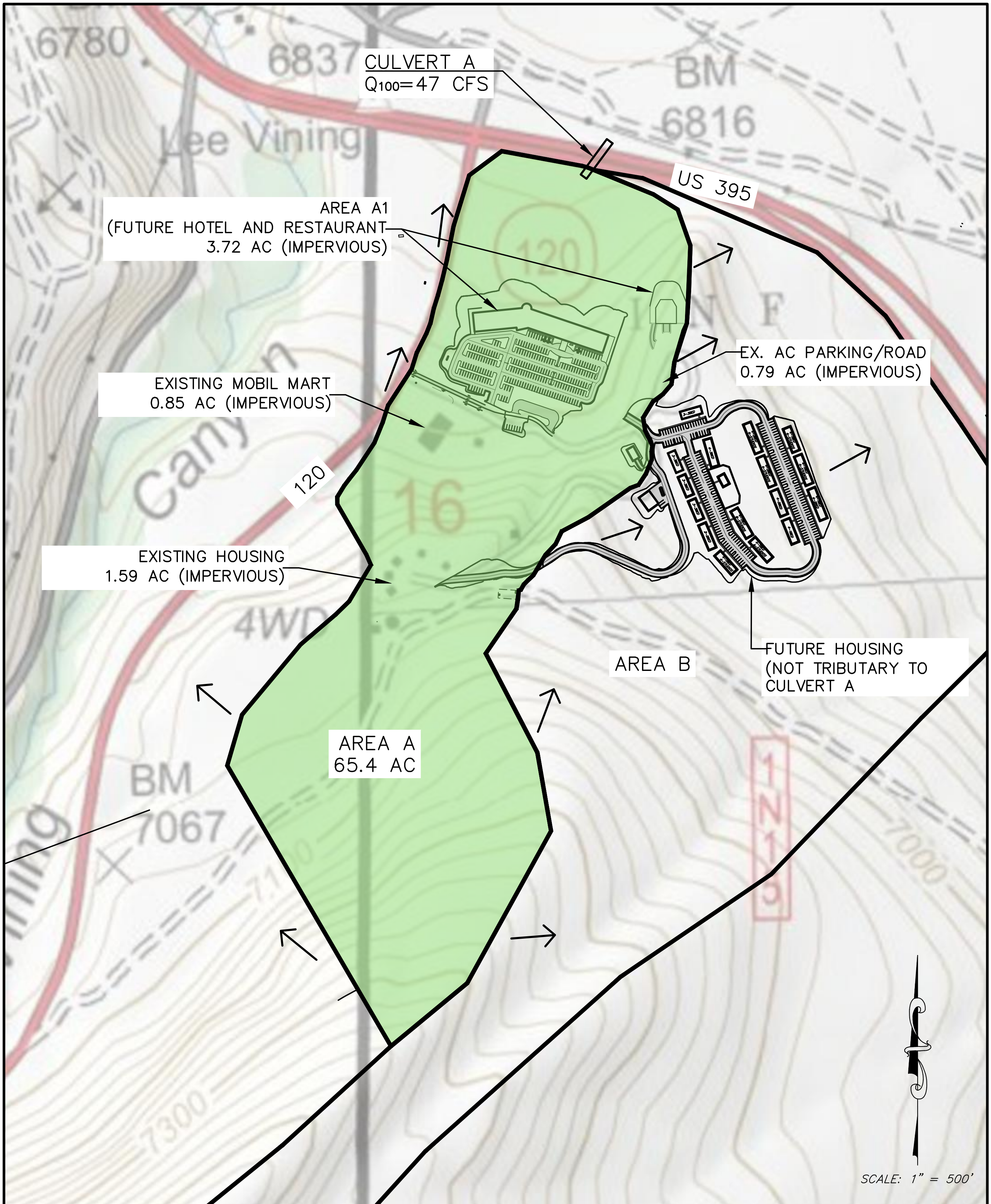
PF graphical

Appendix B – Culverts Capacity



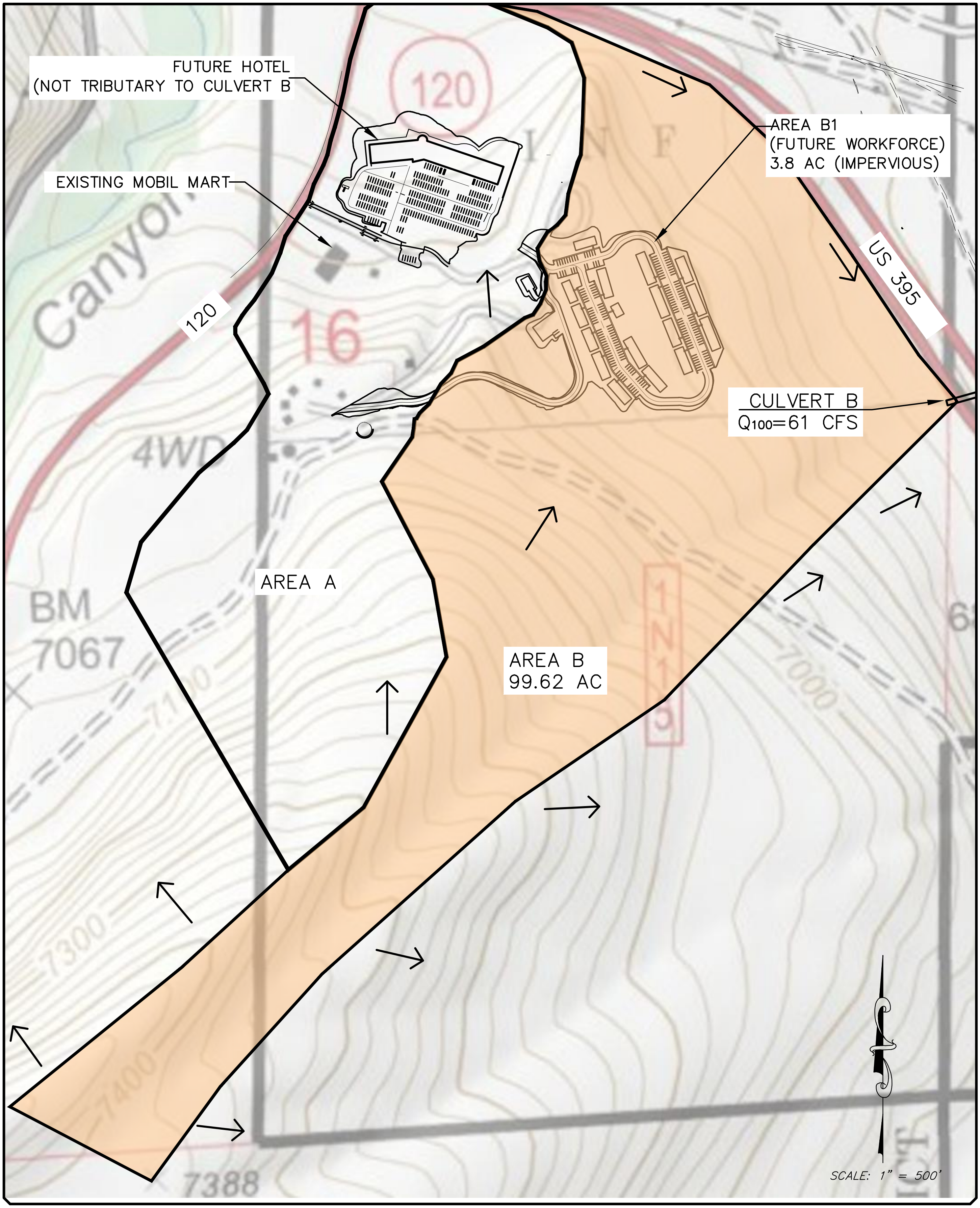
DATE:
11/11/2019

TIOGA INN SPECIFIC PLAN

CULVERT ANALYSIS
FIGURE 1 – CULVERT A TRIBUTARY AREA

triad/holmes assoc
civil engineering
land surveying

C:\Users\mpavlovsky\appdata\local\temp\AcPublish_10744\Tioga Inn Drainage.dwg Nov 15,2019 – 5:08pm, mpavlovsky



DATE:
11/11/2019

TIOGA INN SPECIFIC PLAN

CULVERT ANALYSIS
FIGURE 2 – CULVERT B TRIBUTARY AREA

triad/holmes assoc
civil engineering
land surveying

C:\Users\mpavlovsky\appdata\local\temp\AcPublish_10744\Tioga Inn Drainage.dwg Nov 15,2019 – 5:08pm, mpavlovsky

Dimensionless Hydrograph		
T/tc	Q/Qp	Qa/Qp
0	0	0
0.1	0.03	0.001
0.2	0.1	0.006
0.3	0.19	0.017
0.4	0.31	0.035
0.5	0.47	0.065
0.6	0.66	0.107
0.7	0.82	0.163
0.8	0.93	0.228
0.9	0.99	0.3
1	1	0.375
1.1	0.99	0.45
1.2	0.93	0.522
1.3	0.86	0.589
1.4	0.78	0.65
1.5	0.68	0.705
1.6	0.56	0.751
1.7	0.46	0.79
1.8	0.39	0.822
1.9	0.33	0.849
2	0.28	0.871
2.2	0.207	0.908
2.4	0.147	0.934
2.6	0.107	0.953
2.8	0.077	0.967
3	0.055	0.977
3.2	0.04	0.984
3.4	0.029	0.989
3.6	0.021	0.993
3.8	0.015	0.995
4	0.011	0.997
4.5	0.005	0.999
5	0	1

Future Hotel and Restaurant			
tp =	33	min	Cumulative Volume
100 yr Q=	11.00	cfs dev	
0	0.00	0.0	
3.3	0.33	11.6	12
6.6	1.10	47.9	59
9.9	2.09	104.0	163
13.2	3.41	176.6	340
16.5	5.17	272.3	612
19.8	7.26	391.1	1003
23.1	9.02	509.9	1513
26.4	10.23	602.3	2115
29.7	10.89	661.7	2777
33	**11.00**	**688.1**	**3465**
36.3	10.89	691.4	4156
39.6	10.23	671.6	4828
42.9	9.46	632.0	5460
46.2	8.58	585.8	6046
49.5	7.48	529.7	6575
52.8	6.16	460.4	7036
56.1	5.06	391.1	7427
59.4	4.29	338.3	7765
62.7	3.63	298.7	8064
66	3.08	265.7	8329
72.6	2.28	230.0	8559
79.2	1.62	192.7	8752
85.8	1.18	166.3	8918
92.4	0.85	149.8	9068
99	0.61	139.3	9207
105.6	0.44	133.7	9341
112.2	0.32	131.7	9473
118.8	0.23	132.0	9605
125.4	0.17	134.0	9739
132	0.12	137.3	9876
148.5	0.06	145.5	10021
165	0.00	158.4	10180

Future Workforce			
tp =	33	min	Cumulative Volume
100 yr Q=	12.00	cfs dev	
0	0.00	0.0	
3.3	0.36	12.5	12
6.6	1.20	51.8	64
9.9	2.28	112.7	177
13.2	3.72	191.6	368
16.5	5.64	295.7	664
19.8	7.92	425.0	1089
23.1	9.84	554.3	1643
26.4	11.16	654.8	2298
29.7	11.88	719.3	3017
33	**12.00**	**747.8**	**3765**
36.3	11.88	751.1	4516
39.6	11.16	729.2	5245
42.9	10.32	685.7	5931
46.2	9.36	635.0	6566
49.5	8.16	573.5	7139
52.8	6.72	497.6	7637
56.1	5.52	421.7	8058
59.4	4.68	363.8	8422
62.7	3.96	320.3	8742
66	3.36	284.0	9026
72.6	2.48	244.6	9271
79.2	1.76	203.3	9474
85.8	1.28	173.9	9648
92.4	0.92	155.3	9804
99	0.66	143.2	9947
105.6	0.48	136.5	10083
112.2	0.35	133.7	10217
118.8	0.25	133.5	10351
125.4	0.18	135.1	10486
132	0.13	138.1	10624
148.5	0.06	146.0	10770
165	0.00	158.6	10928

NOAA Atlas 14, Volume 6, Version 2
Location name: Lee Vining, California, USA*
Latitude: 37.9458°, Longitude: -119.1114°
Elevation: 7012.8 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

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/hour)[1]

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**1.31** (1.15-1.50)	**1.69** (1.49-1.94)	**2.24** (1.97-2.58)	**2.72** (2.36-3.17)	**3.43** (2.84-4.18)	**4.02** (3.25-5.03)	**4.67** (3.65-6.02)	**5.38** (4.07-7.19)	**6.43** (4.61-9.07)	**7.33** (5.03-10.8)
10-min	**0.936** (0.822-1.07)	**1.21** (1.07-1.39)	**1.61** (1.41-1.85)	**1.95** (1.69-2.27)	**2.46** (2.04-2.99)	**2.88** (2.33-3.60)	**3.34** (2.62-4.31)	**3.86** (2.91-5.15)	**4.61** (3.31-6.50)	**5.26** (3.61-7.73)
15-min	**0.752** (0.664-0.864)	**0.980** (0.860-1.12)	**1.30** (1.14-1.49)	**1.57** (1.36-1.83)	**1.98** (1.64-2.41)	**2.32** (1.88-2.90)	**2.70** (2.11-3.48)	**3.11** (2.35-4.16)	**3.72** (2.66-5.24)	**4.24** (2.91-6.24)
30-min	**0.510** (0.448-0.584)	**0.662** (0.582-0.760)	**0.876** (0.768-1.01)	**1.06** (0.922-1.24)	**1.34** (1.11-1.63)	**1.57** (1.27-1.96)	**1.82** (1.43-2.35)	**2.10** (1.59-2.81)	**2.51** (1.80-3.54)	**2.86** (1.96-4.21)
60-min	**0.345** (0.304-0.395)	**0.448** (0.394-0.514)	**0.593** (0.520-0.683)	**0.720** (0.624-0.838)	**0.907** (0.753-1.10)	**1.06** (0.858-1.33)	**1.23** (0.965-1.59)	**1.42** (1.07-1.90)	**1.70** (1.22-2.40)	**1.94** (1.33-2.85)
2-hr	**0.241** (0.212-0.276)	**0.309** (0.272-0.354)	**0.404** (0.355-0.466)	**0.488** (0.423-0.568)	**0.609** (0.506-0.741)	**0.709** (0.573-0.886)	**0.817** (0.640-1.05)	**0.935** (0.706-1.25)	**1.11** (0.793-1.56)	**1.25** (0.858-1.84)
3-hr	**0.196** (0.173-0.225)	**0.250** (0.220-0.287)	**0.326** (0.286-0.376)	**0.392** (0.340-0.456)	**0.486** (0.404-0.591)	**0.563** (0.455-0.704)	**0.646** (0.506-0.833)	**0.736** (0.556-0.984)	**0.865** (0.620-1.22)	**0.971** (0.666-1.43)
6-hr	**0.140** (0.123-0.160)	**0.178** (0.157-0.205)	**0.231** (0.202-0.266)	**0.275** (0.239-0.320)	**0.339** (0.281-0.412)	**0.390** (0.315-0.487)	**0.443** (0.347-0.572)	**0.501** (0.378-0.670)	**0.582** (0.418-0.821)	**0.648** (0.445-0.955)
12-hr	**0.099** (0.087-0.114)	**0.127** (0.112-0.146)	**0.165** (0.145-0.191)	**0.197** (0.171-0.230)	**0.242** (0.201-0.295)	**0.278** (0.224-0.347)	**0.314** (0.246-0.406)	**0.353** (0.267-0.473)	**0.407** (0.292-0.574)	**0.451** (0.309-0.663)
24-hr	**0.070** (0.062-0.080)	**0.091** (0.081-0.104)	**0.119** (0.105-0.137)	**0.142** (0.125-0.165)	**0.174** (0.148-0.209)	**0.199** (0.165-0.244)	**0.225** (0.182-0.283)	**0.252** (0.199-0.327)	**0.289** (0.218-0.391)	**0.319** (0.232-0.447)
2-day	**0.044** (0.039-0.050)	**0.057** (0.051-0.066)	**0.075** (0.066-0.086)	**0.089** (0.079-0.104)	**0.110** (0.093-0.132)	**0.125** (0.104-0.154)	**0.141** (0.115-0.178)	**0.158** (0.125-0.205)	**0.181** (0.137-0.245)	**0.199** (0.145-0.279)
3-day	**0.032** (0.029-0.037)	**0.042** (0.037-0.048)	**0.055** (0.049-0.063)	**0.066** (0.058-0.076)	**0.081** (0.068-0.097)	**0.092** (0.077-0.113)	**0.104** (0.084-0.131)	**0.116** (0.091-0.150)	**0.133** (0.100-0.180)	**0.146** (0.106-0.205)
4-day	**0.026** (0.023-0.030)	**0.034** (0.030-0.039)	**0.045** (0.040-0.051)	**0.053** (0.047-0.062)	**0.066** (0.056-0.079)	**0.075** (0.062-0.092)	**0.084** (0.068-0.106)	**0.094** (0.074-0.122)	**0.108** (0.081-0.146)	**0.119** (0.086-0.166)
7-day	**0.017** (0.015-0.019)	**0.022** (0.020-0.025)	**0.029** (0.026-0.034)	**0.035** (0.031-0.041)	**0.043** (0.036-0.051)	**0.049** (0.041-0.060)	**0.055** (0.045-0.070)	**0.062** (0.049-0.080)	**0.071** (0.053-0.095)	**0.077** (0.056-0.108)
10-day	**0.012** (0.011-0.014)	**0.016** (0.015-0.019)	**0.022** (0.019-0.025)	**0.026** (0.023-0.030)	**0.032** (0.027-0.039)	**0.037** (0.031-0.045)	**0.041** (0.034-0.052)	**0.046** (0.036-0.060)	**0.053** (0.040-0.071)	**0.058** (0.042-0.081)
20-day	**0.008** (0.007-0.009)	**0.011** (0.009-0.012)	**0.014** (0.013-0.016)	**0.017** (0.015-0.020)	**0.021** (0.018-0.025)	**0.024** (0.020-0.029)	**0.027** (0.022-0.034)	**0.030** (0.024-0.039)	**0.034** (0.026-0.046)	**0.037** (0.027-0.052)
30-day	**0.006** (0.005-0.007)	**0.008** (0.007-0.009)	**0.011** (0.010-0.013)	**0.013** (0.012-0.015)	**0.016** (0.014-0.019)	**0.018** (0.015-0.023)	**0.021** (0.017-0.026)	**0.023** (0.018-0.030)	**0.026** (0.020-0.035)	**0.028** (0.021-0.040)
45-day	**0.005** (0.004-0.006)	**0.007** (0.006-0.008)	**0.009** (0.008-0.010)	**0.011** (0.009-0.012)	**0.013** (0.011-0.016)	**0.015** (0.012-0.018)	**0.017** (0.014-0.021)	**0.018** (0.015-0.024)	**0.021** (0.016-0.028)	**0.022** (0.016-0.032)
60-day	**0.004** (0.004-0.005)	**0.006** (0.005-0.006)	**0.008** (0.007-0.009)	**0.009** (0.008-0.010)	**0.011** (0.009-0.013)	**0.013** (0.010-0.015)	**0.014** (0.011-0.018)	**0.016** (0.012-0.020)	**0.018** (0.013-0.024)	**0.019** (0.014-0.026)

[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

Figure 819.2A

Runoff Coefficients for Undeveloped Areas

Watershed Types

	Extreme	High	Normal	Low
Relief	.28 -.35 Steep, rugged terrain with average slopes above 30%	.20 -.28 Hilly, with average slopes of 10 to 30%	.14 -.20 Rolling, with average slopes of 5 to 10%	.08 -.14 Relatively flat land, with average slopes of 0 to 5%
Soil Infiltration	.12 -.16 No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity	.08 -.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity, imperfectly or poorly drained	.06 -.08 Normal; well drained light or medium textured soils, sandy loams, silt and silt loams	.04 -.06 High; deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover	.12 -.16 No effective plant cover, bare or very sparse cover	.08 -.12 Poor to fair; clean cultivation crops, or poor natural cover, less than 20% of drainage area over good cover	.06 -.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	.04 -.06 Good to excellent; about 90% of drainage area in good grassland, woodland or equivalent cover
Surface Storage	.10 -.12 Negligible surface depression few and shallow; drainageways steep and small, no marshes	.08 -.10 Low; well defined system of small drainageways; no ponds or marshes	.06 -.08 Normal; considerable surface depression storage; lakes and pond marshes	.04 -.06 High; surface storage, high; drainage system not sharply defined; large floodplain storage or large number of ponds or marshes

Given	An undeveloped watershed consisting of; 1) rolling terrain with average slopes of 5%, 2) clay type soils, 3) good grassland area, and 4) normal surface depressions.	Solution: Relief 0.14 Soil Infiltration 0.08 Vegetal Cover 0.04 Surface Storage 0.06 C = 0.32
Find	The runoff coefficient, C, for the above watershed.	

Table 819.2B

Runoff Coefficients for Developed Areas [(1)]

Type of Drainage Area	Runoff Coefficient
Business:	
Downtown areas	0.70 - 0.95
Neighborhood areas	0.50 - 0.70
Residential:	
Single-family areas	0.30 - 0.50
Multi-units, detached	0.40 - 0.60
Multi-units, attached	0.60 - 0.75
Suburban	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial:	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90
Parks, cemeteries:	0.10 - 0.25
Playgrounds:	0.20 - 0.40
Railroad yard areas:	0.20 - 0.40
Unimproved areas:	0.10 - 0.30
Lawns:	
Sandy soil, flat, 2%	0.05 - 0.10
Sandy soil, average, 2-7%	0.10 - 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil, flat, 2%	0.13 - 0.17
Heavy soil, average, 2-7%	0.18 - 0.22
Heavy soil, steep, 7%	0.25 - 0.35
Streets:	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs:	0.75 - 0.95

NOTES:
(1) From HDS No. 2.

regression equations are considered the best estimates of flood frequency and are used to reduce the time-sampling error that may occur in a station flood-frequency estimate.

(d) The flood-frequency flows and the maximum peak discharges at several stations in a region should be used whenever possible for comparison with the peak discharge estimated at an ungaged site using a rainfall-runoff approach or regional regression equation. The watershed characteristics at the ungaged and gaged sites should be similar.

(4) *National Resources Conservation Service (NRCS) Methods.* The Soil Conservation Service's SCS (former title) National Engineering Handbook, 1972, and their 1975, "Urban Hydrology for Small Watersheds", Technical Release 55 (TR-55), present a graphical method for estimating peak discharge. Most NRCS equations and curves provide results in terms of inches of runoff for unit hydrograph development and are not applicable to the estimation of a peak design discharge unless the design hydrograph is first developed in accordance with prescribed NRCS procedures. NRCS methods and procedures are applicable to drainage areas less than 3 square miles (approx. 2,000 acres) and result in a design hydrograph and design discharge that are functionally acceptable to form the basis for the design of highway drainage facilities.

819.3 Statistical Methods

Statistical methods of predicting stream discharge utilize numerical data to describe the process. Statistical methods, in general, do not require as much subjective judgment to apply as the previously described deterministic methods. They are usually well documented mathematical procedures which are applied to measured or observed data. The accuracy of statistical methods can also be measured quantitatively. However, to assure that statistical method results are valid, the method and procedures used should be verified by an experienced engineer with a thorough knowledge of engineering statistics.

The use of flow length alone as a limiting factor for the Kinematic wave equation can lead to circumstances where the underlying assumptions are no longer valid. Over prediction of travel time can occur for conditions with significant amounts of depression storage, where there is a high Manning's n-value or for flat slopes. One study suggests that the upper limit of applicability of the Kinematic wave equation is a function of flow length, slope and Manning's roughness coefficient. This study used both field and laboratory data to propose an upper limit of 100 for the composite parameter of $nL/s^{1/2}$. It is recommended that this criteria be used as a check where the designer has uncertainty on the maximum flow length to which the Kinematic wave equation can be applied to project conditions.

Where sheet flow travel distance cannot be determined, a conservative alternative is to assume shallow concentrated flow conditions without an independent sheet flow travel time conditions. See Index 816.6(2).

Table 816.6A
Roughness Coefficients For Sheet Flow

Surface Description	*n*
Hot Mix Asphalt	0.011-0.016
Concrete	0.012-0.014
Brick with cement mortar	0.014
Cement rubble	0.024
Fallow (no residue)	0.05
Grass	
Short grass prairie	0.15
Dense grass	0.24
Bermuda Grass	0.41
Woods[(1)]	
Light underbrush	0.40
Dense underbrush	0.80

(1) Woods cover is considered up to a height of 1 inch, which is the maximum depth obstructing sheet flow.

(2) *Shallow concentrated flow travel time.* After short distances, sheet flow tends to concentrate in rills and gullies, or the depth exceeds the range where use of the Kinematic wave equation applies. At that point the flow becomes defined as shallow concentrated flow. The Upland Method is commonly used when calculating flow velocity for shallow concentrated flow. This method may also be used to calculate the total travel time for both the sheet flow and the shallow concentrated flow segments under certain conditions (e.g., where use of the Kinematic wave equation to predict sheet flow travel time is questionable, or where the designer cannot reasonably identify the point where sheet flow transitions to shallow concentrated flow).

Average velocities for the Upland Method can be taken directly from Figure 816.6 (Source NRCS, National Engineering Handbook part 650) or may be calculated from the following equation:

$$V = (3.28)\ kS^{1/2}$$

Where S is the slope in percent and k is an intercept coefficient depending on land cover as shown in Table 816.6B. It is assumed that the depth range is 0.1 to 0.2 feet, except for grassed waterways, where the depth range is 0.1 to 0.4 feet,

Table 816.6B
Intercept Coefficients for Shallow Concentrated Flow

Land cover/Flow regime	k
Forest with heavy ground litter; hay meadow	0.076
Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland	0.152
Short grass pasture	0.213
Cultivated straight row	0.274
Nearly bare and untilled alluvial fans	0.305
Grassed waterway	0.457
Pavement and small upland gullies	0.620

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow