APPENDIX K – MAXIMUM PREDICTED DISCHARGE BASED ON STATION RECORDS AND ENVELOPE CURVE

1.0 Introduction

Many temporary structures and the vast majority of temporary water management (TWM) facilities are in place during the dry season, only. Mean daily exceedance discharges can be used to design most of these dry season facilities. The largest exceedance discharge is the 5 percent exceedance flow. This discharge, during an average year, is expected to be exceeded on 5 percent of the days during the specified month. This is one or two days during a typical month.

Some TWM and temporary construction features may be of too critical importance to use the 5 percent exceedance flow as either a design or check discharge. In these cases, the risk of damage or failure caused by a discharge exceeded one or two days a month is too great. Examples of these facilities could be cofferdams, water diversion pipes or temporary bridges on critical roadways, or work bridges.

These critical dry season facilities can be designed using the 5-year event as the design discharge and the 10 or 25-year event as the check discharge. This is done for TWM facilities and temporary construction to be in place all year or through the flood season. A dry season facility or structure designed using 5-year event discharges will almost always have enough hydraulic capacity for the dry season discharges. In most cases, it would have far too much hydraulic capacity and be unduly expensive.

The procedure described in this appendix is an alternative to using the 5-year discharge as a design or check flow for dry season structures and TWM facilities. The method is based on an envelope curve and the maximum mean daily discharges recorded at nearby stream gages during the months the TWM or temporary structure will be in place. It is intended to provide a maximum predicted discharge that is not expected to be exceeded during the dry season. The maximum predicted discharge is typically less than the 5-year event discharge and greater than the 5 percent mean daily exceedance flow.

Note: The maximum discharge predicted by the envelope curve is not necessary for many TWM or temporary structure applications. It is only calculated and reported if needed.

2.0 Limitations of Method

This procedure is based on daily discharges recorded at nearby gaging stations. Rarely are these nearby watersheds identical to the subject drainage to be studied. Local watershed characteristics can strongly influence the discharge magnitude, and these characteristics are often unique to the subject basin. In addition, there are often substantial differences in discharges from year-to-year due to variability in climate and water use. Some factors that influence daily flows are:

- climatic conditions such as rainfall, snowpack, and evaporation,
- the amount and type of vegetation in the riparian areas (vegetated riparian areas tend to sustain dry season flows),
- diversions to or from the subject stream,
- infiltration into exceptionally pervious rock formations or streambed materials,
- water entering the stream from springs and seeps,
- release or retention of streamflow in storage reservoirs, and
- consumptive uses such as livestock watering or irrigation.

Many of these factors are investigated when the exceedance discharges are calculated and water use and parol information is collected. This is discussed in **Chapter 7** Appendix J. The water use information and parol evidence should also be used to verify the results calculated by this procedure are reasonable. This is especially critical for streams in agricultural areas where considerable discharge could be routed through the project site during the irrigation season.

3.0 Gage Data Statistics

This procedure is based on the maximum mean daily recorded discharges at streamflow gages during the months the TWM or temporary construction will be in place. Daily statistics for gaged basins in Oregon and nearby states are available in tabular form on the United States Geological Service (USGS) website http://water.usgs.gov/ Daily discharge statistics are also summarized in the USGS "Water Resources Data – Oregon" books issued for each water year. A typical page is shown in the example.

The daily streamflow statistic used in this procedure is the maximum daily mean discharge for the water year during the months the TWM or temporary structure will be in place. These maximums are circled on Figure 2 in the example. The remarks from the stream gage records are also used, and they are inside the box shown on the figure.

Note: The remarks mentioning upstream storage, consumption, or diversions are not listed on the USGS website with the statistical data. They are included in the USGS annual books, as shown in Figure 1. The remarks pertaining to upstream storage, consumption, or diversions are also listed with the mean daily exceedance flow statistics on the ODOT Geo-Environmental Sections' Engineering and Asset Management Unit website. Remarks for many gages are also listed in the tables to ***Chapter 7*** *Appendix I.*

4.0 Procedure

There are six steps to the envelope curve discharge calculation procedure, and all are discussed in detail in this section and shown in a subsequent example. In summary, the process is as follows.

- Collect station statistics and determine the maximum discharges of record at suitable nearby gages.
- Calculate the yields from the maximum discharges of record, yields from the 5 percent exceedance discharges, and yields from the 5-year events.
- Plot the yields from the maximum discharges of record against the corresponding drainage areas. Draw an envelop curve that includes the maximum yields of record.
- Plot the yields from the 5 percent exceedance discharges and the 5-year events. Compare the envelope curve against these yields. This is done to verify that the envelope curve is reasonable.
- Calculate the discharge from the subject basin based on the envelope curve. This is the maximum discharge expected at the site based on data from nearby gages.
- Compare the discharge calculated in the previous step against water use and parole evidence.

Step 1 - Locate gages on the stream or in nearby similar watersheds. Locate the watersheds using guidelines in Appendix J for the exceedance discharges. Tabulate the maximum mean daily discharges during the months the TWM or temporary structure will be in place for each year of record. This is shown in Table 1 of the example.

Note: The gages used for the exceedance analysis are almost always suitable for this procedure. An exception is when the gage is on a watershed with significant upstream storage, consumptive use, or diversions, and the exceedance data is based on "natural" *stream flows that were adjusted to account for these factors. The monthly maximum daily flow data from the gage data will be based on "measured" stream flows and it will not have been adjusted. Data from this gage may be acceptable for the exceedance discharge calculations and it should not be used for the envelope curve analysis. A discussion of "natural" and "measured" stream flows is in Appendix J.*

Step 2 - Determine the maximum discharge of record for each gage during the period of the year when the TWM or temporary structure is in place in cubic feet per second. Use the data summarized in the previous step. Divide this maximum discharge by the gaged basin drainage area in square miles. This will calculate the highest recorded daily yield in cubic feet per second per square mile.

Determine the 5 percent exceedance yield for each basin by dividing the 5 percent exceedance discharge by the basin area. The 5 percent exceedance discharges are determined using procedures in Appendix J.

Determine the 5-year flood yields by dividing the 5-year event discharges by the drainage basin areas. The 5-year event discharges can be calculated by the log-Pearson method described in **Chapter 7** or they can be looked up in a suitable reference.

Note: The previous analyses should provide a single maximum recorded yield, 5 percent exceedance yield, and 5-year event yield for each gaged drainage basin. This is shown in Table 2 of the example.

Step 3 - Select a graph paper with a vertical scale large enough to include all of the yields ranging from the 5 percent exceedance yields up to the 5-year event yields. Assure the horizontal scale is large enough to encompass all of the drainage basin areas. Usually this is graph paper with logarithmic scales on both axes.

Plot the maximum yields of record determined in Step 2 against the drainage areas. Draw an envelope curve that encloses all of the yields of record that are not considered to be outliers. This is shown in Figure 3 of the example.

Note: Usually four to six gages are used in these analyses. Occasionally the maximum recorded yield from one of these basins is significantly larger than the corresponding yields from the others. It may be possible that this high yield was caused by a freak storm or a torrent due to a debris dam collapse, beaver or man-made dam failure, or other cause. This large flow may be considered to be a "high outlier" and not considered when the envelope curve is drawn.

Step 4 - Plot the yields from the 5 percent exceedance discharges determined in Step 3 for each basin on the graph. In general, the 5 percent exceedance yields are less than the peak discharge of record yields. All calculations and data should be carefully reviewed if this does not occur. An error is likely.

Plot the yields from the 5-year event on the graph. They should be significantly higher than the peak discharge of record yields if the following occurs:

- the TWM or temporary structures will be in place during the dry season, and
- the dry season has significantly less runoff than the flood season.

All calculations and supporting data should be reviewed if the period of the year used for the envelope curve is the dry season and the curve predicts yields similar to or greater than the 5-year yields.

Step 5 - Calculate the highest yield expected from the subject basin based on the envelope curve. This is shown in Figure 3 of the example. Estimate the highest expected discharge in cubic feet per second by multiplying the subject basin yield in cubic feet per second per square mile by the subject basin area in square miles.

Step 6 - Compare the calculated discharge from Step 5 against parole evidence collected during the exceedance discharge calculation procedure. Consider water use. The discharge calculated from the envelope curve should be greater than discharges routinely observed at the site. The cause should be investigated if this does not occur. One or more of the following may be possible:

- there is an error in the envelope curve procedure,
- the subject basin has drainage characteristics unlike nearby gaged basin, such as an underground water source (spring or seep),
- there is water diversion into the upstream watershed,
- the dry season flows are augmented by discharge from a wastewater treatment facility or other industrial source, or
- water stored during the flood season is released into the stream during the dry season.

The flow calculated in Step 5 may need to be adjusted using water use data and parol evidence.

5.0 Reporting Discharge Estimate

The maximum predicted discharge based on station records and envelope curve is listed in the TWM section of the Hydraulics Report and shown on the TWM plans. It may also be shown on the plan sheets for the temporary structures it applies to, such as cofferdams or workbridges. The following data should accompany the listed discharge:

- the starting and ending dates of the period of the year to which the discharge applies,
- the name or other description of the drainage,
- a statement saying the listed discharge is based on surface water runoff from the upstream watershed, if this is the case,
- a statement describing the discharge source if it is not surface runoff, and
- a statement saying the listed discharge is based on data from nearby gaged basins and discharges in the subject basin may differ.

The maximum predicted discharge can be included in the table accompanying the exceedance discharges. These notes do not need to be repeated if this is the case.

6.0 Example – Maximum Predicted Discharge Based on Station Records and Envelope Curve

Honey Creek is a small tributary to the North Umpqua River draining a forested mountain watershed. TWM and temporary construction may be in place during the in-water work period of July 1 through September 15. The watershed area is measured on a USGS 7.5 minute quadrangle map with a planimeter. It is 5.35 square miles. The mouth of the drainage basin is at elevation 850 feet.

One temporary feature will be a water diversion pipe under the North Umpqua Highway. This pipe will have minimal fill cover. It is critical that this pipe pass all discharges expected during the in-water work period with minimal upstream headwater elevation. This will keep the highway from overtopping and the pipe from washing out. The risk of potential damage and delay to traffic justifies use of the maximum predicted discharge as a diversion pipe check flow rather than the 5-percent discharge. The 5-percent discharge will be used as the design flow.

Step 1 - This watershed is in undeveloped condition. The basin has not been gaged. There are several gaged basins in the surrounding area on rural mountainous forested watersheds.

Gage data from six nearby basins will be used to estimate discharges from the Honey Creek basin. These basins are shown in Figure 1. They are:

Gage 14316495 Boulder Creek near Tokatee Falls, drainage area = 30.4 square miles, gage elevation = 1,640 feet. Boulder Creek is a tributary to the North Umpqua River to the east of Honey Creek.

Gage 14316700 Steamboat Creek near Glide, drainage area = 227 square miles, gage elevation = 1,128 feet. Steamboat Creek is another tributary to the North Umpqua River east of Honey Creek.

Gage 14317600 Rock Creek near Glide, drainage area = 97.4 square miles, gage elevation = 940 feet. Rock Creek is a tributary to the North Umpqua River to the west of Honey Creek.

Gage 14318000 Little River at Peel, drainage area = 177 square miles, gage elevation = 828 feet. Little River is another tributary to the North Umpqua River west of Honey Creek.

Gage 14319850 Gassy Creek near Nonpareil, drainage area = 9.19 square miles, gage elevation = 790 feet. Gassy Creek is a tributary to Calapooya Creek. The Calapooya drainage is adjacent to, and immediately to the north of, the North Umpqua River drainage.

Gage 14319900 Calapooya Creek at Nonpareil, drainage area = 88.6 square miles, gage elevation = 699 feet.

Daily discharge data is available for all of these watersheds from the USGS website or annual USGS "Water Resources Data – Oregon" publications. A page from the Water Year 1988 publication listing Calapooya Creek data is shown in Figure 2. The "Remarks" tell whether or not the stream was regulated or had major diversions during the water year. The remarks for Calapooya Creek are enclosed in a box drawn on Figure 2. The remarks state there are minor diversions, only. Regulation is not mentioned. No reservoirs are shown on the USGS 7-1/2 minute quadrangle map. It is assumed the watershed is unregulated. This step was repeated for each of the other five watersheds to verify they were unregulated.

The maximum recorded daily mean discharges in Calapooya Creek during July, August, and September of the 1988 Water Year period are circled. This step is repeated for the other five gages for each year of record. The maximum discharges are tabulated for each gage. The tabulation for the Calapooya Creek gage is shown in Table 1.

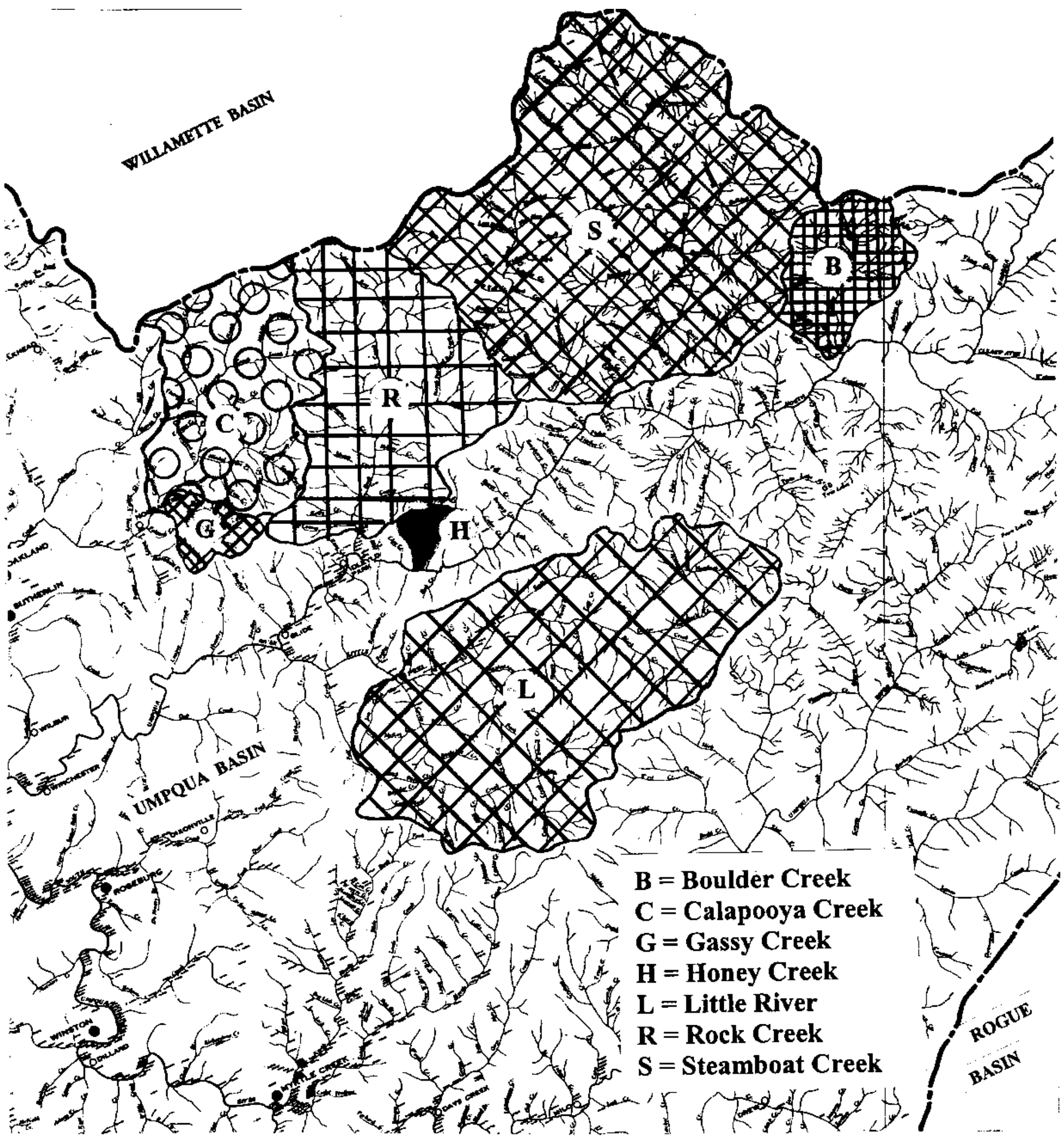

Figure 1 Location of Nearby Watersheds

236 NORTH UMPQUA RIVER BASIN

14319900 CALAPOOYA CREEK AT NONPAREIL, OR

LOCATION.--Lat 43°25′04″, long 123°09′13″, in SW 1/4 SE 1/4 sec.3, T.25 S., R.4 W., Douglas County, Hydrologic Unit 17100303, on left bank 0.3 mi upstream from county road bridge, 0.9 mi northeast of Nonpareil, and at mile 26.7.

DRAINAGE AREA.--88.6 mi^2.

PERIOD OF RECORD.--July 1976 to September 1988 (discontinued).

GAGE.--Water-stage recorder and crest-stage gage. Datum of gage is 699.22 ft above National Geodetic Vertical Datum of 1929 (Douglas County Survey bench mark).

REMARKS.--Records good except those for estimated daily discharges and periods of backwater Oct. 1 to Dec. 3 and July 19 to Sept. 30, which are fair. Only minor diversions by pumping for irrigation upstream from station. Several measurements of water temperature were made during the year.

AVERAGE DISCHARGE.--12 years, 201 ft^3/s, 30.81 in/yr, 145,600 acre-ft/yr.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 7,640 ft^3/s Dec. 6, 1981, gage height, 11.16 ft; minimum discharge, 3.7 ft^3/s Sept. 23-25, 1987.

EXTREMES FOR CURRENT YEAR.--Peak discharges greater than base discharge of 2,700 ft^3/s and maximum (*):

Date	Time	Discharge (ft^3/s)	Gage height (ft)	Date	Time	Discharge (ft^3/s)	Gage height (ft)
Jan. 10	0730	*3,040	*7.49	No other peak greater than base discharge.			

Minimum discharge, 4.1 ft^3/s Oct. 2.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	4.8	11	112	142	e300	111	159	276	538	46	17	9.6
2	4.5	17	194	128	e250	100	164	281	472	44	18	9.0
3	4.5	18	460	126	e210	113	313	374	404	46	16	7.7
4	5.2	13	534	129	e190	132	406	397	320	47	14	7.2
5	6.5	12	362	128	e170	195	377	356	266	43	13	7.0
6	6.8	12	427	123	e160	238	321	340	221	42	13	7.2
7	6.5	12	482	120	e150	242	341	570	200	38	13	7.9
8	5.9	12	345	141	e140	231	299	528	178	36	12	8.2
9	6.8	14	313	480	e200	513	259	476	183	34	10	8.3
10	7.5	15	1020	2340	e550	493	220	385	259	32	9.9	7.5
11	7.7	14	634	1410	e400	345	186	304	225	31	11	7.4
12	7.1	37	362	833	e330	262	162	274	187	32	13	7.5
13	6.1	46	253	553	e280	213	146	315	160	30	12	6.9
14	5.4	51	199	717	e230	181	156	268	141	30	13	6.3
15	6.8	31	185	e1450	e200	159	140	234	124	30	13	5.5
16	7.3	32	283	976	e190	142	130	252	111	28	13	5.9
17	7.7	28	234	665	e170	126	128	245	101	26	13	6.7
18	7.4	22	180	478	e140	115	123	221	93	25	13	7.4
19	7.4	17	151	358	128	107	122	195	87	24	12	17
20	7.6	14	131	e280	123	100	125	174	81	23	11	21
21	7.3	16	159	e240	118	97	432	158	73	22	10	12
22	7.0	18	211	e220	113	93	538	144	68	21	9.9	9.3
23	6.8	29	226	e210	108	133	387	133	65	21	9.1	8.2
24	6.8	42	200	e220	103	142	283	124	62	20	8.0	7.7
25	6.8	68	172	e200	97	148	227	117	59	20	8.9	7.9
26	6.5	38	152	e190	94	161	190	110	58	20	9.0	12
27	6.6	27	137	e180	90	225	164	104	56	19	9.2	26
28	6.8	21	133	e190	87	231	150	122	54	18	9.5	17
29	6.4	17	145	e220	84	217	178	138	56	17	9.6	12
30	6.8	19	142	e340	---	199	215	137	50	16	9.7	9.9
31	8.7	---	155	e400	---	174	---	142	---	17	9.5	---
TOTAL	206.0	723	8693	14187	5405	5938	7041	7894	4952	898	362.3	293.2
MEAN	6.65	24.1	280	458	186	192	235	255	165	29.0	11.7	9.77
MAX	8.7	68	1020	2340	550	513	538	570	538	47	18	26
MIN	4.5	11	112	120	84	93	122	104	50	16	8.0	5.5
AC-FT	409	1430	17240	28140	10720	11780	13970	15660	9820	1780	719	582
CFSM	.08	.27	3.17	5.17	2.10	2.16	2.65	2.87	1.86	.33	.13	.11
IN.	.09	.30	3.65	5.96	2.27	2.49	2.96	3.31	2.08	.38	.15	.12

CAL YR 1987 TOTAL 46310.5 MEAN 127 MAX 1580 MIN 3.7 AC-FT 91860 CFSM 1.43 IN. 19.44
WTR YR 1988 TOTAL 56592.5 MEAN 155 MAX 2340 MIN 4.5 AC-FT 112300 CFSM 1.75 IN. 23.76

e Estimated

Figure 2 Page from USGS Annual "Water Resources Data – Oregon" Publication

HIGHEST MEAN DAILY FLOW FOR MONTHS
TWM OR TEMPORARY STRUCTURES WILL BE IN-PLACE

CALAPOOYA CREEK GAGE # 14319900			
WATER YEAR	JULY HIGHEST DISCHARGE[1]	AUGUST HIGHEST DISCHARGE[1]	SEPTEMBER HIGHEST DISCHARGE[1]
1976	36	101	23
1977	26	39	135
1978	59	56	188
1979	30	25	56
1980	173	54	20
1981	51	14	207
1982	50	23	74
1983	234	94	56
1984	69	23	18
1985	51	14	207
1986	50	13	373[2]
1987	189	33	11
1988	47	18	26

[1] All discharges in cubic feet per second.
[2] Highest recorded daily discharge for period of record during TWM work period. This discharge is used in subsequent basin yield calculation.

Table 1 Highest Monthly Mean Daily Discharge Tabulation for Period of Record

Step 2 - The highest daily mean discharge during the period of record is determined for each of the six gages. This discharge for Calapooya Creek is 373 cubic feet per second. This occurred in September 1986 during the 1976 through 1988 period of record, as shown in Table 1.

The highest mean daily discharges for all six gages, in cubic feet per second, are divided by their respective drainage areas in square miles. This calculates the highest yields of record during the in-water work period in cubic feet per second per square mile. Table 2 shows these yields for all six gages. The yield from the Calapooya Creek basin is 4.2 cubic feet per second per square mile.

The 5 percent exceedance discharges were calculated using procedures in **Chapter 7** Appendix J. These discharges are divided by their respective drainage areas to get the 5 percent exceedance yields shown in Table 2. The largest 5 percent yield for the Calapooya Creek basin is predicted to occur in July and it is 0.73 cubic feet per second per square mile.

The 5-year event discharges were calculated using log-Pearson Type III procedures as discussed in **Chapter 7**. These discharges are divided by their respective drainage areas to get the 5-year event yields listed in Table 2. The 5-year event yield from the Calapooya Creek basin is estimated to be 67 cubic feet per second per square mile.

YIELDS FOR MONTHS TWM WILL BE IN PLACE
BASINS NEAR HONEY CREEK

GAGE	DRAINAGE AREA (Square miles)	WATER YEAR	MONTH OF HIGHEST DAILY DISCHARGE	HIGHEST DAILY DISCHARGE[1]	HIGHEST YIELD[2,3]	5 PERCENT EXCEEDENCE YIELD[2,4]	5-YEAR FLOOD YIELD[2,5]
14319850	9.19	1993	JULY	12	1.3	.24	110
14319900	88.6	1986	SEPTEMBER	373	4.2	.73	67
14316495	30.4	1999	JULY	79	2.6	1.6	-- [6]
14316700	227.0	1986	SEPTEMBER	2220	9.8	.83	93
14317600	97.4	1971	SEPTEMBER	334	3.4	.96	106
14318000	177.0	1986	SEPTEMBER	1360	7.6	.73	76

[1] All discharges in cubic feet per second.
[2] All yields in cubic feet per second per square mile.
[3] Highest yield based on highest recorded daily discharge during TWM work period.
[4] Largest of the monthly 5% exceedence discharges calculated for the TWM work period.
[5] 5- year floods for gaged watersheds based on log-Pearson Type III analyses.
[6] Log-Pearson analysis not done: Insufficient years of record.

Table 2 Yield Tabulations for Each Gage

Step 3 - The highest yields for the periods of record are plotted on logarithmic graph paper versus the drainage areas. An envelope curve is drawn to include all yields of record except high outliers. The six data points and an example curve is shown in Figure 3.

None of the six points appear to be an outlier. An outlier would be a data point that did not fit the pattern established by the other data points, and it would indicate an exceptionally high or low yield from a basin. The cause of an exceptional event would be investigated. Possible causes are discussed in the previous section. Professional judgment would be used to decide whether or not to include this exceptional yield within the envelope curve.

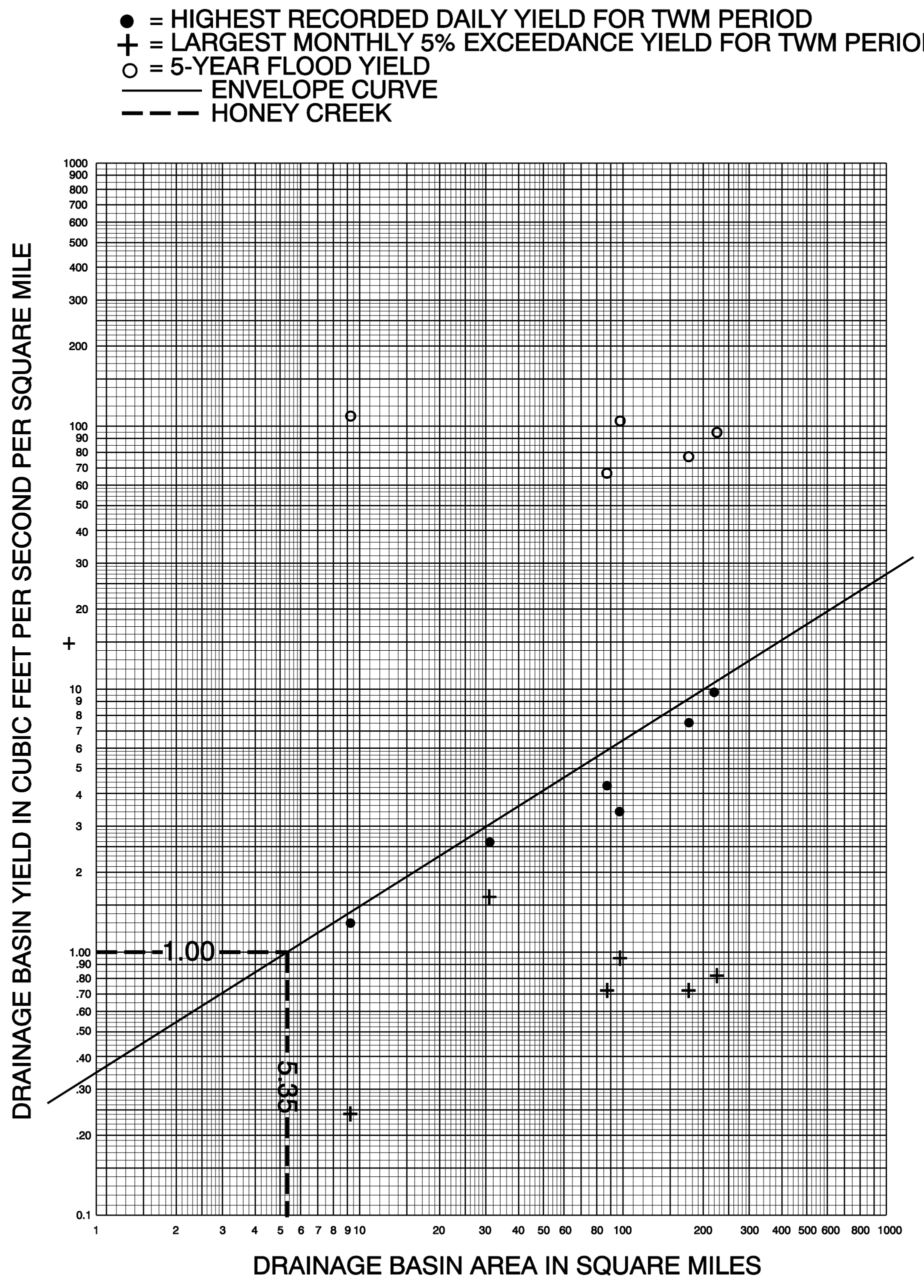

Figure 3 Envelope Curve for Highest Expected Discharge During TWM Period

Step 4 - Both the 5 percent exceedance discharges and 5 year event yields are plotted on the graph versus their respective drainage areas. The envelope curve is compared to these yields. The curve is lower than the 5-year yields and higher than the 5 percent exceedance discharges, as shown in Figure 3. This is a typical case. The cause would be investigated if it was otherwise. There may be errors in the calculation procedures.

Step 5 - The highest yield expected from the subject basin is determined from the envelope curve, as shown in Figure 3. It is 1.0 cubic feet per second per square mile. This is multiplied by the 5.35 square mile Honey Creek drainage basin area to get a maximum predicted discharge of 5.3 cubic feet per second.

Step 6 - Water use and parol evidence are considered in this step. Permitted water use in the upstream watershed was determined from information on the OWRD website, as discussed in **Chapter 7** Appendix J. The OWRD Water Rights Point of Diversion Summary lists total permitted withdrawls of 0.76 cubic feet per second. Most of these withdrawls are from small ponds, reservoirs, or tributary creeks on the ridges surrounding the Honey Creek drainage. They are not expected to significantly influence the maximum predicted discharge. One permitted withdrawl is directly from Honey Creek. It is 0.01 cubic feet per second for irrigation. This loss is considered to be minor, and it is not included in the maximum predicted discharge calculations.

Parol evidence was collected by interviewing people familiar with Honey Creek. Nothing in the parol evidence indicates the calculated 5.3 cubic foot per second maximum predicted discharge is not realistic.

Step 7 - The maximum predicted discharge is reported as shown in Figure 4. It is reported along with the exceedance discharges.

HONEY CREEK
ESTIMATED DISCHARGES
FOR TEMPORARY WATER MANAGEMENT

	AVERAGE DAILY DISCHARGE IN CUBIC FEET PER SECOND (GALLONS PER MINUTE)		
NOTE	**1**	**2**	**3**
JULY	4.7 (2100)	2.1 (940)	1.4 (630)
AUGUST	1.7 (760)	0.93 (420)	0.65 (290)
SEPTEMBER	1.4 (630)	0.81 (360)	0.49 (220)
MAXIMUM PREDICTED DISCHARGE			
JULY 1 – SEPTEMBER 30			5.3 (2400)

1) 5 Percent Exceedance Discharge (Average daily discharge expected to be exceeded 2 days each month.)
2) 25 Percent Exceedance Discharge (Average daily discharge expected to be exceeded 8 days each month.)
3) 50 Percent Exceedance Discharge (Average daily discharge expected to be exceeded 16 days each month.)

Discharges are not expected to exceed the maximum predicted discharge.

In-water work period extends from 1 July through 15 September. Temporary water management shown on plans recommended throughout in-water work period. Listed discharges are surface water runoff from the upstream watershed. The estimated discharges are based on nearby gaged basins. Discharges in the subject watershed may differ.

Figure 4 Table Reporting Maximum Predicted Discharge