Section 1

Probability, Risk, & Rainfall

Observed Flow Probability Example

Year	Observed Flow	Probability of Occurring	Return Frequency
1983	1,000		
1984	750		
1985	2,500	2/10 => 20% Chance	5 year
1986	1,250		
1987	850		
1988	1,500	5/10 => 50% Chance	2 year
1989	1,700	4/10 => 40% Chance	
1990	4,000	1/10 => 10% Chance	10 year
1991	1,300		
1992	2,000	3/10 => 30% Chance	

Return Frequency vs. Occurrence

Return Frequency	Chance Of Occurring In Any Given Year
2 year	50%
10 year	10%
25 year	4%
100 year	1%
500 year	0.2%

Washington State Department of Transportation

Project _____ Sheet No. _____ of _____ Sheet

S.R. _____ Made by _____ Checked by _____ Date _____ Supv. _____

Log-Pearson Type III Distribution

$$\overline{\log X} = \frac{\Sigma \log X}{n}$$

$$\sigma_{\log x} = \left(\frac{\Sigma (\log X - \overline{\log X})^2}{n-1} \right)^{1/2}$$

$$G = \frac{n \Sigma (\log X - \overline{\log X})^3}{(n-1)(n-2)(\sigma_{\log x})^3}$$

G = Skew Coefficient $\Rightarrow K$

$$\log X = \overline{\log X} + K \sigma_{\log x}$$

Gumbel Distribution

$$y = -\ln(-\ln(1-p))$$

p = probability of occurrence

$$X = \bar{X} + (0.7797 y - 0.45) \sigma_x$$

RUNOFF DATA

RIVER BASIN --- KLICKITAT

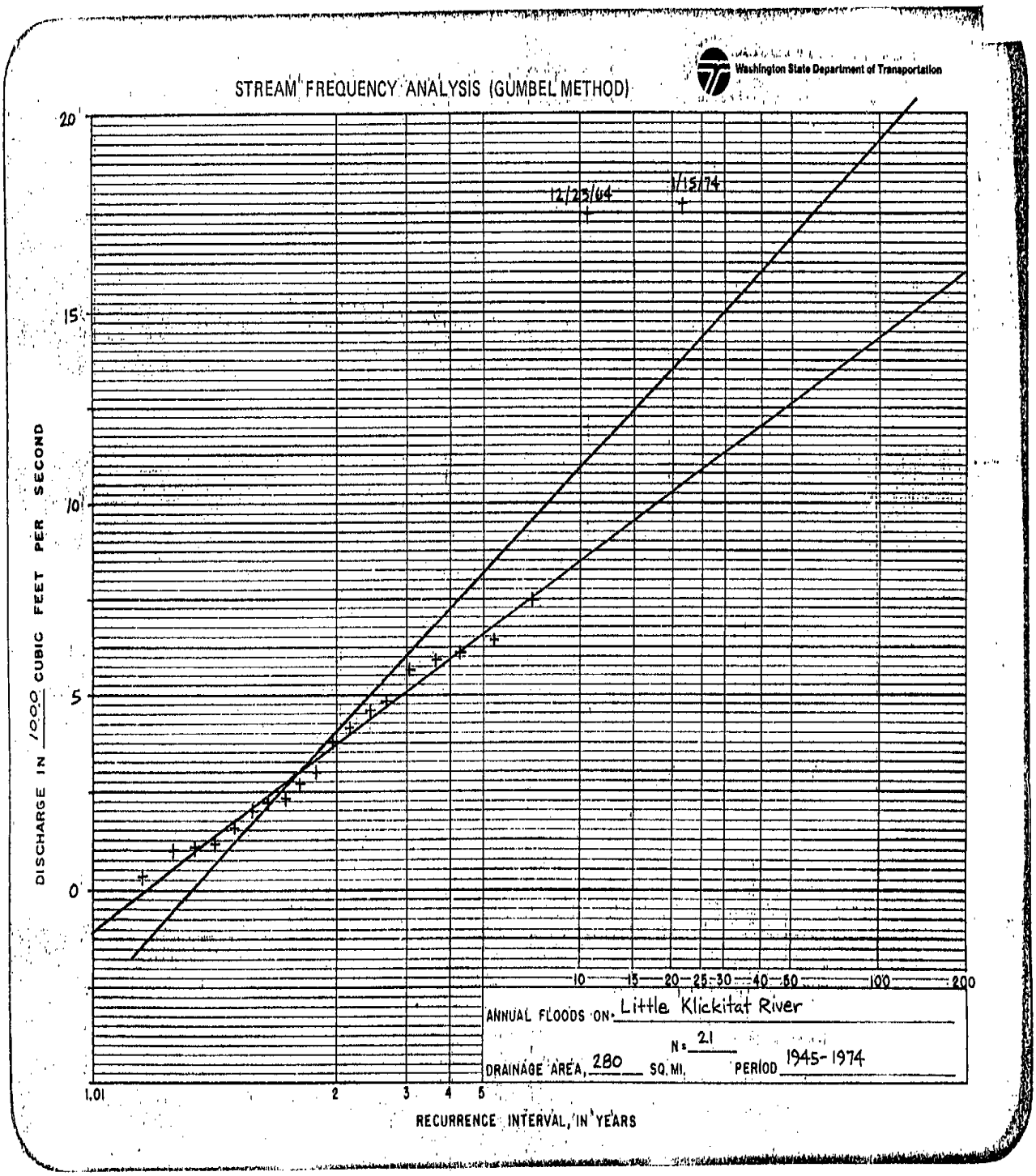
LITTLE KLICKITAT RIVER NR WAHKIACUS, WN.

DRAINAGE AREA 280.0 SQ. MI.

WATER YEAR	DATE	PEAK DISCHARGE, CFS
1974	01-15-74	17,500.0
1965	12-23-64	17,300.0
1948	01-07-48	7,000.0
1948	12-28-47	6,600.0
1961	02-10-61	5,960.0
1949	02-17-49	5,820.0
1956	12-21-55	5,500.0
1963	02-03-63	4,720.0
1952	02-04-52	4,450.0
1953	01-09-53	4,140.0
1951	02-09-51	3,700.0
1958	02-16-58	2,830.0
1964	01-25-64	2,540.0
1954	02-21-54	2,410.0
1957	03-09-57	2,290.0
1959	01-12-59	1,910.0
1947	12-15-46	1,530.0
1960	03-29-60	1,050.0
1962	12-20-61	1,000.0
1945	02-08-45	932.0
1955	04-13-55	304.0

200 yr. =21,468	17,500	66 yr
100 yr. =19,002	17,300	62 yr.
25 yr. = 14,032		
10 yr. = 10,670		
2 yr. = 3,991		

9/PD(HYD)-1


Washington State Department of Transportation
STREAM FREQUENCY ANALYSIS (GUMBEL METHOD)
DISCHARGE IN 1000 CUBIC FEET PER SECOND
20
15
10
5
0
12/23/64
1/15/74
10
15
20
25
30
40
50
100
200
1.01
2
3
4
5
RECURRENCE INTERVAL, IN YEARS
ANNUAL FLOODS ON Little Klickitat River
N = 21
DRAINAGE AREA, 280 SQ. MI.
PERIOD 1945-1974

1-4

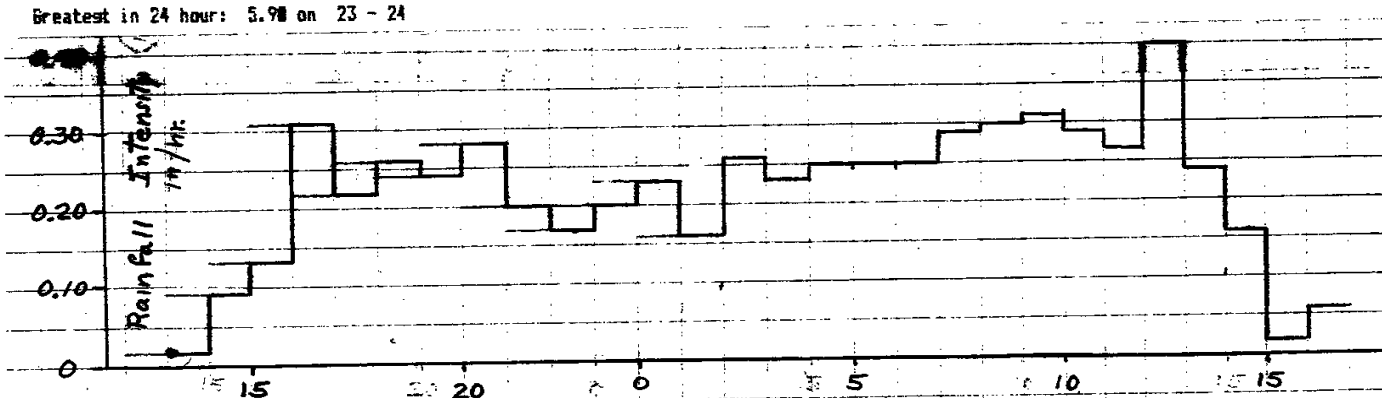
Station: WSO OLYMPIA WA
Date: NOV 1990 To convert LST to UTC: +8

Col.40 Hourly Precipitation

November 1990

Day	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
1																									
2																						T	0.01	0.01	0.02
3	T	0.01	0.01	0.02	T		0.01	0.01	0.01	T	0.08	0.03	0.05	0.04	0.03	0.02	0.01	T	T	T		0.01	T		0.34
4				0.03	0.11	0.06	0.04	T							T										0.24
5																									
6																						T	0.03	0.02	0.05
7	0.04	0.02	0.01	0.03	0.02	0.07	0.04	T			T	T	T	T											0.23
8		T			T	T								T	T	0.02	0.03	0.02	0.07	0.03	0.02	T			0.19
9				T	T	T	0.03	0.12	0.15	0.20	0.17	0.13	0.10	0.05	0.08	0.06	0.08	0.07	0.06	0.02	0.01	0.06	0.03	0.06	1.52
10	0.02	T	0.03	0.01	0.05	0.01	T	T	T	T	0.03	T	T	T	T			0.02	T						0.17
11																									
12																		0.03	0.13	0.10	0.17	0.04	T	0.02	0.49
13	0.04	0.07	0.05	0.05	0.22	0.10	0.07	T	T	0.01	0.01	T		0.05	0.01	0.10	T			0.01	0.09	0.03		T	0.91
14	0.09	T											0.01	0.20	0.04	0.05	0.06	0.01	0.01	T		0.01	0.02	0.02	0.52
15	0.01	0.02	0.01	T	T		T	T		T	T	T	T												0.04
16																					T			0.01	0.01
17	0.01	0.04	0.08	0.07	0.01		0.01	T	T	T	T	T													0.22
18																									
19									T	T	T	0.01	0.02	T					T	T	T	0.01			0.04
20											T	T			T	0.01	T	0.02	T	T	T	T	0.01	0.06	0.10
21	0.01	0.01	T					T	0.01	0.01	0.03	0.04	0.07	0.10	0.08	0.09	0.22	0.19	0.10	0.06	0.02	0.01	0.01	0.01	1.07
22	T	0.01	T	T	T	T	T	0.09	0.07	0.06	0.07	0.01	0.01	0.02	0.03	0.03	0.01	T	0.06	0.02				T	0.49
23	T	T	0.04	0.05	0.11	0.05	0.04	0.02	0.02	T	0.02	0.03	0.04	0.02	0.09	0.13	0.31	0.22	0.26	0.24	0.28	0.20	0.17	0.20	2.54
24	0.23	0.16	0.26	0.23	0.25	0.25	0.25	0.29	0.30	0.31	0.29	0.27	0.40	0.24	0.16	0.02	0.06	0.04	T	T		0.01	0.04	0.02	4.08
25	0.01	0.01	0.01		0.01	0.01		0.04	0.02	0.05	0.02	T													0.18
26														T	0.01	T	T		0.01	0.04	0.11	0.10	0.01	0.01	0.29
27				T	T					T	T													0.01	0.01
Day	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
	0.46	0.35	0.50	0.49	0.78	0.55	0.49	0.57	0.58	0.64	0.72	0.52	0.70	0.72	0.53	0.53	0.78	0.62	0.72	0.52	0.70	0.50	0.33	0.45	13.75

Greatest in 24 hour: 5.90 on 23 - 24



Fri. Nov. 23, 1990 → ← Sat. Nov. 24, 1990

MRI

0.96 in/3hr | 0.32 in/hr. — 2 yr

5.90 in/24 hrs = 0.246 in/hr. — 10 yr

3.34 in/12 hrs = 0.278 in/hr. — 12 yr

1.86 in/6 hr = 0.310 in/hr. — 6 yr

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Jan 9, 1990 Olympia Rainfall Record

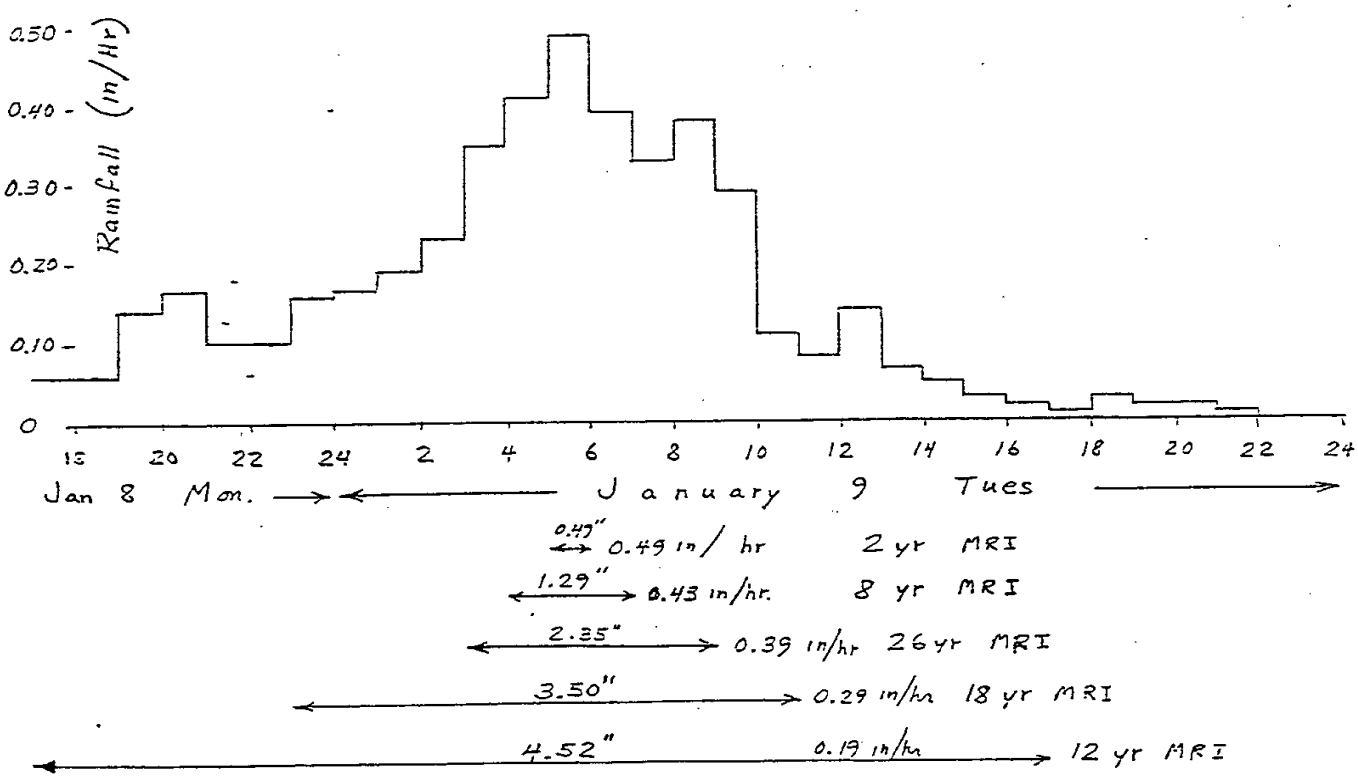
Station: WSO OLYMPIA WA
Date: JAN 1990 To convert LST to UTC: +8

Col.40 Hourly Precipitation

Day	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
1	0.39	0.13	0.01	0.01	0.02	0.02	0.01	T	0.01	T					T	T	0.02					0.02	0.02		0.35
2																						0.01			0.01
3				T	T		T	T	T	T	T	T	0.01	0.03	0.07	0.02	T	0.04	T	T	T	T	0.03	0.02	0.22
4	0.06	0.05	0.07	0.11	0.10	0.09	T	T	0.02	0.01	T	T	T	T											0.51
5				T	T	0.04	0.07	0.02	0.04	0.01	T	0.01	T	0.02	0.12	0.16	0.19	0.01					0.03	T	0.72
6	T											0.01	0.01	T	0.04	0.07	0.10	0.10	0.13	0.16	0.14	0.15	0.23	0.14	1.29
7	0.04	0.01	0.04		0.01	0.02	T			T	T	0.09	T	T	0.01	0.01	0.08	0.09	0.07	0.08	0.03	0.05	0.11	0.08	0.84
8	0.17	0.20	0.01	T		T	T	T	0.01		0.01	0.01					T	0.06	0.06	0.14	0.17	0.10	0.10	0.16	1.20
9	0.17	0.19	0.23	0.35	0.41	0.49	0.37	0.33	0.38	0.29	0.11	0.08	0.14	0.07	0.05	0.03	0.02	0.01	0.03	0.02	0.02	0.01			3.82
10																									
11					T	T	T					T	0.02	0.03	0.02										0.07
Day	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
	0.52	0.58	0.36	0.47	0.54	0.66	0.47	0.35	0.46	0.31	0.12	0.19	0.18	0.15	0.31	0.29	0.41	0.31	0.29	0.40	0.36	0.37	0.52	0.40	9.82

Greatest in 24 hour: 4.52 on 8 - 9

4.5



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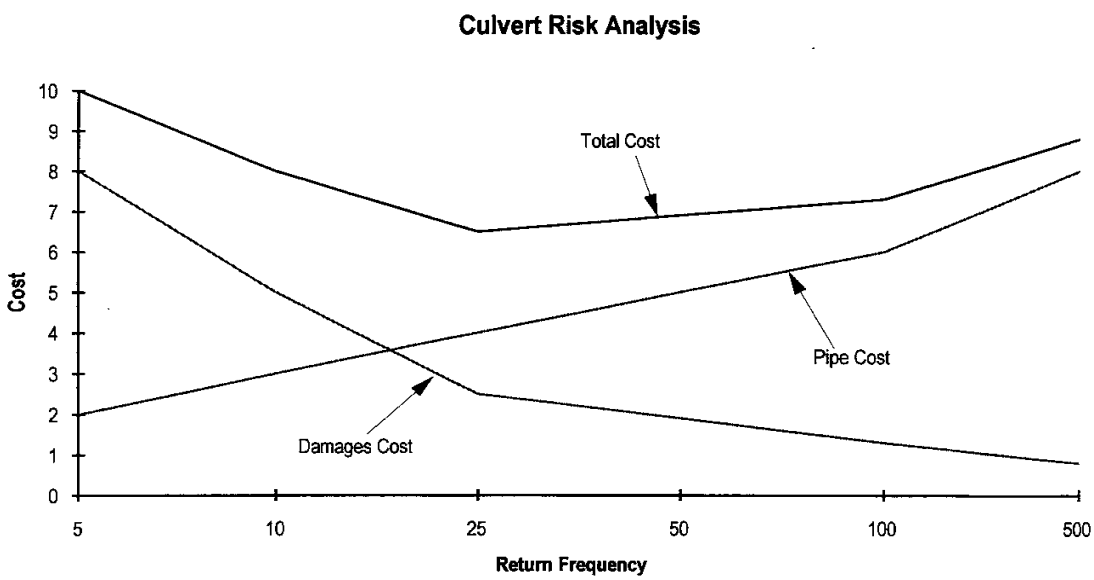
Culvert Risk Analysis
Cost
10
9
8
7
6
5
4
3
2
1
0
Total Cost
Pipe Cost
Damages Cost
5
10
25
50
100
500
Return Frequency

Type of Structure	MRI (Years)
Gutters	10
Storm Drain Inlets — On Longitudinal Slope	10
Storm Drain Inlets — Vertical Curve Sag	50
Storm Drain Laterals	10
Storm Drain Trunk Lines	25
Ditches	10
Standard Culverts — Design For HW/D Ratio	25
Standard Culverts — Check For High Flow Damage	100
Bottomless Culverts — Design For HW Depth	25 and 100
Bridges — Design For Flow Passage And Foundation Scour	100
Bridges — Check For High Flow Damage	500

Figure 1-4

Design Frequency for Hydraulic Structures