USACE Methods for Quantifying Extreme Flood Hazards

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USACE DAM SAFETY PROGRAM

PORTFOLIO RISK ASSESSMENT (PRA)

INFLOW FLOOD HYDROGRAPHS

METHODOLOGY & EXAMPLE APPLICATIONS

Wolf Creek Dam Spillway

NOVEMBER 2008

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314-1000

ETL 1110-2-XXX

CEXX-XX

Technical Letter
No. 1110-2-XXX

30 September 2012

EXPIRATION DATE
Engineering and Design
FREQUENCY CURVE EXTENSION FOR EXTREME FLOOD EVENTS

1. Purpose. This engineer technical letter (ETL) provides guidance for the development of inflow frequency curves that extend to the Probable Maximum Flood (PMF). The inflow frequency needs to address both the peak inflow and the volume associated with events of various durations. Furthermore, the coincident basin condition downstream of a project needs to be appropriately correlated with the hydrologic scenario that is defining the project inflow.

2. Applicability. This ETL applies to all HQUSACE elements and all USACE commands having Civil Works responsibility for hydrologic analysis associated with dam safety studies, and other projects that require analyzing flow frequencies out to very rare events.

3. Distribution Statement. Approved for public release, distribution is unlimited.

4. References. See Appendix A.

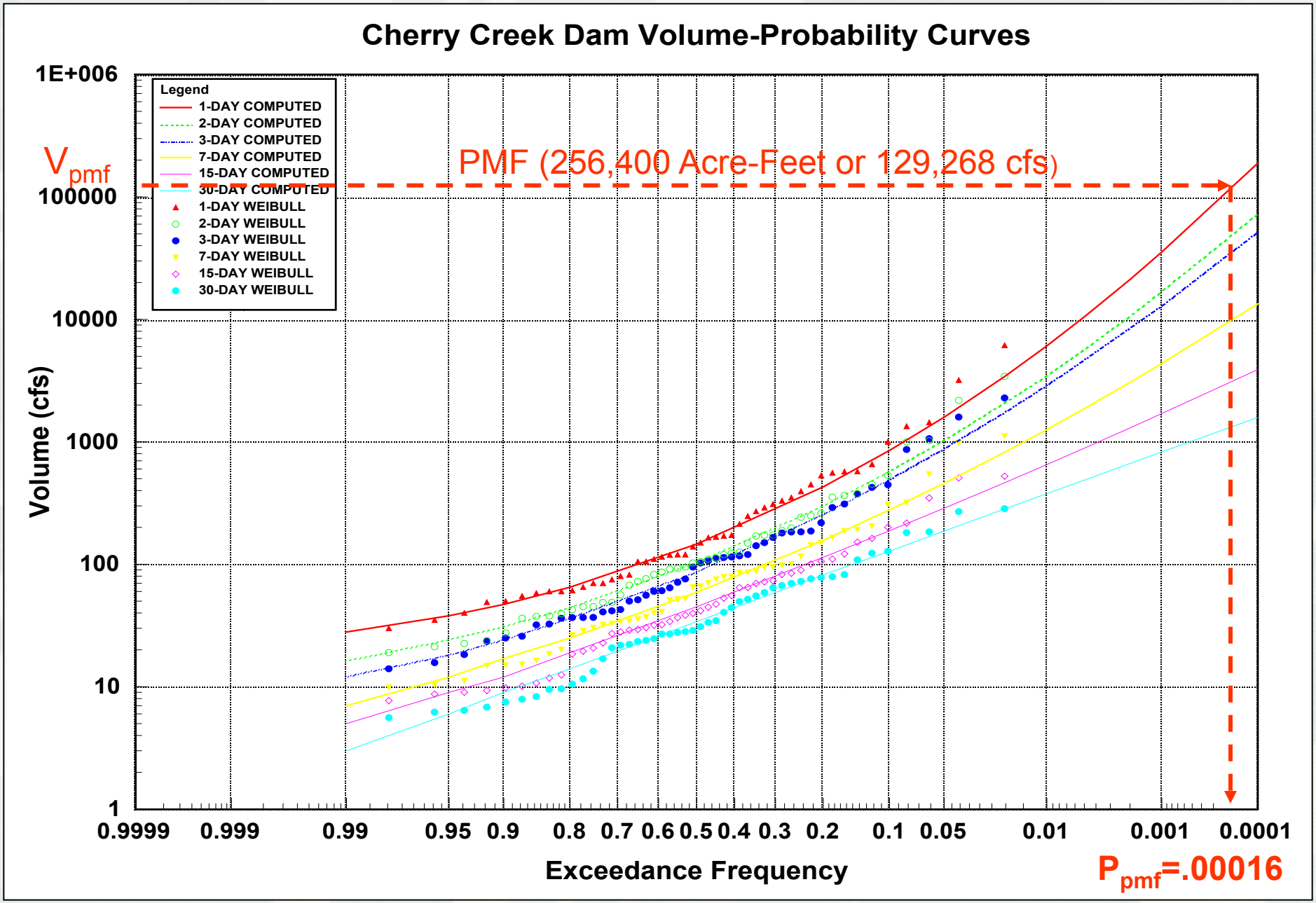
5. Discussion. Currently there is no credible scientific approach to assign a single probability to a flood of the magnitude of the PMF. Additionally, no single method exists for extending gaged frequency curves out to the PMF level. This ETL presents a process for development of credible estimates of infrequent Annual Exceedance Probabilities (AEP) that rely on the use of data from multiple sources and a regional approach.

Quantification of the frequency curve out to rare events, such as the PMF, is necessary to evaluate the hydrologic risk for any project. Per the National Weather Service, the Probable Maximum Precipitation (PMP) is theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of the year. The PMF is a function of the PMP and basin conditions and is characterized as the upper limit of hydrologic loading for the Corps dams. While the frequency curves must be defined out to the PMF, more emphasis needs to be placed on defining the curves from the 100-year to the 5,000-year event, as this area of the curve plays a much more important role in the Portfolio Risk Assessment (PRA) analysis. Several techniques have been identified as candidates for use. The technical basis, data and resource requirements for each are summarized in the following chapters. As several of these various techniques may be used for any project, a method is described for blending the resultant frequency curves to prepare the adopted frequency curve. It is important to note that the application of these methods requires an experienced

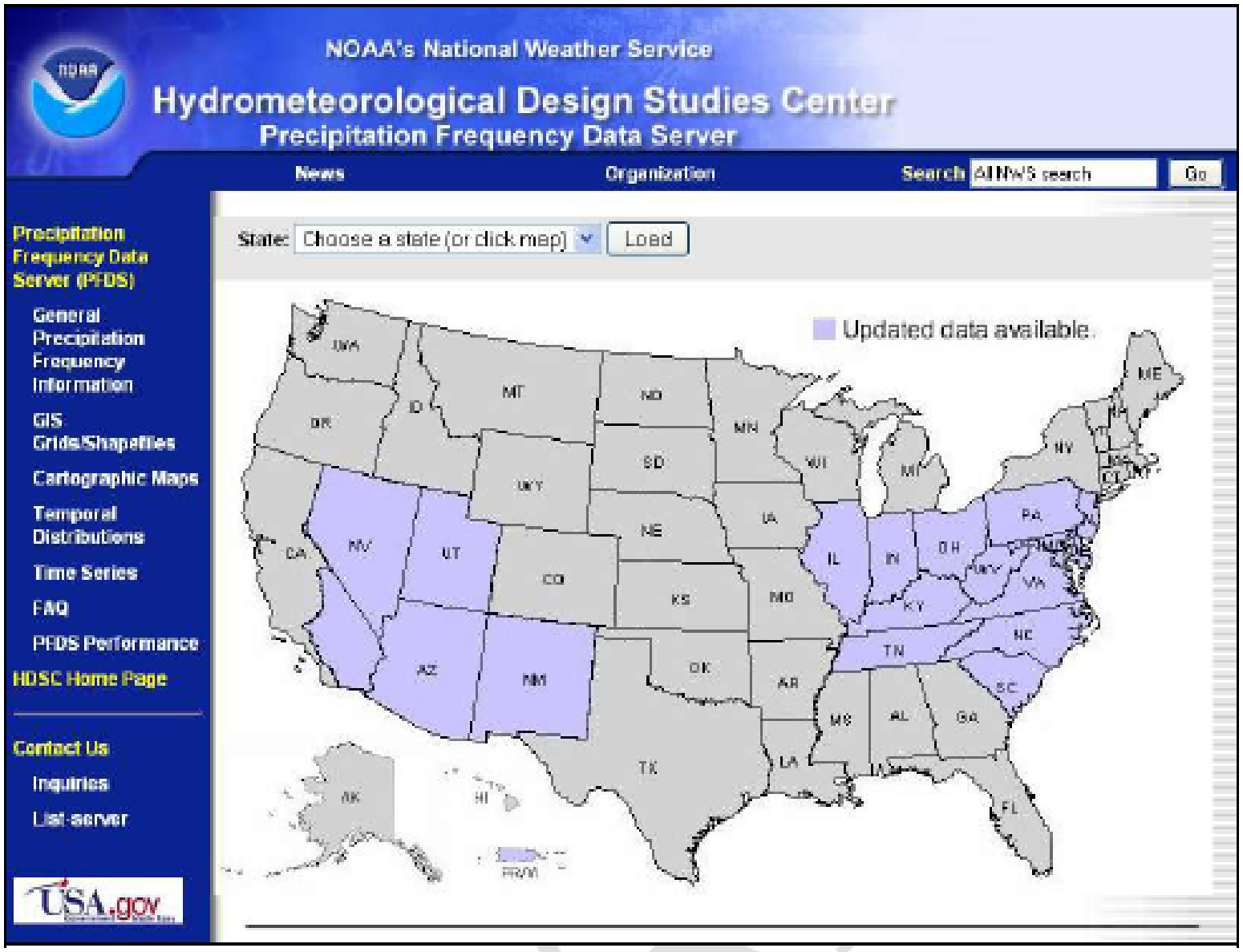
Methods to Extend Frequency Curves

1. Extension using Bulletin 17B Methods
2. Hydrologic Modeling using frequency based storm events
3. Regional Probability of the PMF
4. Stochastic Event Flood Model (SEFM)
5. Application of the GRADEX Method
6. Utilization of Paleoflood Information

Extension using Bulletin 17B Methods



Hydrologic Modeling Using Frequency Based Storm Events



http://www.nws.noaa.gov/ohd/hdsc/index.html

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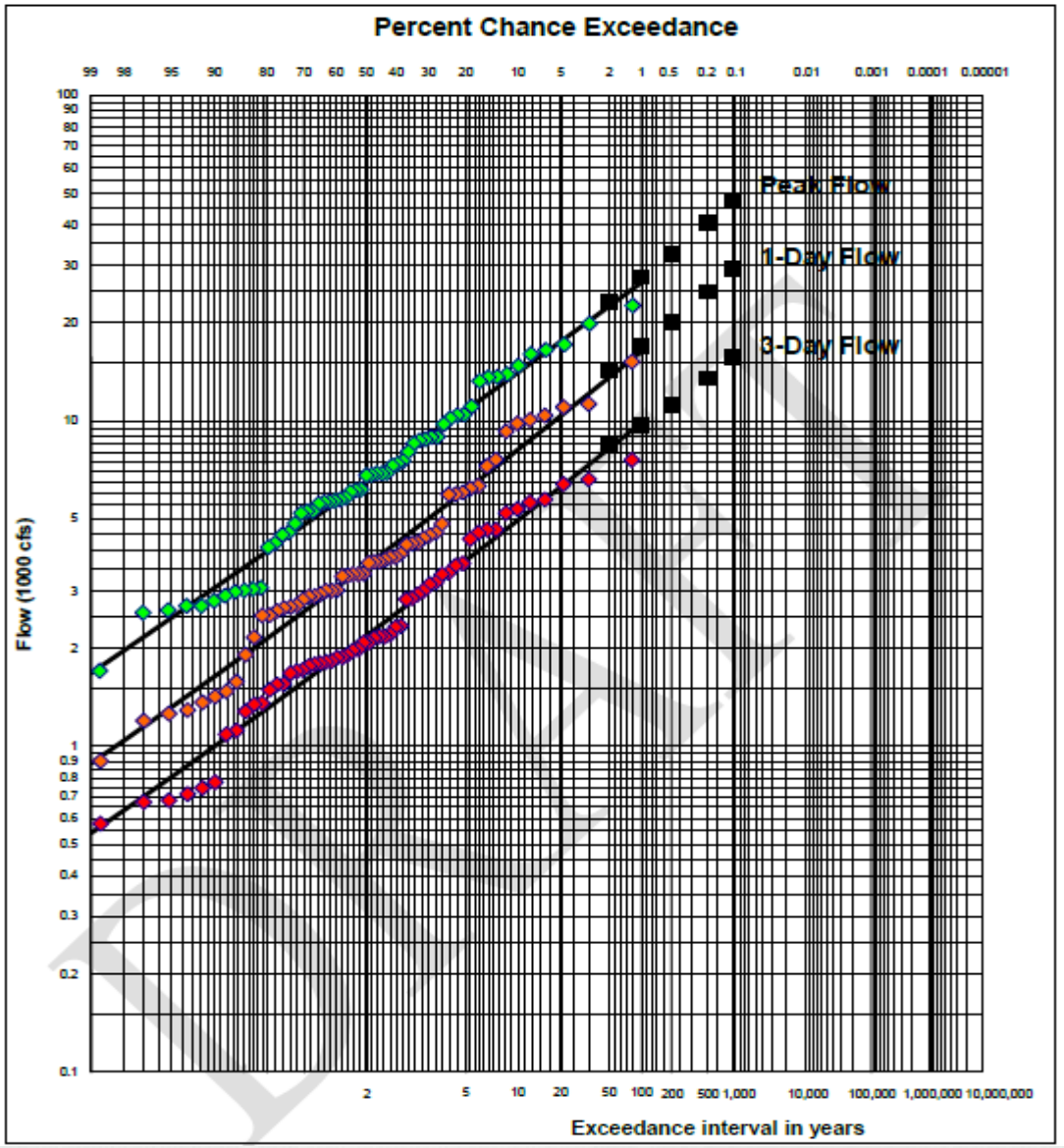
Hydrologic Modeling Using Frequency Based Storm Events



Regionalized Probability of PMF

$$AEP = 10^{-[(1-Ratio)\times Range + MinValue]}$$

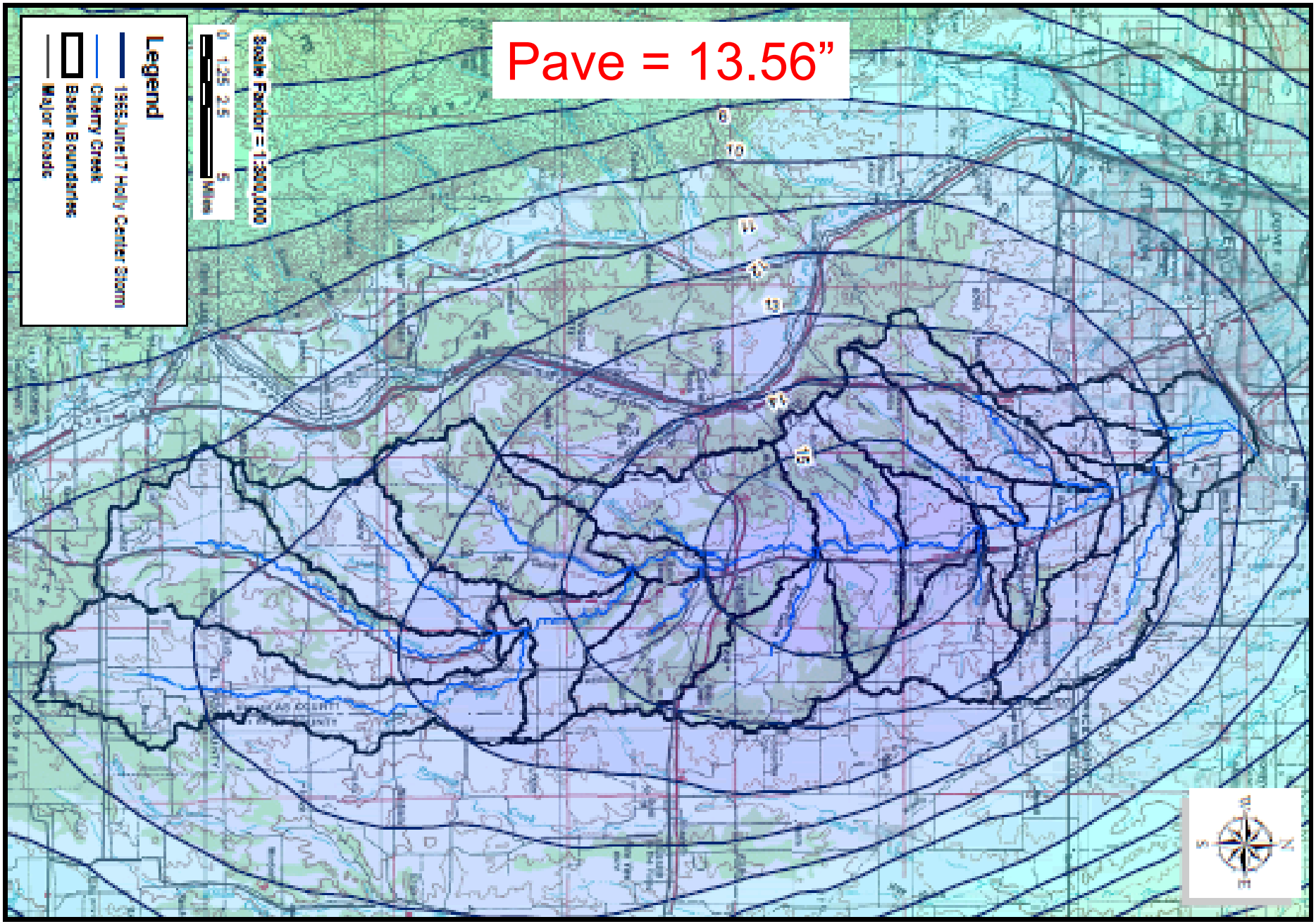
Ratio = Historical Max Precip/PMP

Range = 10^{-3} to 10^{-5} = (-3)-(-5) = 2

Min Value = 10^{-3} = 3

$$AEP = 10^{-[(1-Ratio)\times 2 + 3]}$$

1965 Holly Storm Centered Over Cherry Creek Basin



Cherry Creek Transposed Storms

Storm	Maximum Precip (in)	Average Precip (in) CC Basin	HMR55A Vertical Factor	Horizontal Factor	Total Factor	Transposed Basin Ave Precip (in)
1921 Penrose SW 1-23	12	8.21	0.99	1.00	0.99	8.13
1935 Cherry Cr	24	8.08	1.00	0.97	0.97	7.84
1935 Hale	24	8.85	0.89	0.95	0.85	7.48
1965 Plum Cr	14	5.10	1.00	1.00	1.00	5.10
1965 Palmer	16	10.49	1.00	1.00	1.00	**10.49**
1965 Holly	15	**13.56**	0.80	0.94	0.75	10.20
1981 Frijole Creek	14	8.14	1.00	1.00	1.00	8.14
1997 Fort Collins	12	3.84	0.97	1.03	1.00	3.84
1997 Pawnee	15	5.59	0.93	0.97	0.90	5.04

$$AEP = 10^{-[(1-Ratio)\times 2+3]}$$

Cherry Creek 24-hr PMP = 21.1”

Max Historical Precip = 13.56” ➔ Ratio = 13.56/21.1 = 0.643

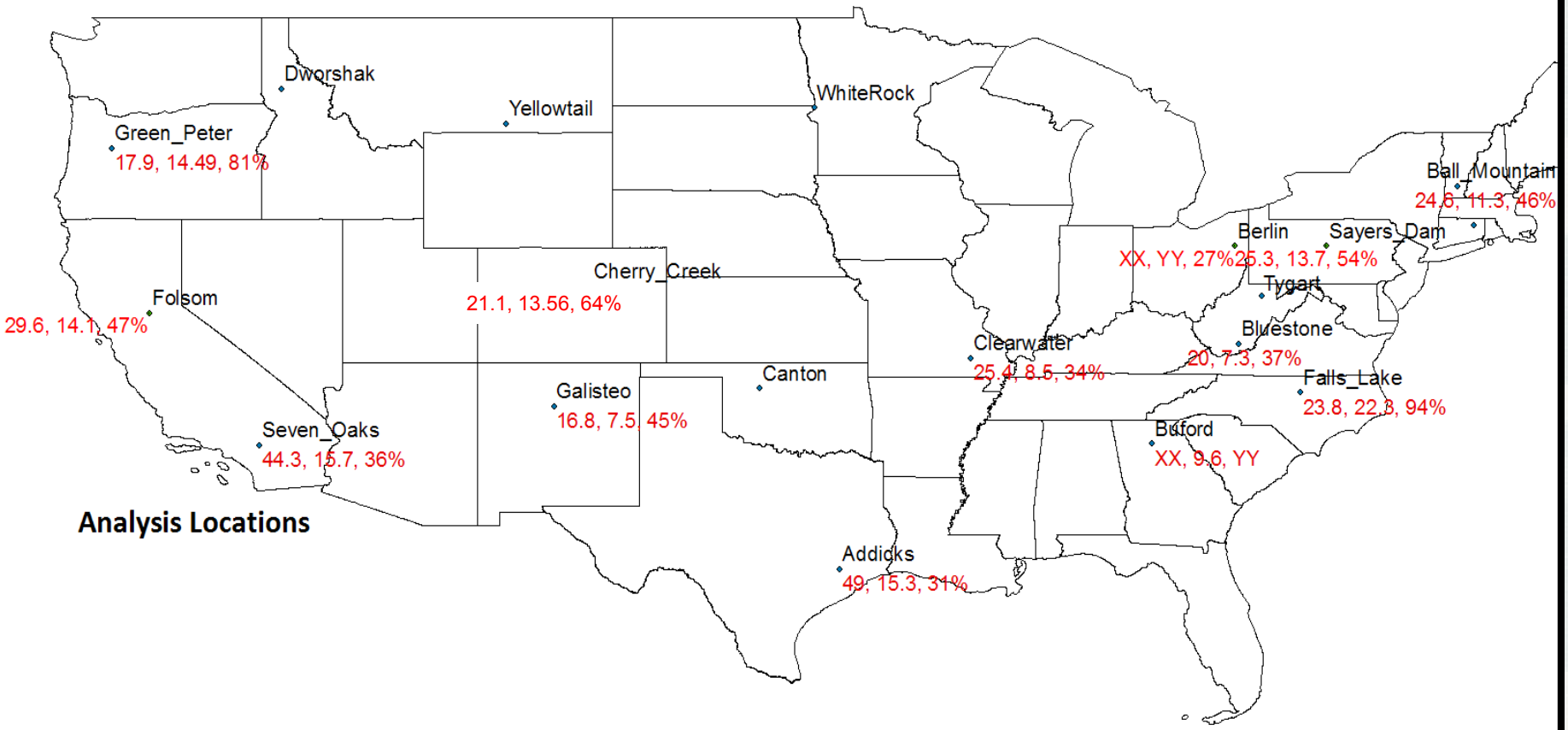
Max Transposed Precip = 10.49” ➔ Ratio = 10.49/21.1= 0.497

$AEP = 10^{-[(1-.643)\times 2+3]} = 0.000193$ ➔ **1 : 5,176**

$AEP = 10^{-[(1-.497)\times 2+3]} = 0.000099$ ➔ **1 : 10,139**

Regionalized Probability of PMF Applications

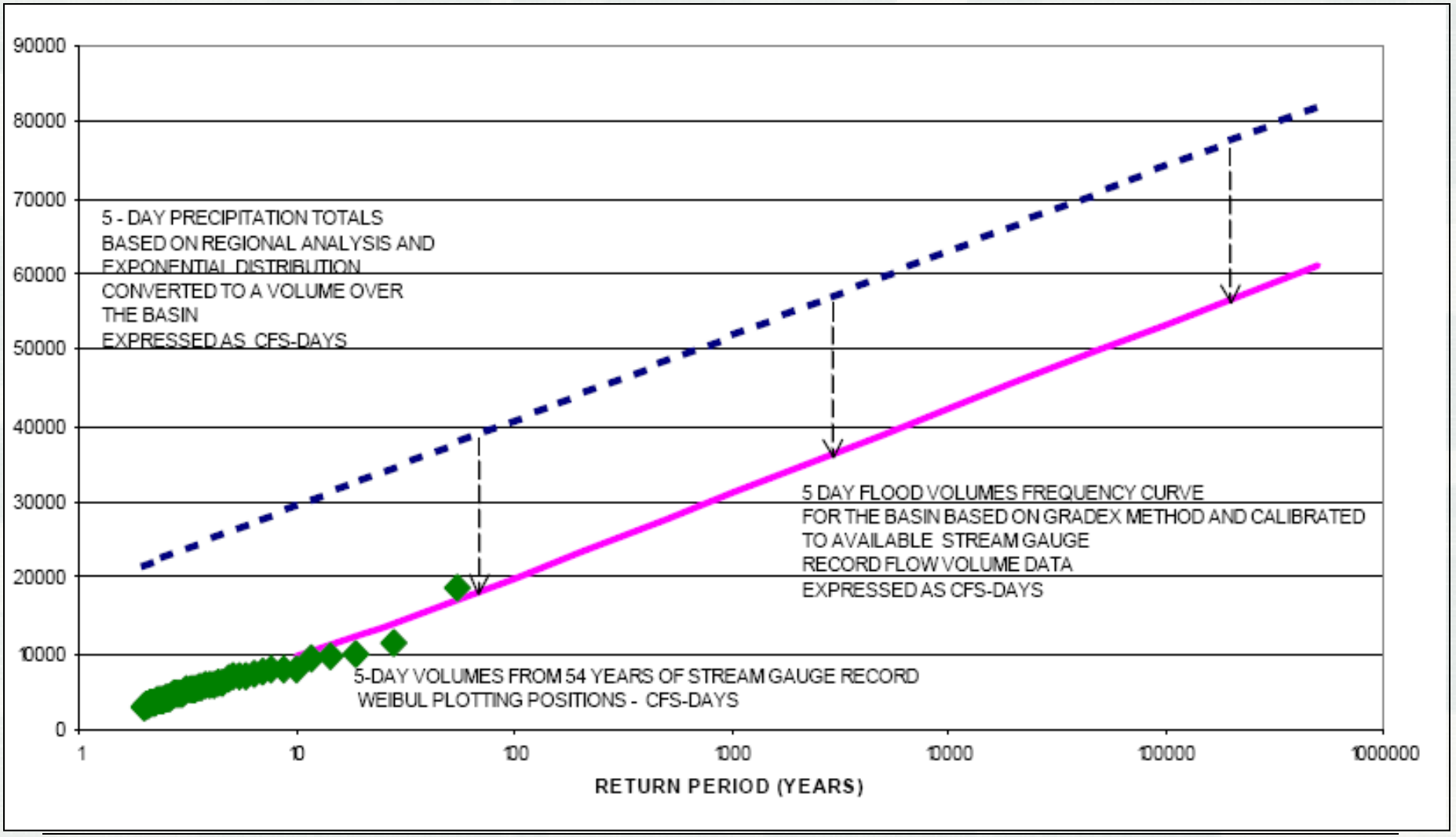
The red numbers represent PMP, Regional Precipitation, Ratio

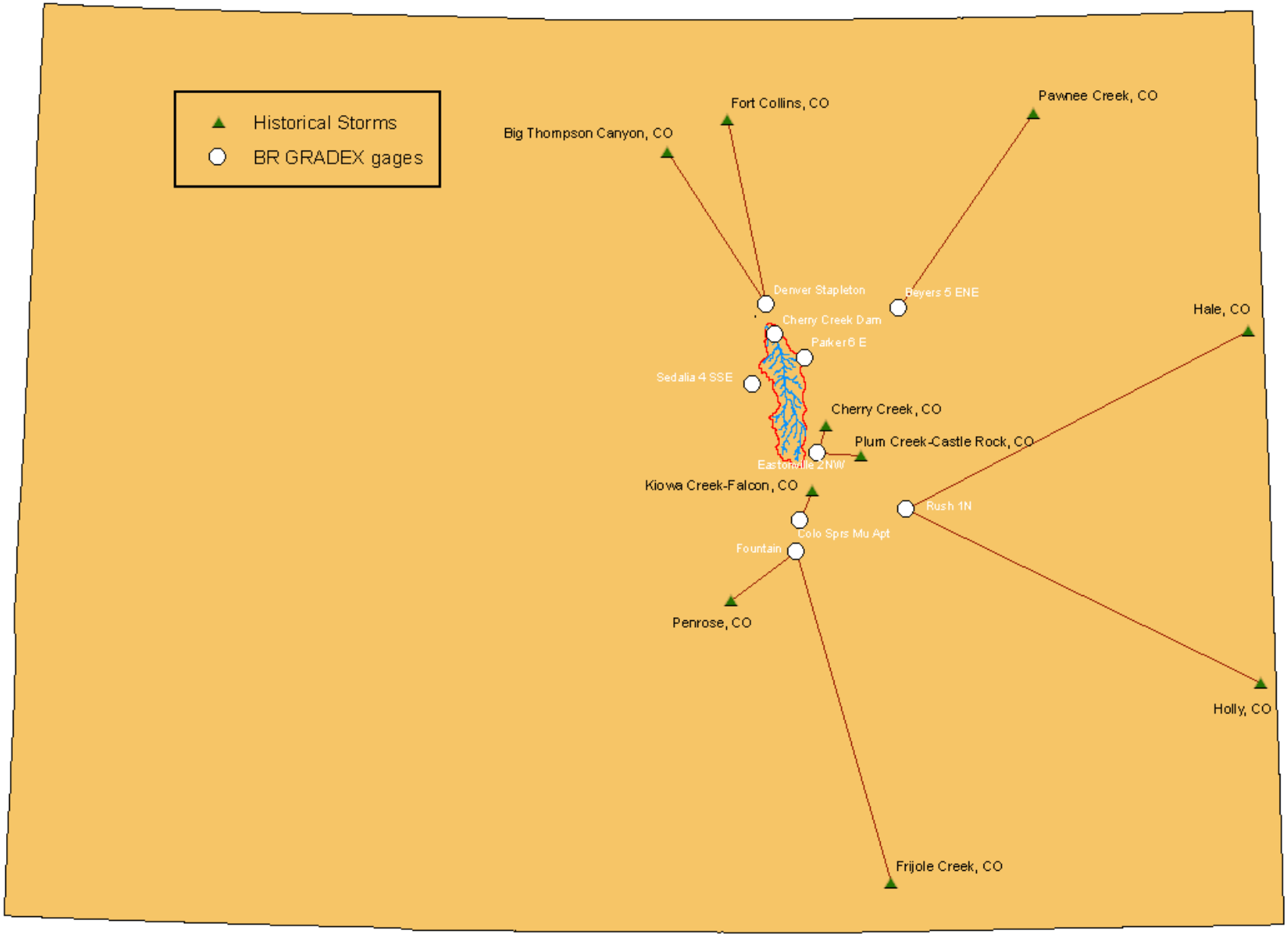


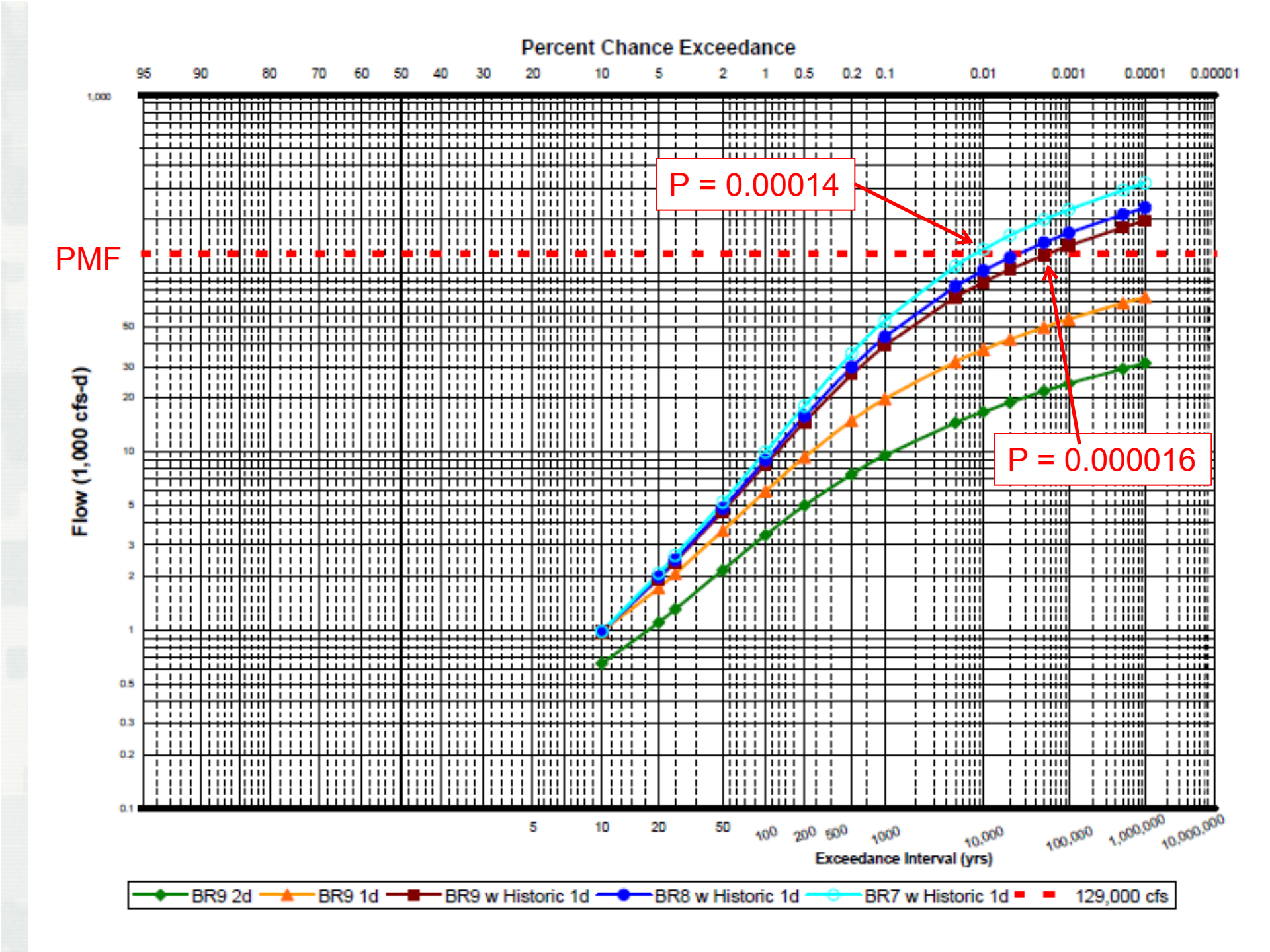
Regionalized Probability of PMF Applications

Location	PMP (in)	Regional Rainfall (in)	Ratio	Return Interval (years)
Addicks	49	15.3	0.31	**23,742**
Bald Eagle	25.3	11.1	0.44	**13,260**
Ball Mountain	24.6	11.3	0.46	**12,059**
Bluestone	20	7.34	0.37	**18,450**
Cherry Creek	21.1	13.6	0.64	**5,176**
Clearwater	25.4	8.5	0.33	**21,415**
Falls Lake	23.8	22.3	0.94	**1,337**
Folsom	29.6	14.1	0.47	**11,254**
Galisteo	16.8	7.5	0.45	**12,798**
Green Peter	17.9	14.5	0.81	**2,398**
Seven Oaks	44.3	15.8	0.36	**19,350**

GRADEX Method



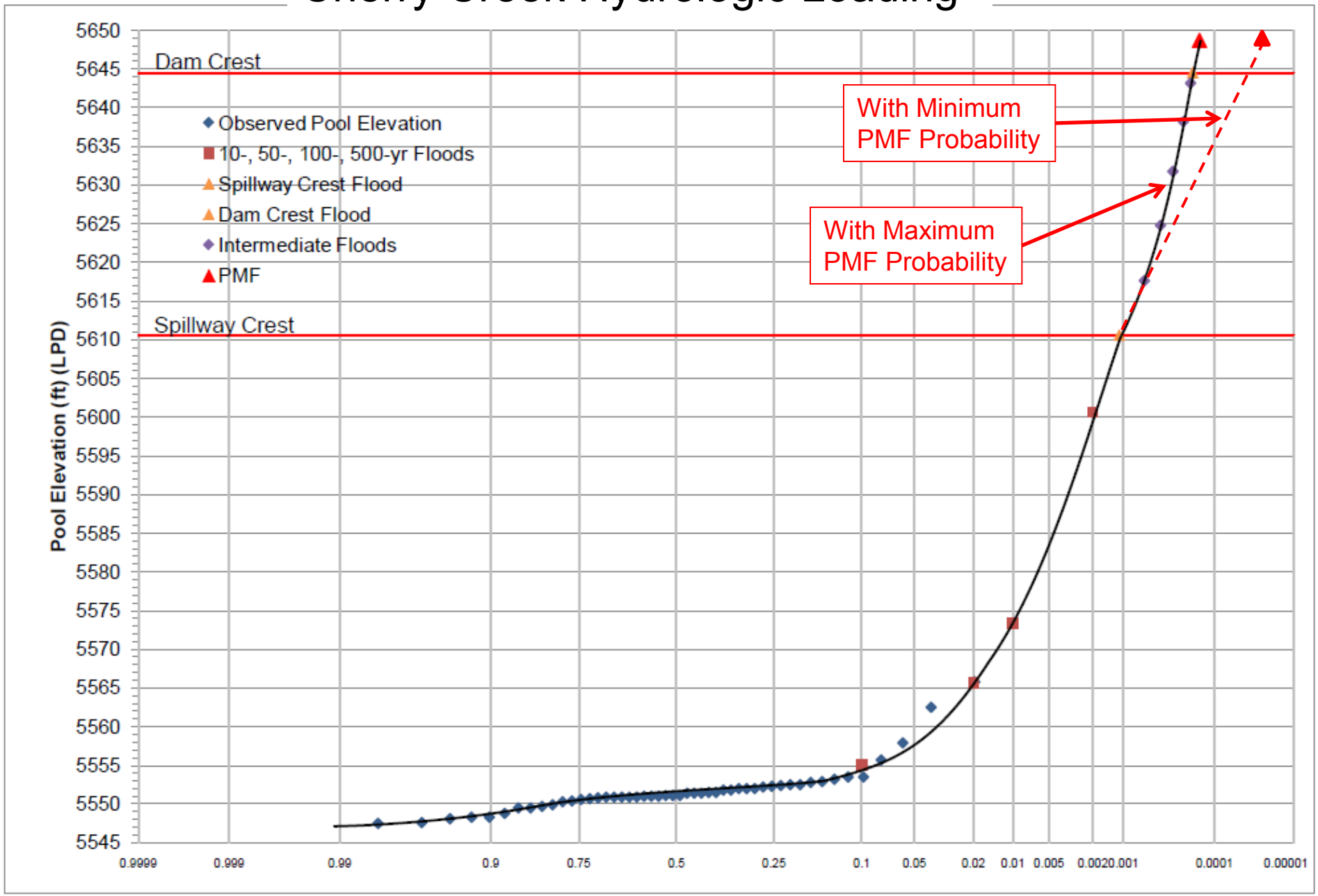

Historical Storms
BR GRADEX gages
Fort Collins, CO
Pawnee Creek, CO
Big Thompson Canyon, CO
Denver Stapleton
Beyers 5 ENE
Hale, CO
Cherry Creek Dam
Parker 6 E
Sedalia 4 SSE
Cherry Creek, CO
Plum Creek-Castle Rock, CO
Kiowa Creek-Falcon, CO
Rush 1N
Colo Sprs Mu Apt
Fountain
Penrose, CO
Holly, CO
Frijole Creek, CO


Percent Chance Exceedance
95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.01 0.001 0.0001 0.00001
1,000
50
30
20
10
5
3
2
1
0.5
0.3
0.2
0.1
Flow (1,000 cfs-d)
P = 0.00014
PMF
P = 0.000016
5 10 20 50 100 200 500 1000 10,000 100,000 1,000,000 10,000,000
Exceedance Interval (yrs)
BR9 2d
BR9 1d
BR9 w Historic 1d
BR8 w Historic 1d
BR7 w Historic 1d
129,000 cfs

Cherry Creek AEP of PMF

Method	Annual Exceedance Probability	Return Interval (years)
Bulletin 17B (Inflow Probability)	0.00016	6,250
Regional Probability (Maximum Centered Precip)	0.000193	5,200
Regional Probability (Maximum Transposed Precip)	0.000099	10,000
GRADEX Method (9 Gages w/ Historic storms)	0.000016	62,500
GRADEX Method (7 Gages w/Historic storms)	0.00014	7,100
Average of all Methods	0.000122	8,200

Cherry Creek Hydrologic Loading



Questions/Discussion