Probable Maximum Flood
Annual Exceedance Probability

California Extreme Precipitation Symposium
University of California, Davis
June 28, 2011

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USACE, Hydrologic Engineering Center

US Army Corps of Engineers
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Topics

- Background
- Curve Extension Methods
- Regional PMP Method
- AEP Estimation
- Samples
Background

- USACE Portfolio Risk Assessment, 2005
- Develop inflow frequency curves for USACE Dams

Challenge

- No single accepted approach for curve extension methodology
- No single accepted approach for AEP of PMF
- Develop a simplified method
Proposal for Simplified Curve Combination and Extension

- Combine Techniques
  - 17B Analysis
  - Hydrologic Modeling using Frequency Based Storms
  - Stochastic Event Flood Model (SEFM)
  - Regional Probability Method
  - Extension of Gaged Freq-Curves with Historic/Paleoflood
  - GRADEX
Documentation

- Draft Documentation
  - Circulating internally for comments
  - Description of each method
  - Example of Regional Analysis

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

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No. 1106-2-XXX
30 September 2010

FREQUENCY CURVE EXTENSION FOR EXTREME FLOOD EVENTS

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 1,000-year event as this area of the curves 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 hydrologist.
Regional Probability Method

- AEP Estimate of PMF from regional precipitation
  - Attempt to regionalize the AEP based on historic, regional rainfall
  - Ratio Historic Precipitation vs PMP
  - Include effects of
    - Regional weather patterns
    - Distance from moisture source
    - Orographic impacts
  - Result is an *ESTIMATED AEP*
NCDC Precipitation Archive

DS3240 - Precipitation Data, Hourly - US & some non-US. Request Summary

Entire Dataset / Selected Stations - includes 100 stations

Date Range (Year / Month / Day):
2008/09/01 to 2008/09/01

Selected Output Format:
Comma Delimited, with station names

Selected Output Media:
FTP

Days of Data Available:
93 - View Inventory

Output File Size (bytes):
16190

☑ Inventory Review: I have reviewed the Inventory File to see if the elements/dates desired are included before ordering. Some time periods or elements may be missing.

IMPORTANT! Please enter a valid email address below so we can notify you when your request has finished processing.

E-mail Address: 

Submit Request
Contour Rainfall
Intersect basin and rainfall to get average precipitation
Regional Probability – Historic Precipitation

- Falls Lake, NC
  - Collect regional rainfall
  - Select large events
    - Sept. 1999
    - July 1997
    - Nov 1980
  - Select largest Historic Event
  - Develop isohyets
  - Center over basin
  - GIS Tools to compute average rainfall
Falls Lake - November 1980

- Small # of stations
- Move to location far away
- 3-day mean, 20.71"
Falls Lake - July 1997

- More stations
- Move to location far away
- 3-day mean, 22.75”
Falls Lake - September 1999

- Same # stations as 1997
- Move to location nearby
- 3-day mean, 22.34”
- Historic/PMP Ratio = .938
The red numbers represent PMP, Regional Precipitation, Ratio.
## AEP of PMF Range

<table>
<thead>
<tr>
<th>Location</th>
<th>PMP</th>
<th>Regional</th>
<th>Date</th>
<th>Percentage</th>
<th>10^{-3} to 10^{-4}</th>
<th>10^{-3} to 10^{-5}</th>
<th>10^{-3} to 10^{-6}</th>
<th>10^{-3} to 10^{-7}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addicks</td>
<td>49</td>
<td>15.3</td>
<td>Jun-01</td>
<td>31%</td>
<td>4,873</td>
<td>23,742</td>
<td>115,682</td>
<td>563,664</td>
</tr>
<tr>
<td>Bald Eagle</td>
<td>25.3</td>
<td>11.1</td>
<td>1972</td>
<td>44%</td>
<td>3,641</td>
<td>13,260</td>
<td>48,283</td>
<td>175,816</td>
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<tr>
<td>Ball Mountain</td>
<td>24.6</td>
<td>11.3</td>
<td>Aug-55</td>
<td>46%</td>
<td>3,473</td>
<td>12,059</td>
<td>41,875</td>
<td>145,412</td>
</tr>
<tr>
<td>Berlin (1-Day)</td>
<td></td>
<td></td>
<td></td>
<td>27%</td>
<td>5,370</td>
<td>28,840</td>
<td>154,882</td>
<td>831,764</td>
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<tr>
<td>Bluestone</td>
<td>20</td>
<td>7.34</td>
<td>Sep-04</td>
<td>37%</td>
<td>4,295</td>
<td>18,450</td>
<td>79,250</td>
<td>340,408</td>
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<tr>
<td>Cherry Creek (1-Day)</td>
<td>21.1</td>
<td>13.5</td>
<td>June-65</td>
<td>64%</td>
<td>2,292</td>
<td>5,253</td>
<td>12,038</td>
<td>27,590</td>
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<tr>
<td>Clearwater</td>
<td>25.4</td>
<td>8.5</td>
<td>Mar-77</td>
<td>33%</td>
<td>4,628</td>
<td>21,415</td>
<td>99,102</td>
<td>458,608</td>
</tr>
<tr>
<td>Falls Lake (No Curve)</td>
<td>23.8</td>
<td>22.3</td>
<td>Sep-99</td>
<td>94%</td>
<td>1,156</td>
<td>1,337</td>
<td>1,546</td>
<td>1,787</td>
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<tr>
<td>Folsom</td>
<td>29.6</td>
<td>14.1</td>
<td>Jan-97</td>
<td>47%</td>
<td>3,355</td>
<td>11,254</td>
<td>37,755</td>
<td>126,658</td>
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<tr>
<td>Galisteo</td>
<td>16.8</td>
<td>7.5</td>
<td>Jun-65</td>
<td>45%</td>
<td>3,577</td>
<td>12,798</td>
<td>45,784</td>
<td>163,789</td>
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<tr>
<td>Green Peter</td>
<td>17.9</td>
<td>14.5</td>
<td>Nov-06</td>
<td>81%</td>
<td>1,549</td>
<td>2,398</td>
<td>3,714</td>
<td>5,751</td>
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<tr>
<td>Seven Oaks (No Curve)</td>
<td>44.3</td>
<td>15.8</td>
<td>Jan-69</td>
<td>36%</td>
<td>4,399</td>
<td>19,350</td>
<td>85,118</td>
<td>374,424</td>
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</tbody>
</table>
Equation

\[ AEP = 10^{-[(1-Ratio) \times \text{Range} + \text{Min. Value}]} \]

Ratio = Max historic storm precipitation divided by PMP for region of interest.
Range = Selected institutional range for probability of the PMF
Min Val = Minimum value of institutional range.

As ratio approaches 1 = More frequent AEP
As ratio approaches 0 = Less frequent AEP
Falls Lake Sample Computation

- 72-Hour Historic Precip = 22.3 inches
- 72-Hour PMP = 23.8 inches
- Ratio = 22.3/23.8 = 0.94

- Range = 3 (10^{-3} to 10^{-6})
- Min Value = 3

- AEP = 10^{-(0.06*3+3)} = 10^{-3.18} = 0.0007 (1 in 1,546)

\[ AEP = 10^{-(1-Ratio) \times Range + Min.Value} \]
Folsom

PMF Range $10^{-3}$ to $10^{-6}$
1 in 38,000

PMF Range $10^{-3}$ to $10^{-5}$
1 in 11,000

3-Day PMF (493,000 cfs)

Regional 47% of PMP

SEFM
## Curve Combination

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Observed Record</th>
<th>Rainfall-Runoff</th>
<th>SEFM</th>
<th>GRADEX</th>
<th>Paleo</th>
<th>Adopted Values (cfs)</th>
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<tbody>
<tr>
<td>0.5</td>
<td>21,000</td>
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<td>0.2</td>
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<td>0.1</td>
<td>72,000</td>
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<tr>
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<td>237,000</td>
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<td>210,000</td>
<td>0.50</td>
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<td>223,000</td>
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</tbody>
</table>
Bald Eagle

- PMF Range $10^{-3}$ to $10^{-6}$
  - 1 in 48,000
- PMF Range $10^{-3}$ to $10^{-5}$
  - 1 in 13,000

1-Day PMF 63,000 cfs

Regional 42% of 72-Hr FMP

NOAA Atlas 14
Galisteo

PMF Range $10^{-3}$ to $10^{-6}$
1 in 46,000

PMF Range $10^{-3}$ to $10^{-5}$
1 in 13,000

Regional 45% of PMP

NOAA Atlas 14

3-Day PMF (32,100 cfs)
Ball Mountain

PMF Range $10^{-3}$ to $10^{-6}$
1 in 42,000

PMF Range $10^{-3}$ to $10^{-5}$
1 in 12,000

3-Day PMF (36,000 cfs)

Regional 46% of PMP
Clearwater

Percent Chance Exceedance

PMF Range $10^{-3}$ to $10^{-6}$
1 in 99,000

PMF Range $10^{-3}$ to $10^{-5}$
1 in 21,000

3-Day PMF (173,000 cfs)

Regional 34% of PMP
Bluestone

PMF Range $10^{-3}$ to $10^{-5}$

PMF Range $10^{-3}$ to $10^{-5}$
1 in 19,000

Regional 37% of PMP

3-Day PMF (288,000 cfs)
Summary

- Collect as much rainfall as possible for applicable duration from available sources.
- Use all data available to generate Combined Curve
- All methods have challenges.
- AEP of PMF is an ESTIMATE
- PMF magnitude needs flow and exceedance error bands