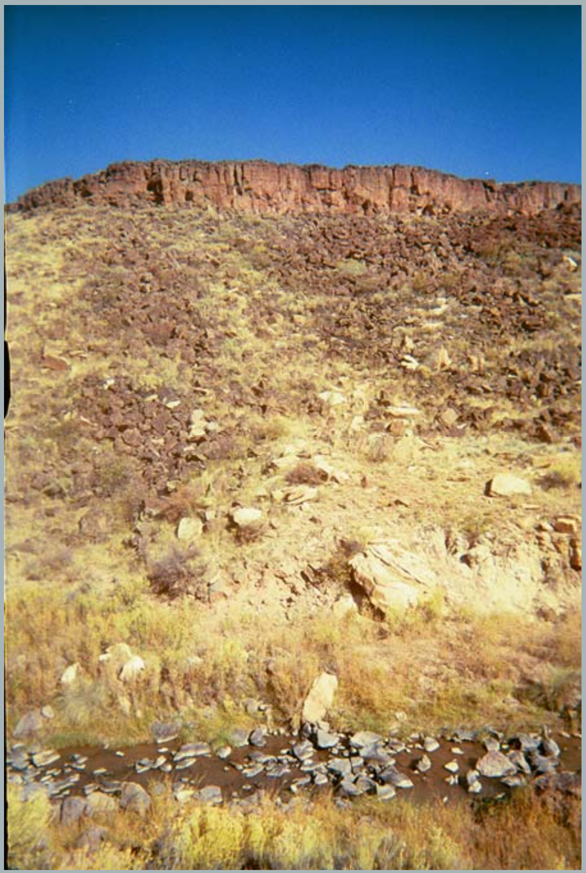
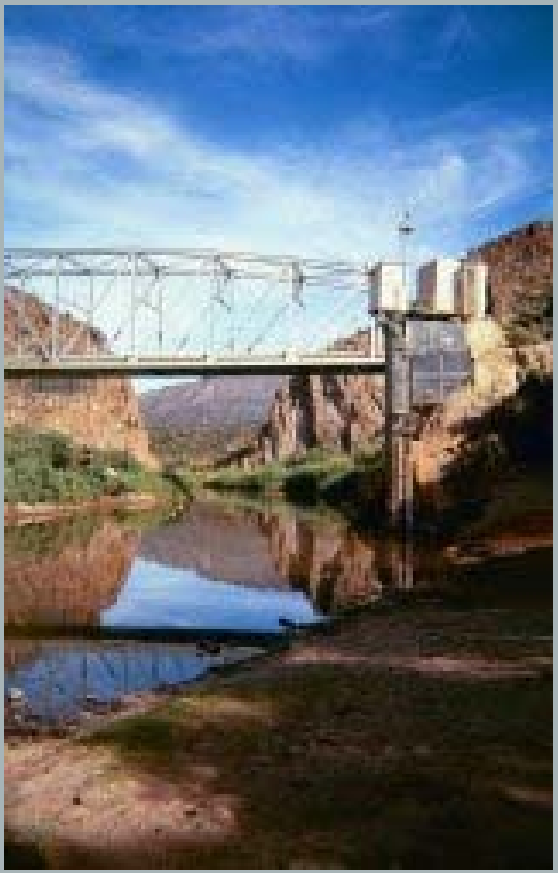
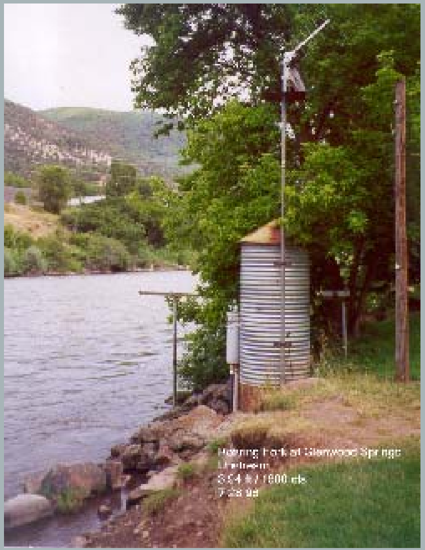
Analytical Approach to Determining Minor, Moderate, and Major Flood Stages

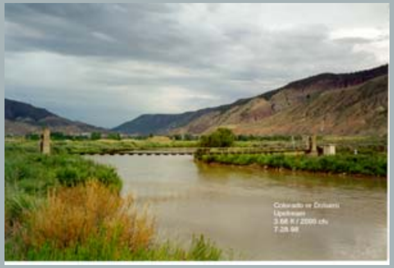


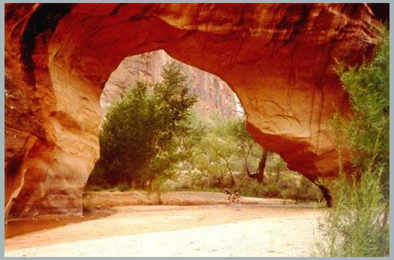


Goal: integrate a diversity of **river landforms**: trying to balance the underlying principles of **fluvial geomorphology**

William B. Reed, Senior Hydrologist,
Colorado Basin River Forecast Center







…with overriding ***anthropogenic influences, perturbations, and concerns***.

William B. Reed, Senior Hydrologist,
Colorado Basin River Forecast Center

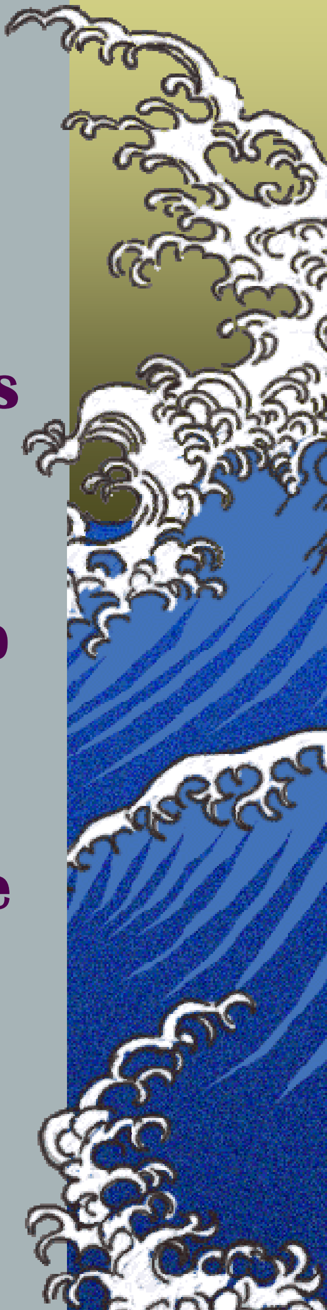
CHALLENGES

I. **FLOOD STAGE as defined by NWS is sometimes not related to bank full; therefore, the corresponding *FLOOD FLOW* may not be a function of recurrence intervals. E-19 is always right.**

II. **Sometimes there is no rating curve. You can try to use Regional Pattern matching to develop synthetic rating for some situations.**

III. **Sometimes there is no record. Therefore the use of methods for ungaged watersheds may be needed.**

IV. **River Continuum is essential for Basinwide Forecasts.**



Spiral Jetty, August 2003

Lakes, Reservoirs, Canals, etc. don't need values…although they can be impacted by floods.

- **Extremes do happen**
- **High Water Marks can be observed**
- **Some people will sleep just about anywhere; will hike just about anywhere; can be just about anywhere**
- **Floods do occur in Wilderness Areas**

Lake Powell, Oct. 2004

In some cases, bank full may be meaningless but bank-to-bank one to two feet deep could be critical.

Burned Areas also need to be watched. Extremes more likely to occur during recovery period.

Hydrologic Response of Post-Burn Watersheds in Southeast Arizona

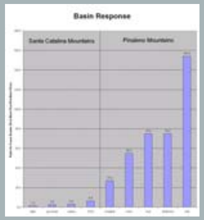
By Mike Schaffner (Tucson Weather Forecast Office) and Bill Reed (Colorado Basin River Forecast Center)

Abstract

Southeast Arizona witnessed a large number of wildfires during 2002-2004. Several of these fires were on the forested steep terrain of the Santa Catalina and Pinaleno Mountains. Frequent flash floods and occasional debris flows followed. A few of the flash floods were particularly severe resulting in one fatality, several evacuations of flood prone areas, and the destruction of four stream gaging sites.

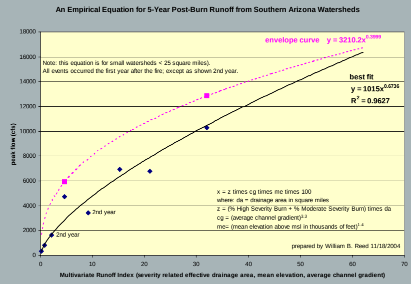
Post-burn flows were 1.3 to 6.5 times pre-burn flows in the Santa Catalina Mountains. Post-burn flows in the Pinaleno Mountains, where the average channel gradients are 2 to 3 times steeper, were 27 to 154 times pre-burn flows.

From these mountainous burn areas, rare hydrologic events occurred from rather common rainfall events. Half hour basin average precipitation frequencies of 2 years resulted in 30-year to 75-year return flows in the Santa Catalina Mountains. Half hour basin average precipitation frequencies of 5 to 7 years resulted in 250-year to 300-year return flows, containing significant debris entrainment in the Pinaleno Mountains.



Basin response for study watersheds in Santa Catalina and Pinaleno Mountains. Watersheds in Pinaleno Mountains have average channel gradients 2 to 3 times steeper than those in the Santa Catalina Mountains.

An Empirical Formula to Estimate 5-year Peak Discharge from Small Watersheds in Southeast Arizona



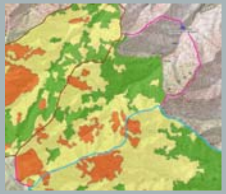
Campo Bonito Wash near Tucson

Watershed shown with burn severity and location of upstream slope-area reach. Image by AZDEM.

Tucson Service Hydrologist points out high water mark from August 14, 2003 event. USGS slope-area estimates peak discharge of 1,900 cfs +/- 20%. This amounts to a pre-burn 100-year runoff event created by a 25-year rainfall.

Campo Bonito Wash downstream from slope-area reach. Flood waters destroyed much of the home seen in this picture. One fatality resulted. While exact timing of flash flood event is not known, local information indicates a minimum of 30 minutes lead time.

Deadman Canyon near Safford

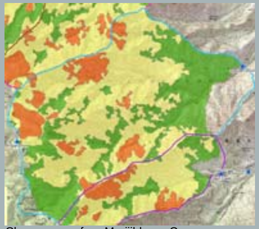


Close-up of Deadman Canyon watershed outlined in pink. Location of ALERT stream gauge shown as blue dot. Image by AZDEM.

Discontinued USGS stream gauge on Deadman Canyon being reactivated as an ALERT gauge on June 26, 2004. Image by JE Fuller Hydrology

Deadman Canyon after August 17, 2004 flash flood event. Minimum peak flow of 5,000 cfs +/- 25% based on high water marks. Image by JE Fuller Hydrology

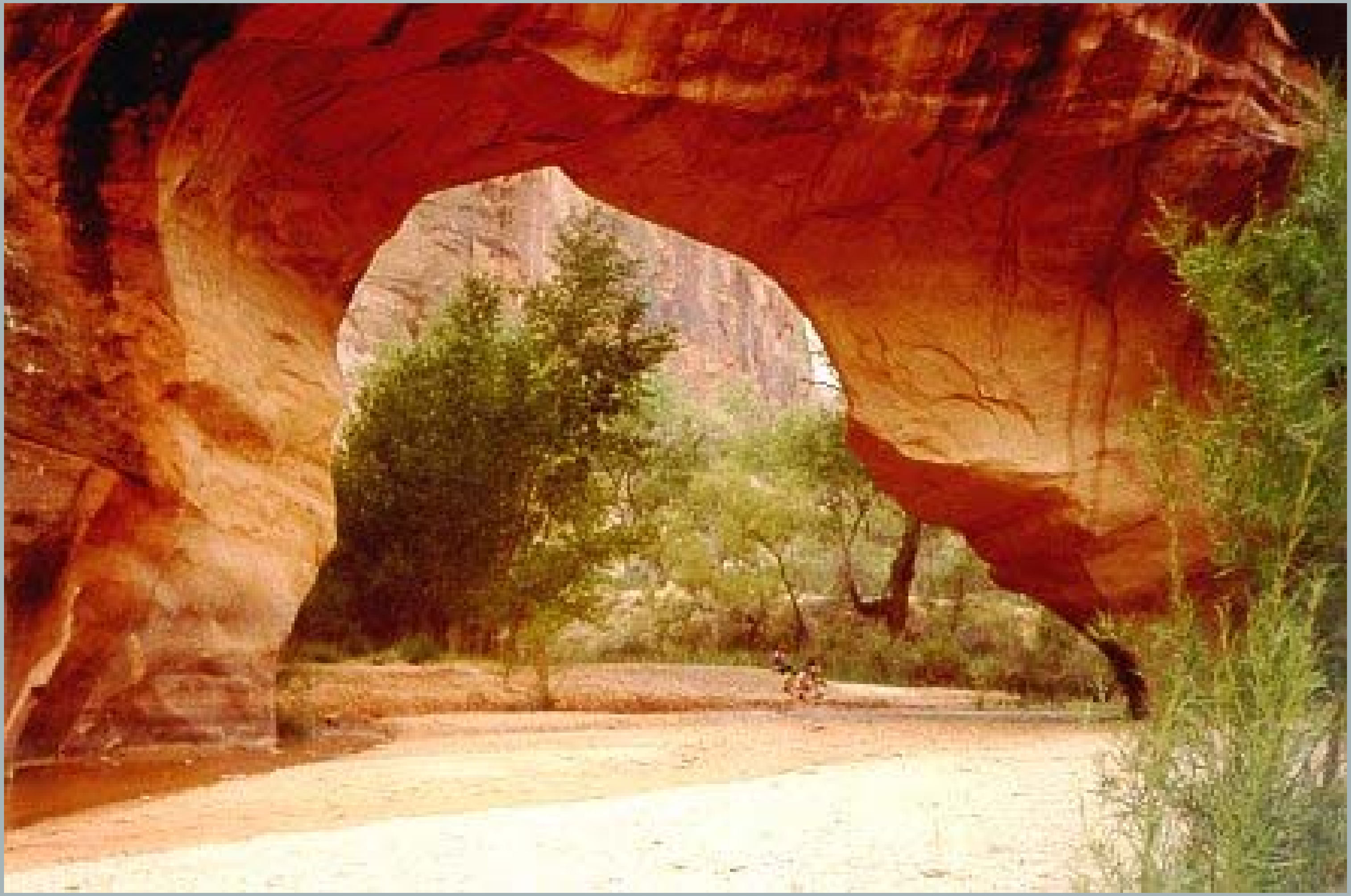
Marijilda Canyon near Safford



Close-up of Marijilda Canyon watershed outlined in blue. Location of slope-area reach shown as blue dot labeled Marijilda Canyon. Image by AZDEM.

Marijilda Canyon with scarring on tree from debris. Tucson Service Hydrologist for scale. Photo taken by USGS.

Marijilda Canyon showing high water from August 17, 2004 event. One quarter mile upstream, USGS slope-area estimated peak discharge of 6,800 cfs +/- 20%. Photo by USGS.



Floods occur in the wilderness, be it a slot canyon or under a natural bridge, these areas present unique flood hazard situations.

Coyote Natural Bridge, 2002

INTRODUCTION

Steps taken:

1. **Determine basin characteristics needed for return intervals calculations (basin size, mean elevation, etc.) and enter data into a spreadsheet**
2. **Calculate return intervals using equations from USGS Water-Supply Paper 2433; using National Flood Frequency Program (NFF) software; or other standard method**
3. **Determine Bank Full (Field Observation or Regional matching)**
4. **Test pattern matching of Minor, Moderate, Major**
5. **Compare to observed/recorded extreme events**
6. **Check River Continuum**
7. **Verify thru Field Investigations and Flood Documentation**
8. **Reiterative process**

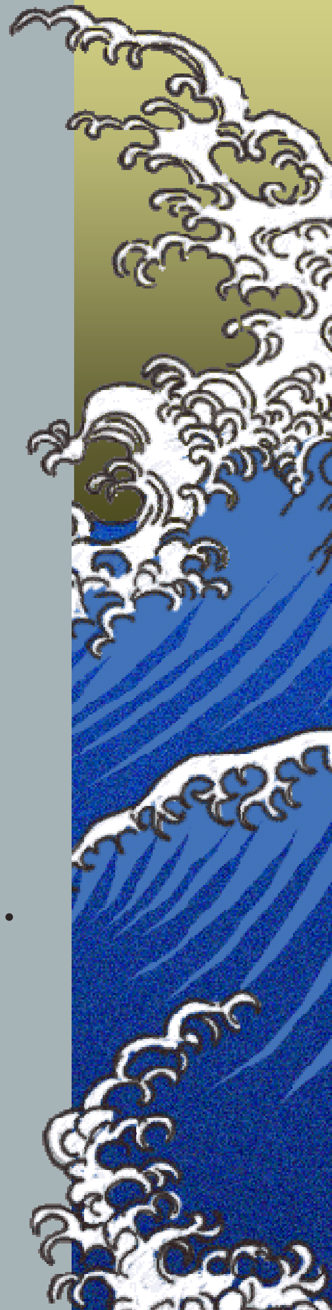
1. **Determine Basin Characteristics needed for return intervals calculations (basin size, mean elevation, etc.) and enter data into a spreadsheet**

2. **Calculate Return Intervals using equations from USGS Water-Supply Paper 2433; using National Flood Frequency Program (NFF) software; or other standard method**

- **Latitude & Longitude**
- **Drainage Area**
- **Mean Basin Elevation**
- **Mean Annual Precipitation**
- **Mean Annual Evaporation**
- **Maximum Peak Discharge of Record**

$Q=618AREA^{0.524}(ELEV/1000)^{-0.70}$ Example of 5-Year Eq.

Ries, K.G., III, and Crouse, M.Y., 2002, The National Flood Frequency Program, Version 3: A Computer Program for Estimating Magnitude and Frequency of Floods for Ungaged Sites: U.S. Geological Survey Water-Resources Investigations Report 02-4168. Available online at http://water.usgs.gov/pubs/wri/wri024168/.



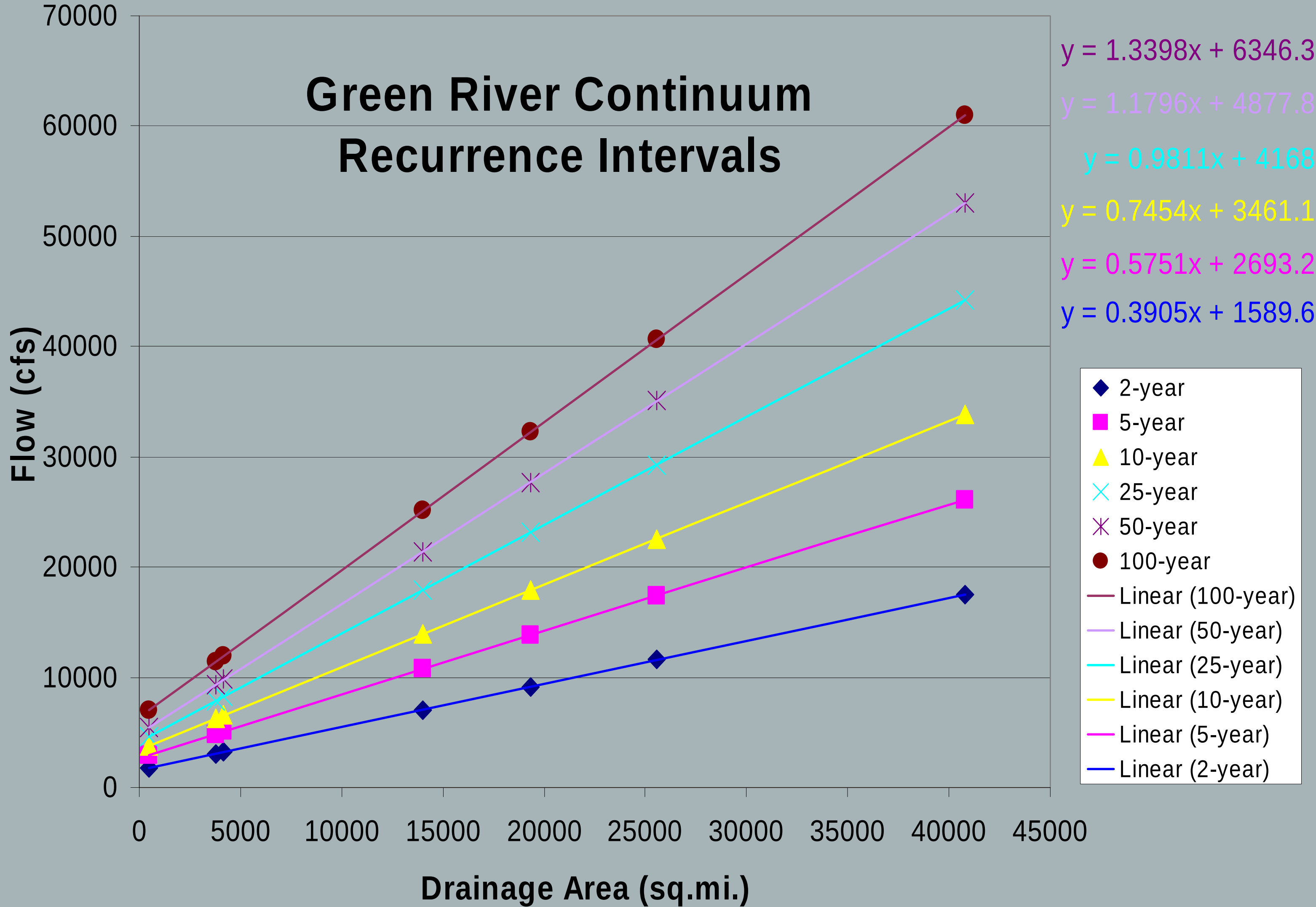
3. Determine Bank Full (Field Observation or Regional matching)

4. Test Pattern Matching of Minor, Moderate, Major

5. Compare to Observed/Recorded Extreme Events

- **Bank Full is easily observed, or first guess from Regional Matching (assumed same as an analogous basin nearby), or equations (Regional Regressions)**
- **As first guess Minor might equal Bank Full or 10-year return period, once decided guess that Moderate is next interval, i.e. 25-year, then look for pattern in either stage or flow increment**
- **Compare Major to Maximum Peak Discharge, repeat if needed (Reiterative Process)**

6. Check River Continuum (flow)



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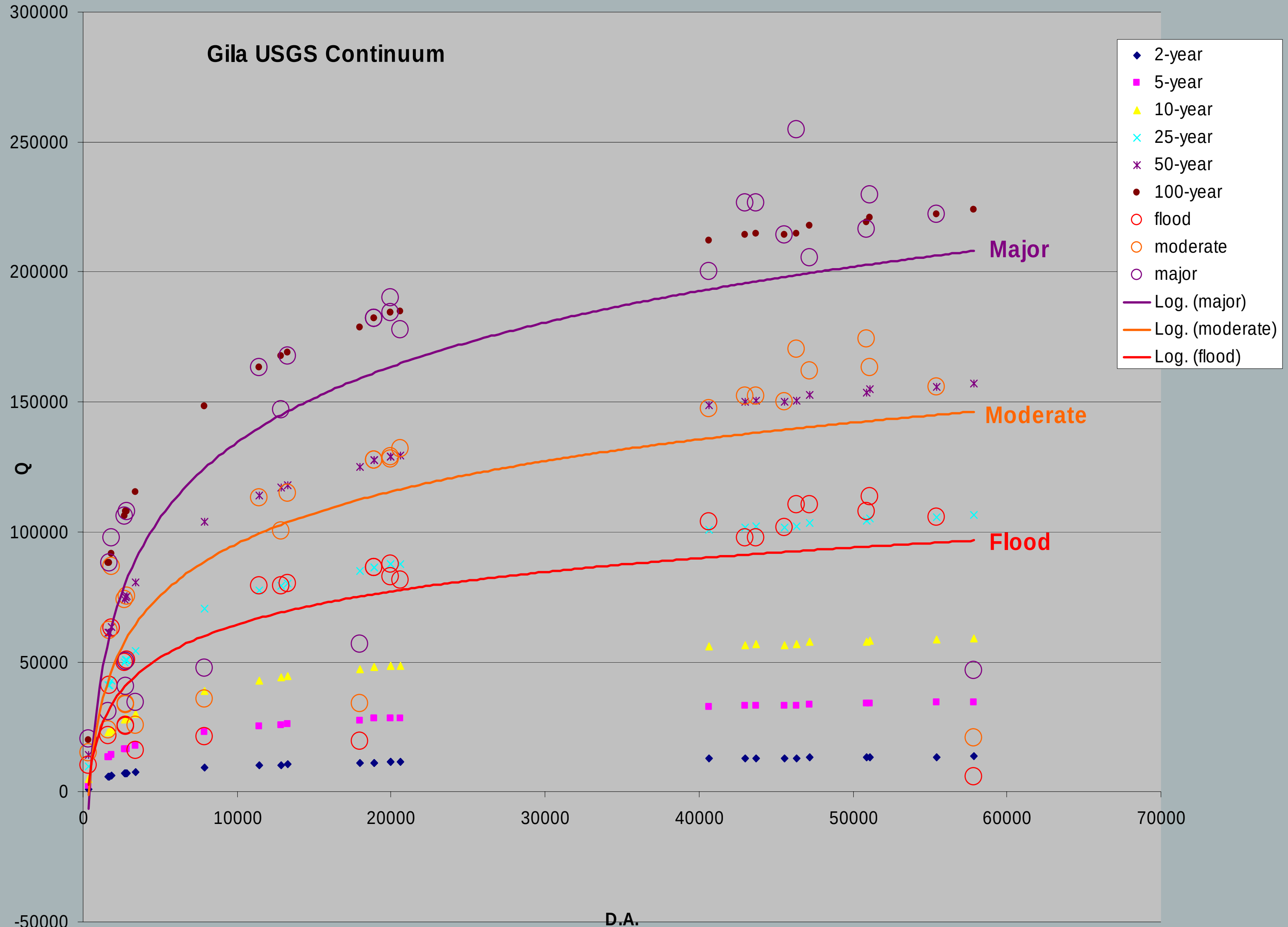

Sites with flood proofing or below dams may not match (three outliers).

7. Verify thru Field Investigations

8. Reiterative Process

FIELD WORK
Verification Work in AZ and NM (applied river morphology, professional judgment, and the trained eye)

- Tom Zickus
- Michael Schaffner
- Barry Pierce
- Tom Clemmons
- Ed Polasko
- Tim Brice

SUMMARY: RETURN INTERVALS, CHANNEL GEOMETRY (PATTERN MATCHING), RIVER CONTINUUM

- **Bank Full - determined from rating curve using bank_hg and checked against expected return interval for basin size - *internally consistent***
- **Minor = Flood = *E-19 if one***
- **Moderate - *reiterative process***
- **Major - *comparative process***

SUGGESTED READING

- **Leopold, Luna**, *"A View of the River"*
- **Rosgen, Dave**, *"Applied River Morphology"*

RELATED WORK

- **Reed, W., L. Pilgrim, and T. Little, 1991.** The Rehabilitation of the Minnehaha Creek Ravine and Stream Channel, George Washington Memorial Parkway: Phase I - Design. In: Proceedings of Conference XXII of the International Erosion Control Association, Erosion Control: "A Global Perspective," IECA, pp. 493-506.

- **Reed, W.B., 1991.** An Evaluation of the Effects of 300 Years of Changing Land Use on the Peak Flows, Base Flow, and Flood Frequency of a Small Pennsylvanian Stream. National Weather Service Eastern Region Technical Attachment No. 91-2A, 8p.

- **Reed, W.B., 1990.** Qualitative Evaluation of the Effects of Changing Watershed Land Uses on the Hydrology, Channel Morphology, and Historical Uses of Valley Creek, Valley Forge National Historical Park, Pennsylvania. U.S. National Park Service Technical Report NPS/NRWRD/NRTR-90/08, 48p.

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Escalante River Gorge, May 2004