Association of State Floodplain Managers
2018 Conference
Phoenix, Arizona

Re-delineation for Two Alluvial Fans in Scottsdale and Phoenix Maricopa County, Arizona

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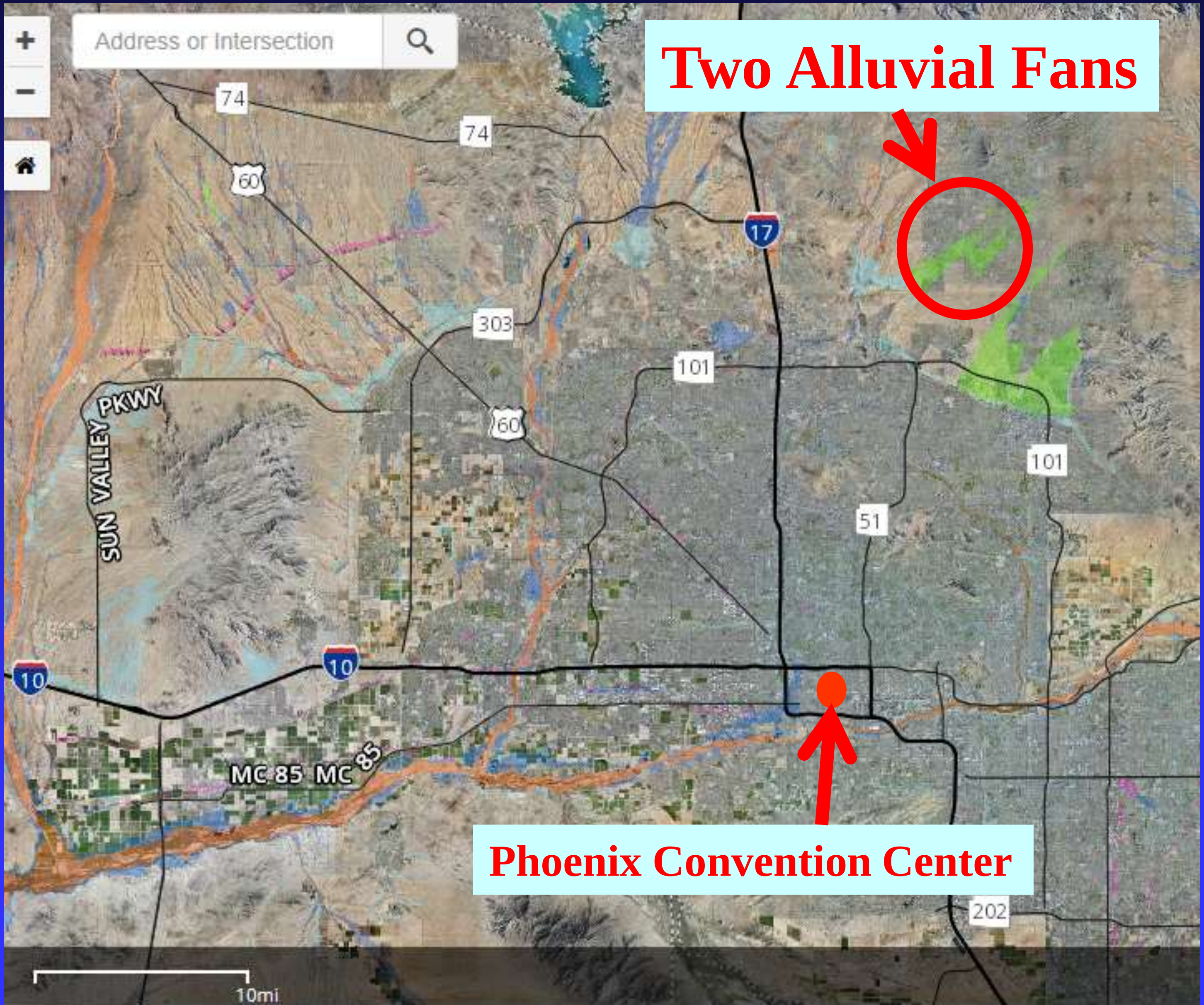
June 20th, 2018

Alluvial Fans Delineated by FEMA (1992)



Alluvial Fans Delineated by FEMA (1992)

Presentation Outline

- **Alluvial Fan No. 5 and Fan No. 6 in Scottsdale and Phoenix**
- **Alluvial Fan Delineation Methodologies**
- **Application of FEMA's Latest Methodology to Fan No. 5 and Fan No. 6 (Stage 1 and Stage 2)**
- **Application of FLO-2D to Fan No. 5 and Fan No. 6 (Stage 3)**

- **Stage 1 and Stage 2 (Li and Zhao, 2014)**

Re-analysis of Alluvial Fans No. 5 and No. 6 in Scottsdale and Phoenix, Maricopa County, Arizona Based on 2003 FEMA Alluvial Fan Guidelines, Shimin Li and Bing Zhao, FCDMC, 2014.

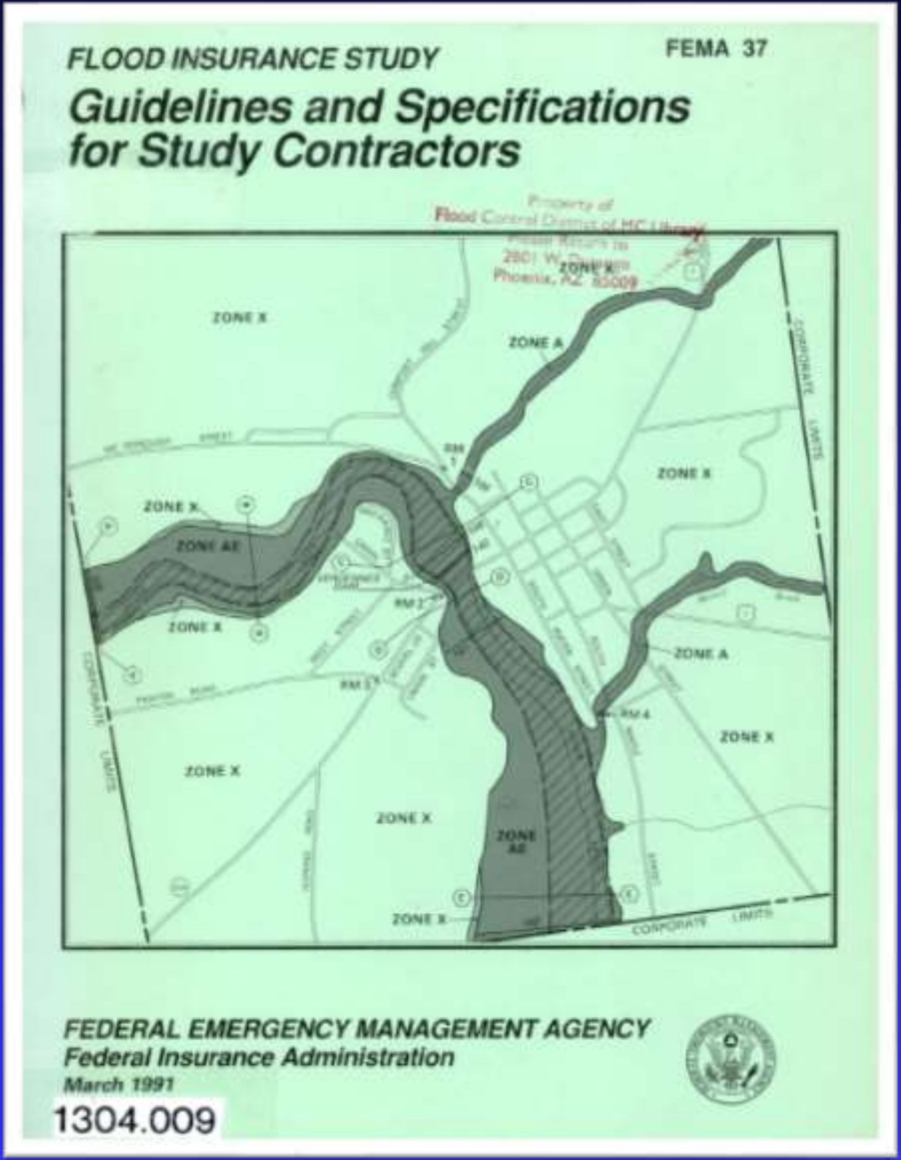
- **Stage 3 – FLO-2D modeling (JE Fuller, 2017)**

Pinnacle Peak West Area Drainage Master Study: Fans 5 and 6 Floodplain Redelineation Study, JE Fuller Hydrology & Geomorphology, Inc., October 2017

Presentation Outline

- ✓ Alluvial Fan No. 5 and Fan No. 6 in Scottsdale and Phoenix
- Alluvial Fan Delineation Methodologies
- Application of FEMA's Latest Methodology to Fan No. 5 and Fan No. 6 (Stage 1 and Stage 2)
- Application of FLO-2D to Fan No. 5 and Fan No. 6 (Stage 3)

1991 FEMA Methodology (FEMA 37)



Dawdy's method

APPENDIX 5. STUDIES OF ALLUVIAL FAN FLOODING

A5-1 INTRODUCTION

"Alluvial fan flooding" means flooding occurring on the surface of an alluvial fan or similar landform, which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flow paths. For the purposes of the NFIP, "apex" means a point on an alluvial fan or similar landform below which the flowpath of the major stream that formed the fan becomes unpredictable and alluvial fan flooding can occur. The degree to which the processes that characterize alluvial fan flooding are present can vary greatly. For example, the fact that active deposition has not recently occurred on some portion of the fan surface does not necessarily preclude the use of FEMA's methodology for determining hazards from alluvial fan flooding.

The methodology follows directly from the definition of the 100-year flood as the flood having a 1-percent chance of being exceeded (at the point at which the definition is being applied) in any given year. Because the path of an alluvial fan flood is unpredictable, the probability of the point in question being inundated by a flood, given that that flood is realized at the apex, contributes to the definition of the 100-year flood. Therefore, if H denotes the event of the point in question being flooded, then, by definition, the 100-year flood discharge at that point is the q_{100} given by

$$.01 = \int_{q_{100}}^{\infty} P(H|Q=q) f_Q(q)\,dq \qquad (1)$$

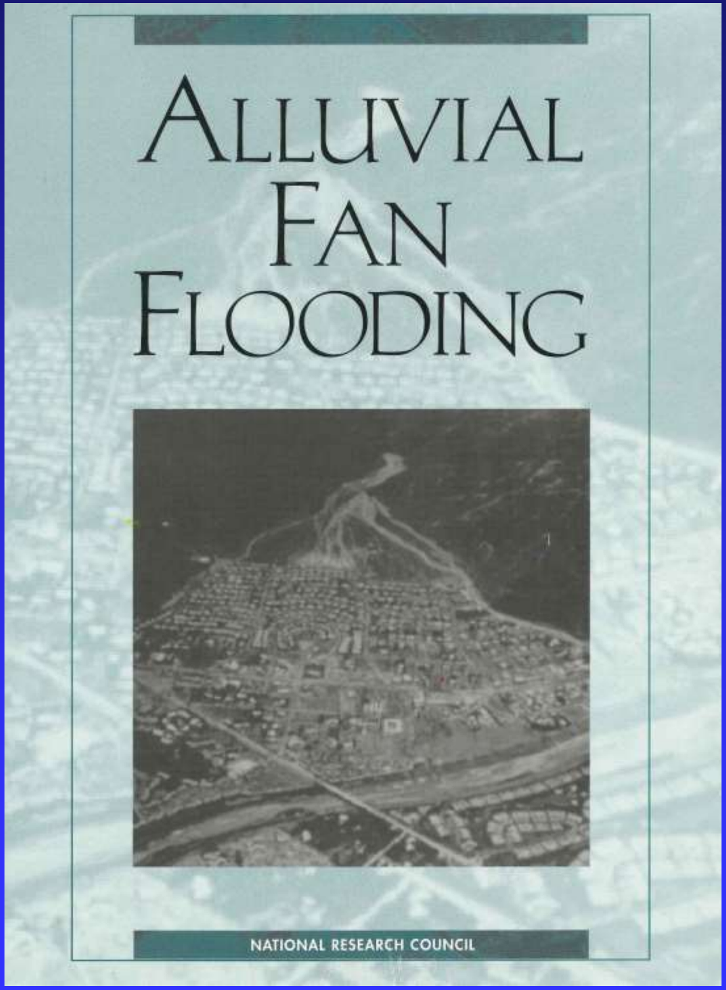
where $P(H|Q=q)$ is the probability of the point being flooded, given that a flood with a magnitude of q cubic feet per second (cfs) is realized at the apex; and $f_Q(q)$ is the probability density function (pdf) of the discharge Q occurring at the apex. Replacing Q with D or V and q with d or v in equation (1) to denote depth or velocity yields the definition of the 100-year flood depth or flood velocity, respectively. Note that when the flood path is predictable, then $P(H|Q=q) = 1$ and the 100-year flood discharge, q_{100}, is determined by the definition familiar to those who model riverine flooding:

$$.01 = \int_{q_{100}}^{\infty} f_Q(q)\,dq \qquad (2)$$

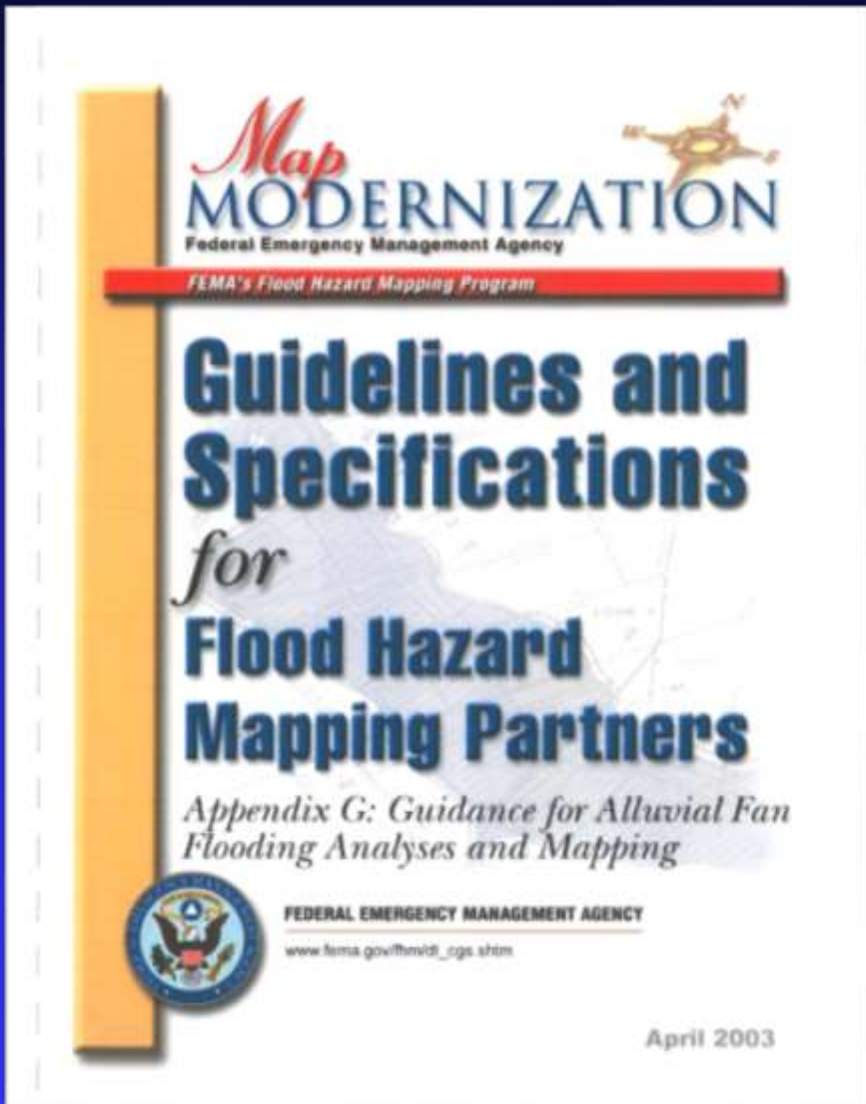
If the flowpaths cannot be predicted with certainty, then equation (1) (i.e., the methodology) must be applied. The reader should note that equation (1) is not an assumption, but is rather the definition of the 100-year flood discharge.

The methodology was first described by Dawdy (Reference 1). In his paper Dawdy uses three assumptions to solve equation (1) for q_{100}.

1996 National Research Council (NRC) Methodology for Alluvial Fan Flooding



2003 FEMA Methodology


Map MODERNIZATION
Federal Emergency Management Agency
FEMA's Flood Hazard Mapping Program

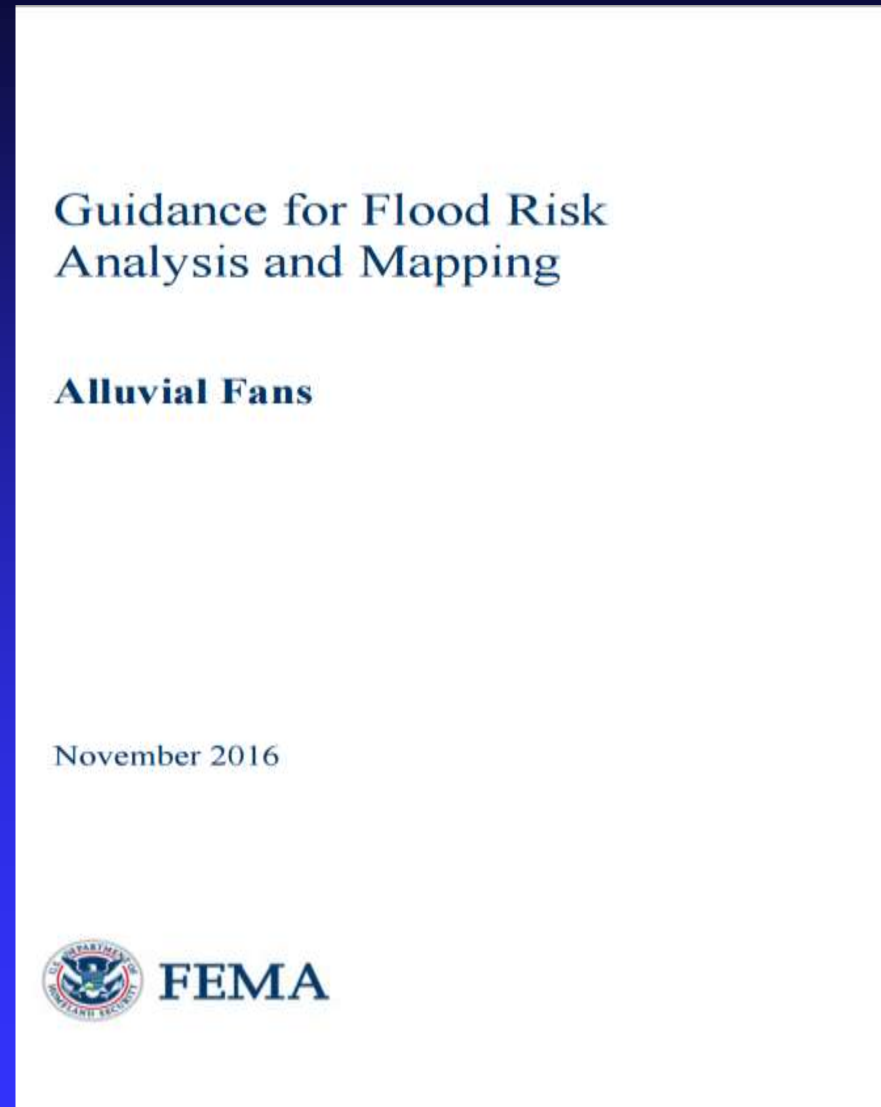
Guidelines and Specifications *for* Flood Hazard Mapping Partners

Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping

FEDERAL EMERGENCY MANAGEMENT AGENCY
www.fema.gov/fhm/dl_cgs.shtm

April 2003

2016 FEMA Methodology


Guidance for Flood Risk Analysis and Mapping

Alluvial Fans

November 2016

FEMA

Application of The Latest FEMA Methodology to Fan 5 and Fan 6

3-stage Approach

- Stage 1 – Identify Alluvial Fan Landforms;
- Stage 2 – Active or Inactive?
- Stage 3 – 100-year Floodplain Delineation

Stage 1 – Recognizing and Characterizing Alluvial Fan Landforms

- **Composition**
- **Morphology**
- **Location**
- **Toe and Lateral Boundaries**

Composition Requirement

Deposits of alluvial sediments or debris flow materials (accumulation of loose, unconsolidated to weakly consolidated sediments).

AZGS Geologic Map

Qy: Holocene Surficial Deposits (0-10 ka). Unconsolidated deposits associated with modern fluvial systems.

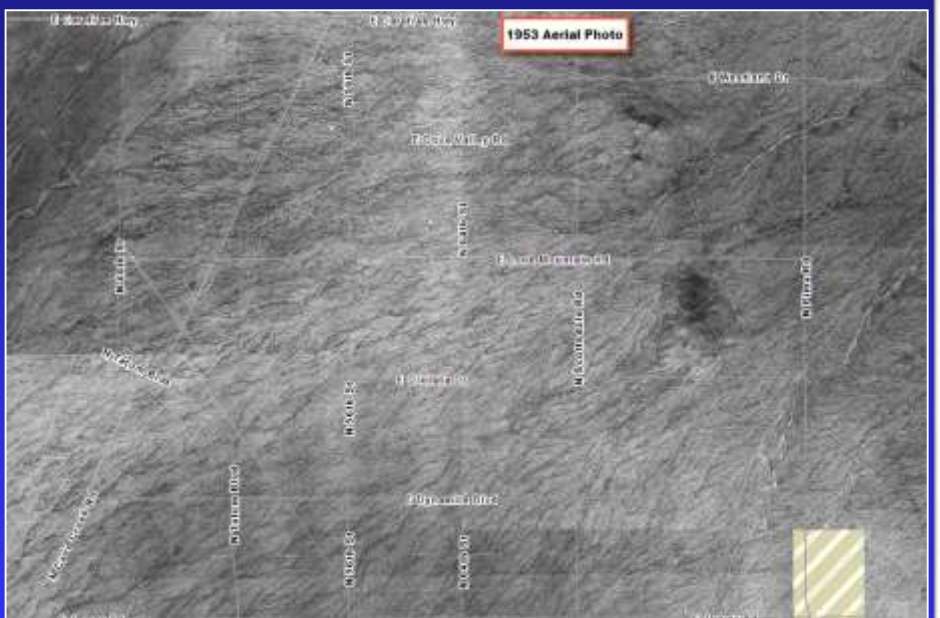
Qm: Late and Middle Pleistocene Surficial Deposits (10 – 750 ka). Unconsolidated to weakly consolidated alluvial fan, terrace, and basin-floor deposits with moderate to strong soil development.

Composition requirement is met.

Morphology Requirement

Shape of a fan, either partly or fully extended. Flow paths may radiate outward to the perimeter of the fan.

1953 Aerial Photo



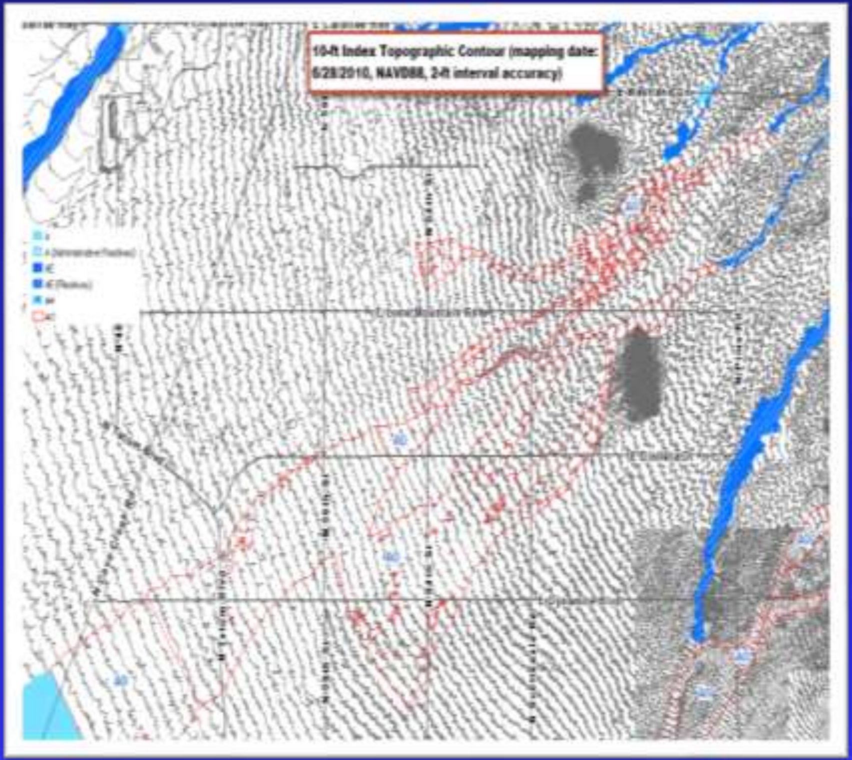
Typical alluvial fan morphology

Fan 5 and Fan 6 do not have typical alluvial fan landform morphology.

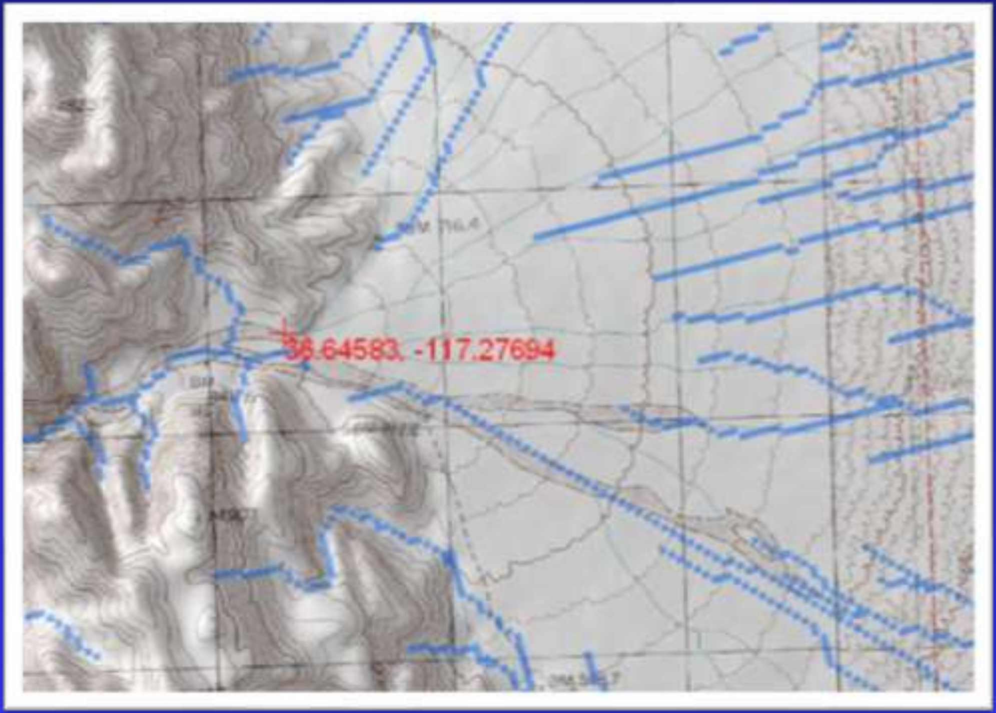
Morphology Requirement

Shape of a fan, either partly or fully extended. Flow paths may radiate outward to the perimeter of the fan.

Topographic Data with Floodplains at Fan No. 5 and Fan No. 6



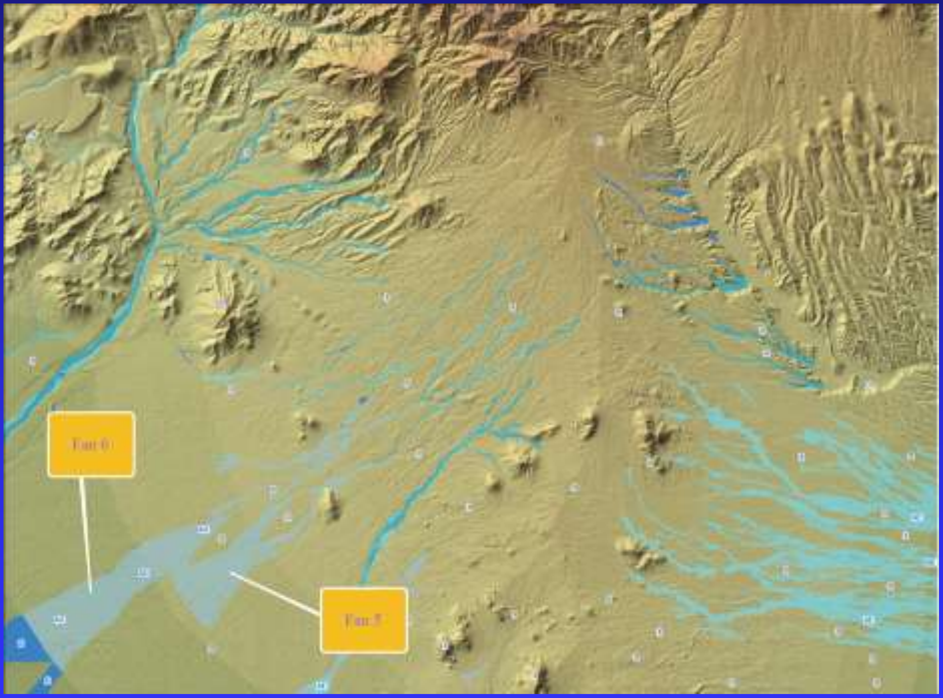
Typical alluvial fan morphology



Fan 5 and Fan 6 do not have typical alluvial fan landform morphology.

Location Requirement

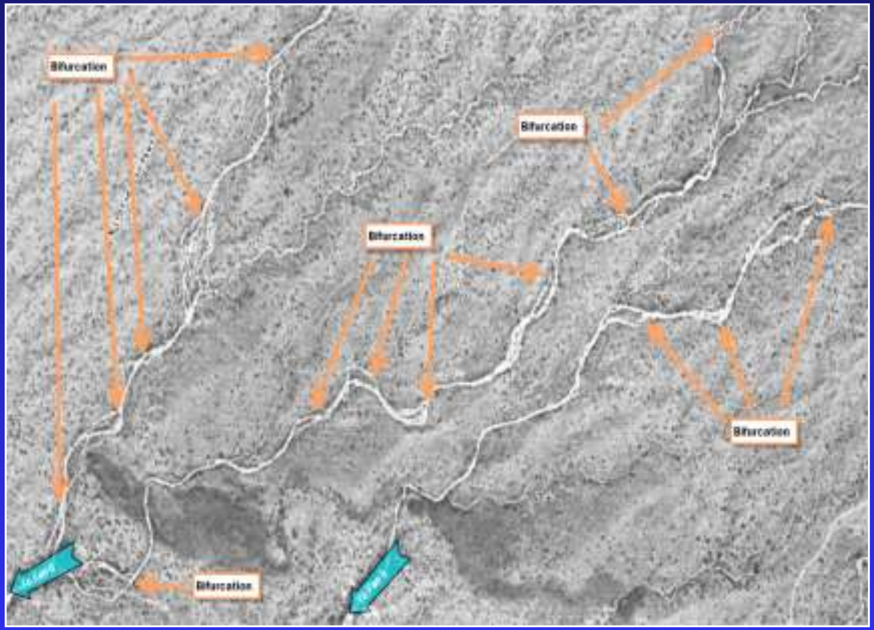
Alluvial fan landforms are located at a topographic break where long-term channel migration and sediment accumulation become markedly less confined than upstream of the break. This locus of increased channel migration and sedimentation is referred to as the alluvial fan apex



There is no typical topographic apex for Fan 5 or Fan 6.

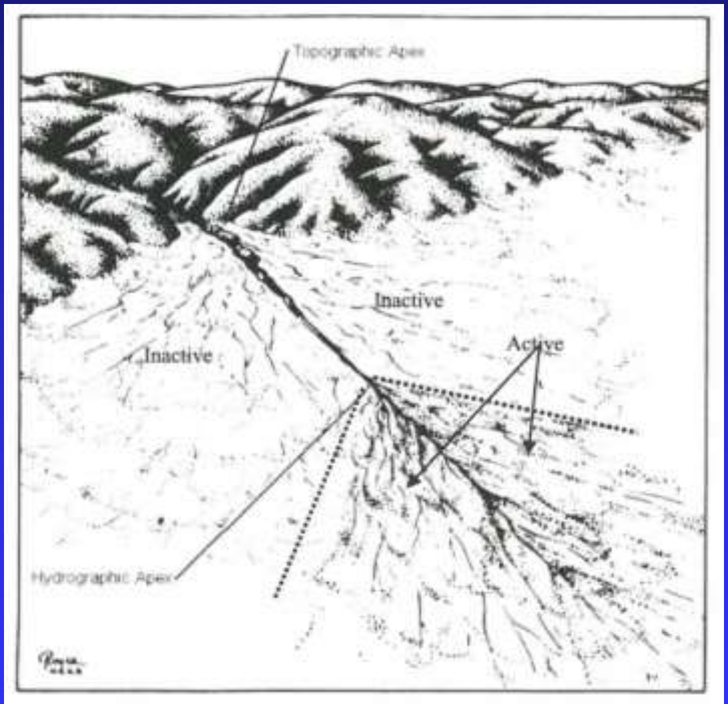
Location Requirement

Hydrographic apex should be the highest point on the alluvial fan where there exists physical evidence of channel bifurcation.



Hydrographic apexes are questionable.

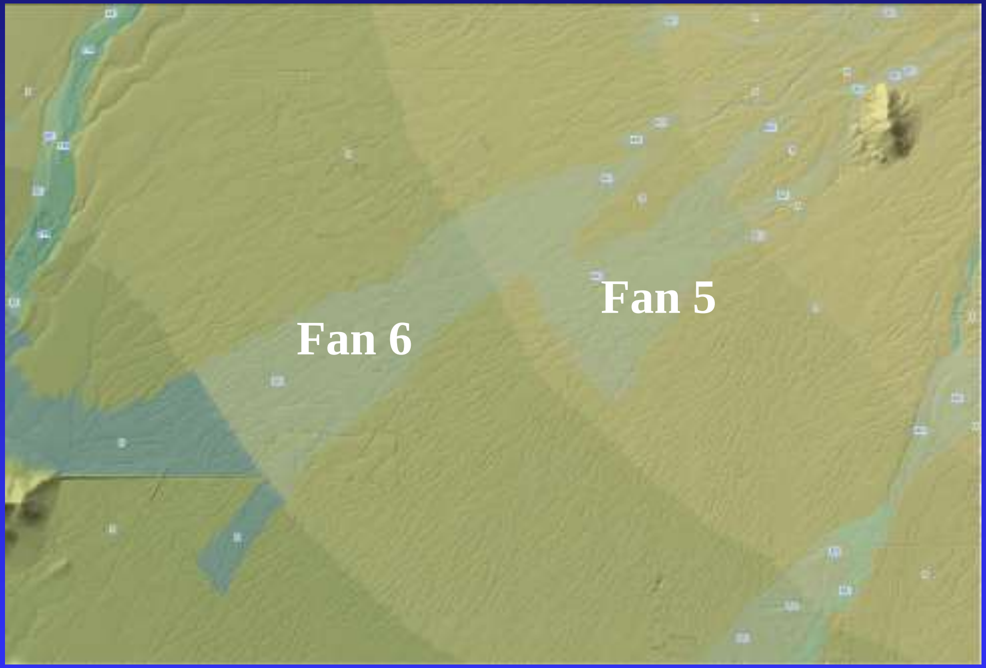
Hydrographic apex on typical alluvial fan



Fan No. 5 and Fan No. 6 are not located at the typical alluvial fan locations.

Alluvial Fan Toe and Lateral Boundaries Requirement

Alluvial fan toe is at a stream that intersects the fan, a playa lake, an alluvial plain, or gentler slopes of piedmont plain. For coalesced fans, boundaries marked by topography trough or ridge.



No stream at the toe that intersects the fans
No obvious trough or ridge at the lateral limits of the fans
No contact of distinct differences between deposits

Summary of Stage 1 Analysis

Fan No. 5 and Fan No. 6 do not really meet all requirements of a typical alluvial fan landform.

However, Stage 2 is still performed.

Stage 2 – Defining Active and Inactive areas of Erosion and Deposition

Criteria for active alluvial fans:

Criterion No.1: Flow path uncertainty below the hydrographic apex (higher flow path uncertainty that cannot be set aside);

Criterion No.2: Abrupt deposition and ensuing erosion of sediment as a stream or debris flow loses its ability to carry material eroded from a steeper, upstream source area; and

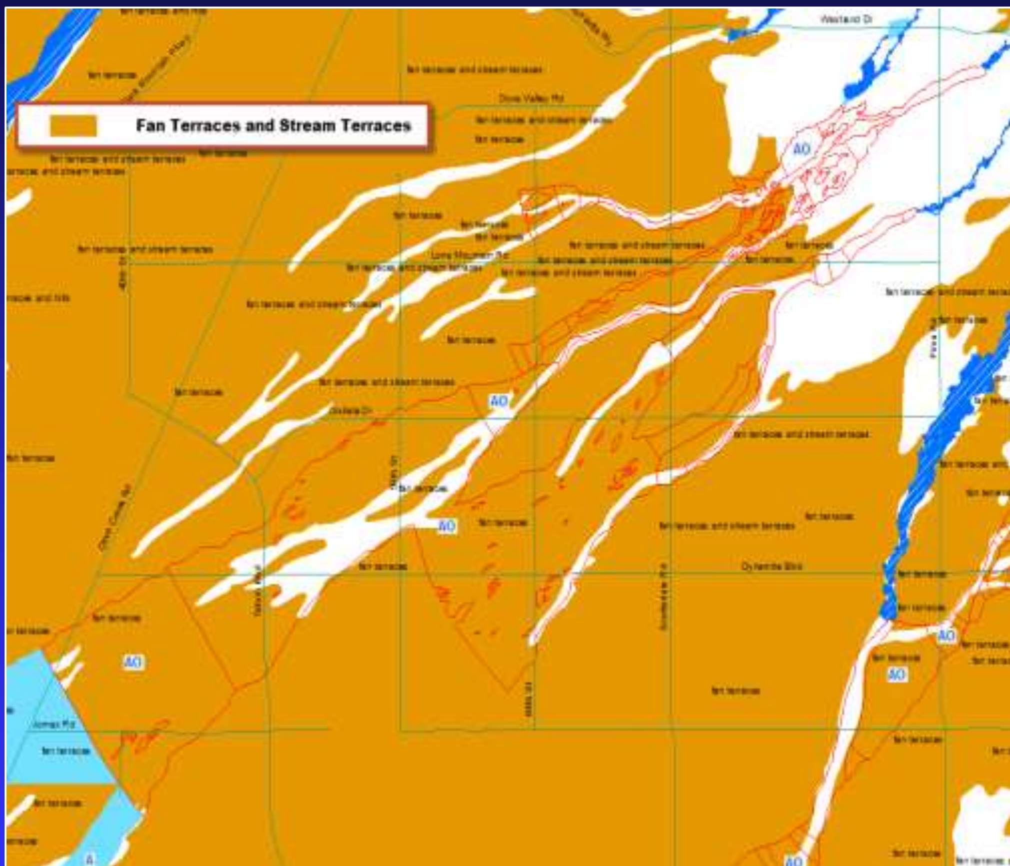
Criterion No.3: An environment where the combination of sediment availability, slope, and topography creates an ultrahazardous condition for which elevation on fill will not reliably mitigate the risk.

Stage 2 – Defining Active and Inactive areas of Erosion and Deposition

Step 1 Geomorphic Analyses

Step 2 Engineering Analyses

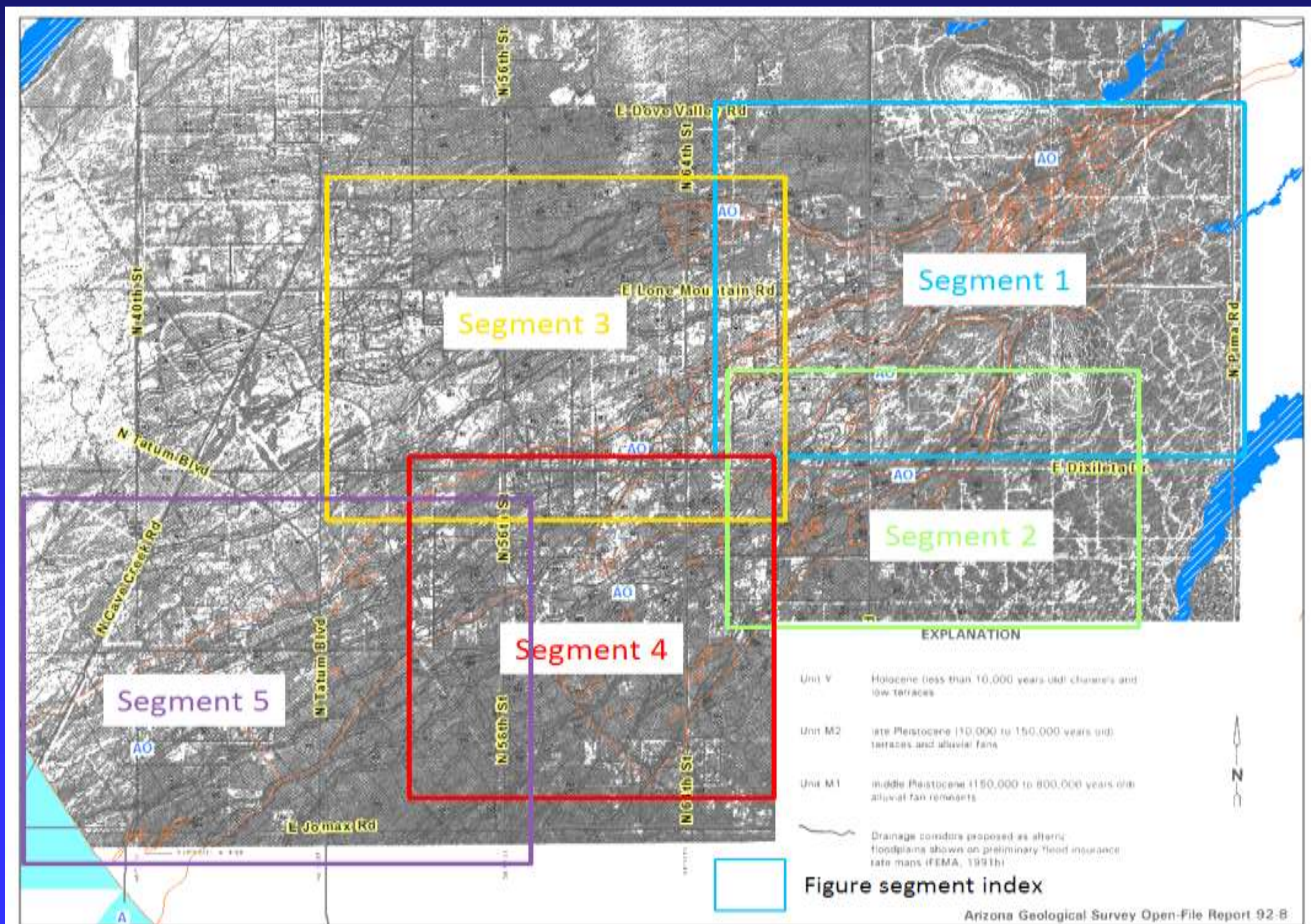
NRCS Soil Map Units for Fan Terraces and Stream Terraces



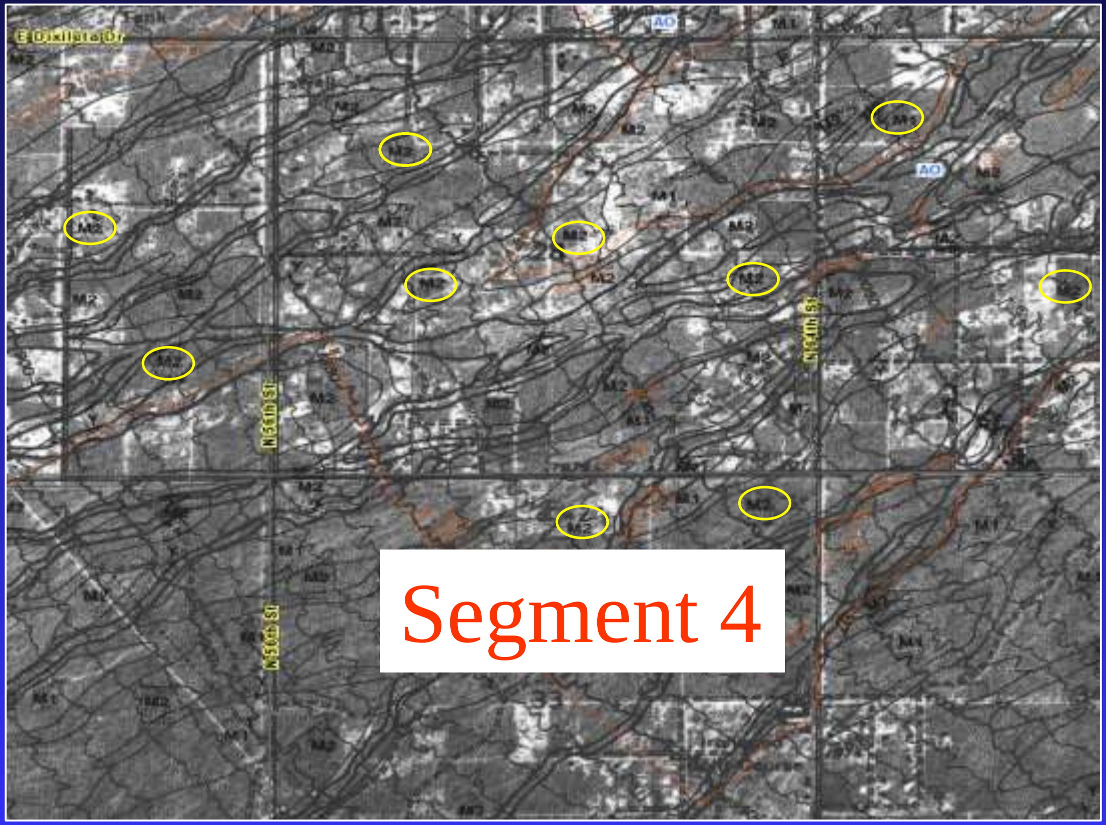
A fan terrace is a relict alluvial fan, no longer a site of active deposition, incised by younger and lower alluvial surfaces (Camp, 1986). It is a fan formed during the Pleistocene Epoch (>10,000 years) (Hjalmarson, 1994).

NRCS soil map indicates that majority of Fan 5 and Fan 6 areas are fan terraces and is older than 10,000 years.

Geomorphic Analysis of Flood Hazards on the Northern McDowell Mountains Piedmont (Pearthree and Wellendorf, 1992)



Geomorphic Analysis of Flood Hazards on the Northern McDowell Mountains Piedmont (Pearthree and Wellendorf, 1992):



Y is for Holocene channels and terraces (less than 10,000 years)

M2 is for late Pleistocene terraces and alluvial fans (10,000 to 150,000 years old)

M1 is middle Pleistocene alluvial fan remnants (150,000 to 800,000 years old).

In Segment 4, most soil are M2 (older than 10,000 years).

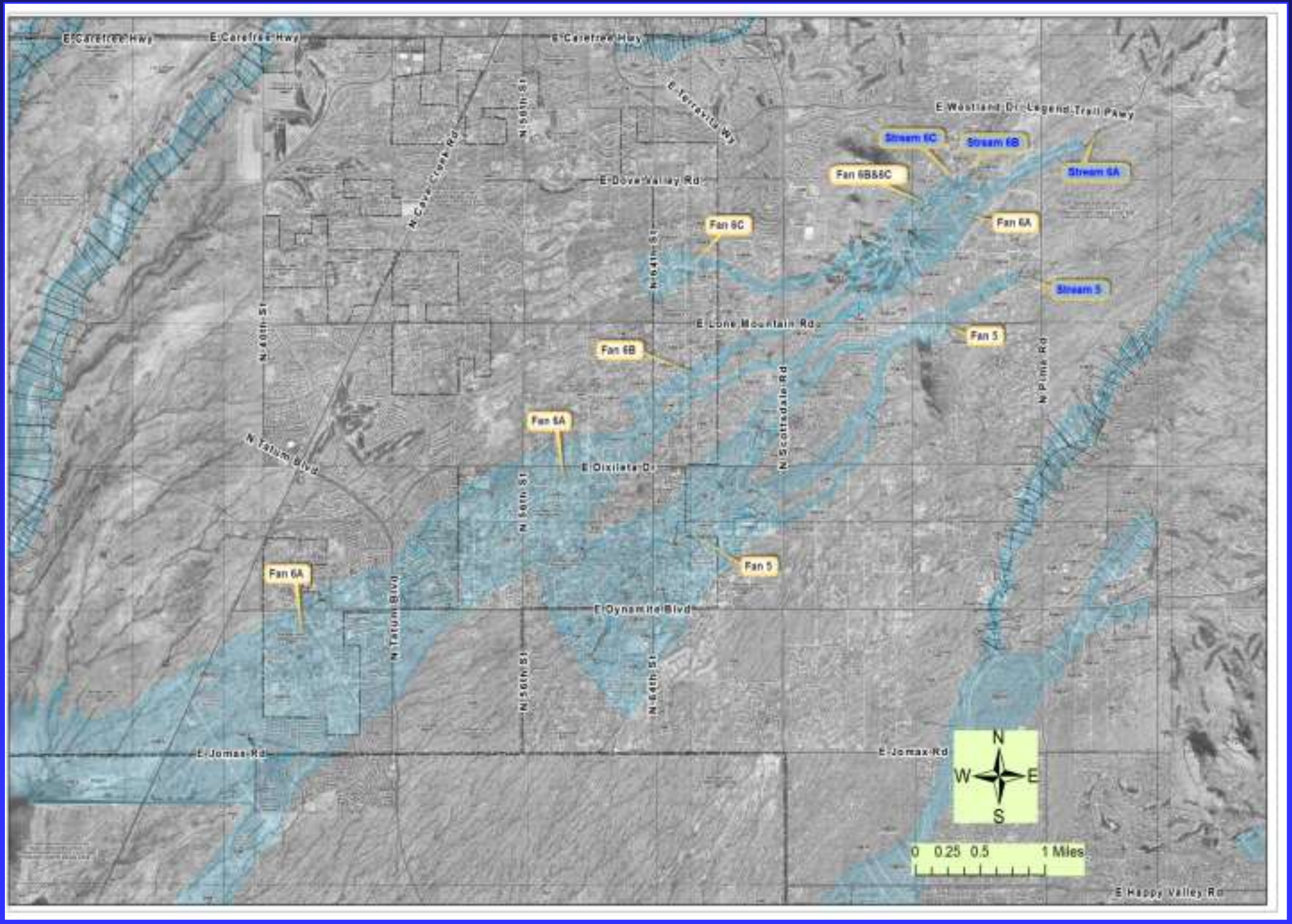
Geomorphic Analysis of Flood Hazards on the Northern McDowell Mountains Piedmont (Pearthree and Wellendorf, 1992)

Conclusions (Pearthree and Wellendorf, 1992):

- **Extent of surfaces less than 10,000 years old is very limited.**
- **Vast majority of the northern MMP is composed of Pleistocene units M2 (older than 10,000 years) and M1(older than 150,000 years).**
- **Distributive channel patterns associated with Fan 5 and Fan 6 are quite stable; channels have not shifted positions for at least 10,000 years**

Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3, 1994)

6A is about 89% of Fan No. 6



Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3, 1994)

The flow paths on 6A are stable because of the following reasons (Hjalmarson, 1994):

- There are abundant **large Palo Verde** and other trees along the banks of the distributary channels.
- **No channel movement was observed** on the distributary flow area from a comparison of aerial photographs taken in 1940, 1953 and 1991.
- The relations between channel width and discharge and mean depth and discharge for channel cross sections are typical of cross sections formed in **cohesive bank material**.

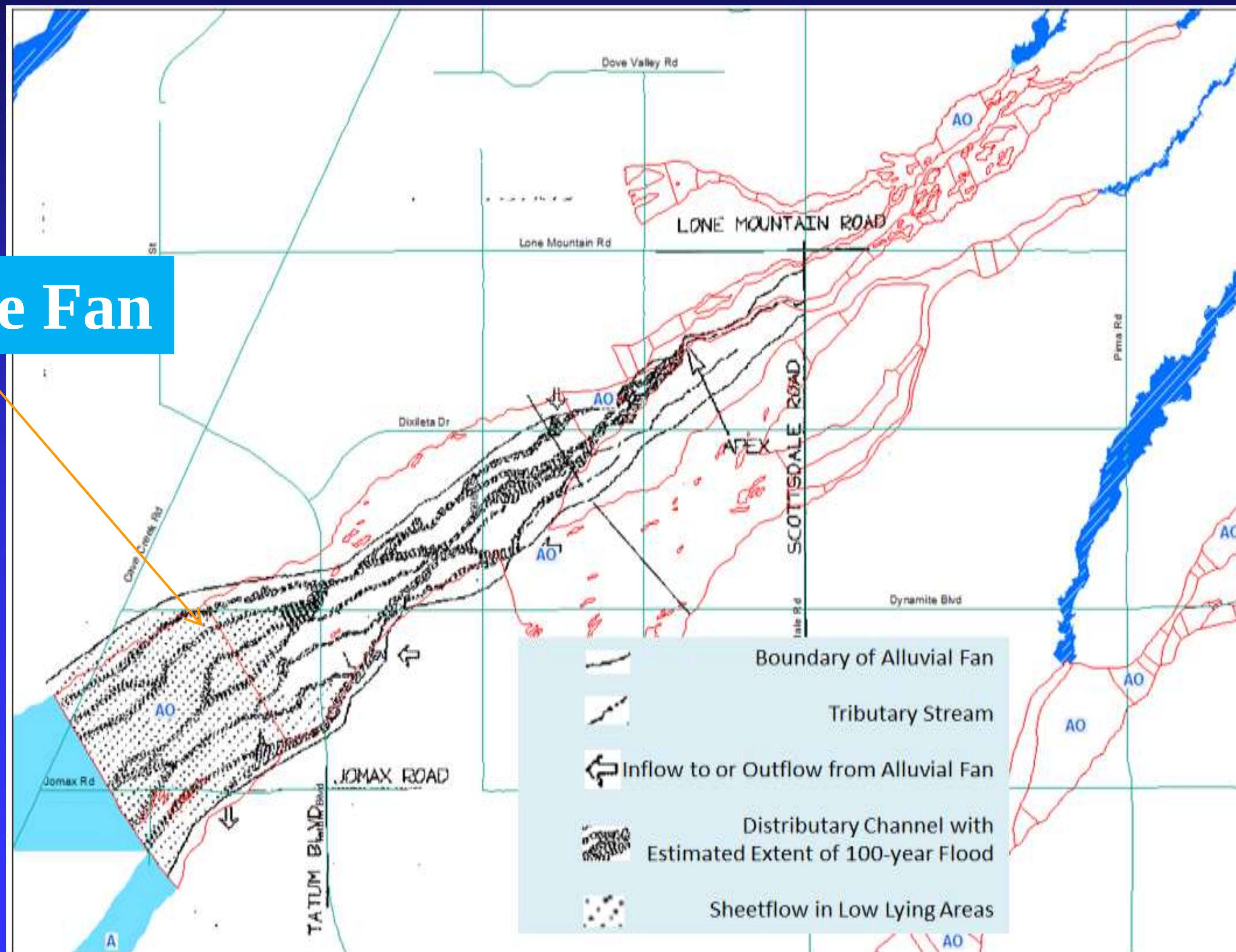
Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3, 1994)

The flow paths on 6A are stable because of the following reasons (Hjalmarson, 1994):

- **The channels are eroded into the cemented Pleistocene sediments and are not perched above the adjacent land.**
- **The soils forming the banks are well developed with dark reddish-brown sandy clay loam and clay loam textures a few inches below the surface and lime masses and may have cemented sediments.**
- **The recent deposits along the distributary channels are horizontally stratified indicating the presence of hydraulic processes and not debris flows.**

National Research Council 1996 Study of Carefree Fan (most of Fan 6)

Carefree Fan



National Research Council 1996 Study on Carefree Fan :

- Most of Carefree fan is on fan terrace.

- The tree-lined distributary channels indicate that the flow paths are fixed and in a condition of relative stability. Many of the large Palo Verde and mesquite trees along the channels are visible on the aerial photographs taken on September 7, 1941, March 8, 1953, and March 30, 1991 for Carefree fan. A comparison of these photos indicates that there has been no change in the location of flow paths.

- Rhoads (1986) found no major changes in the form of channel networks in the general region for a 30-year historical period.

National Research Council 1996 Study on Carefree Fan:

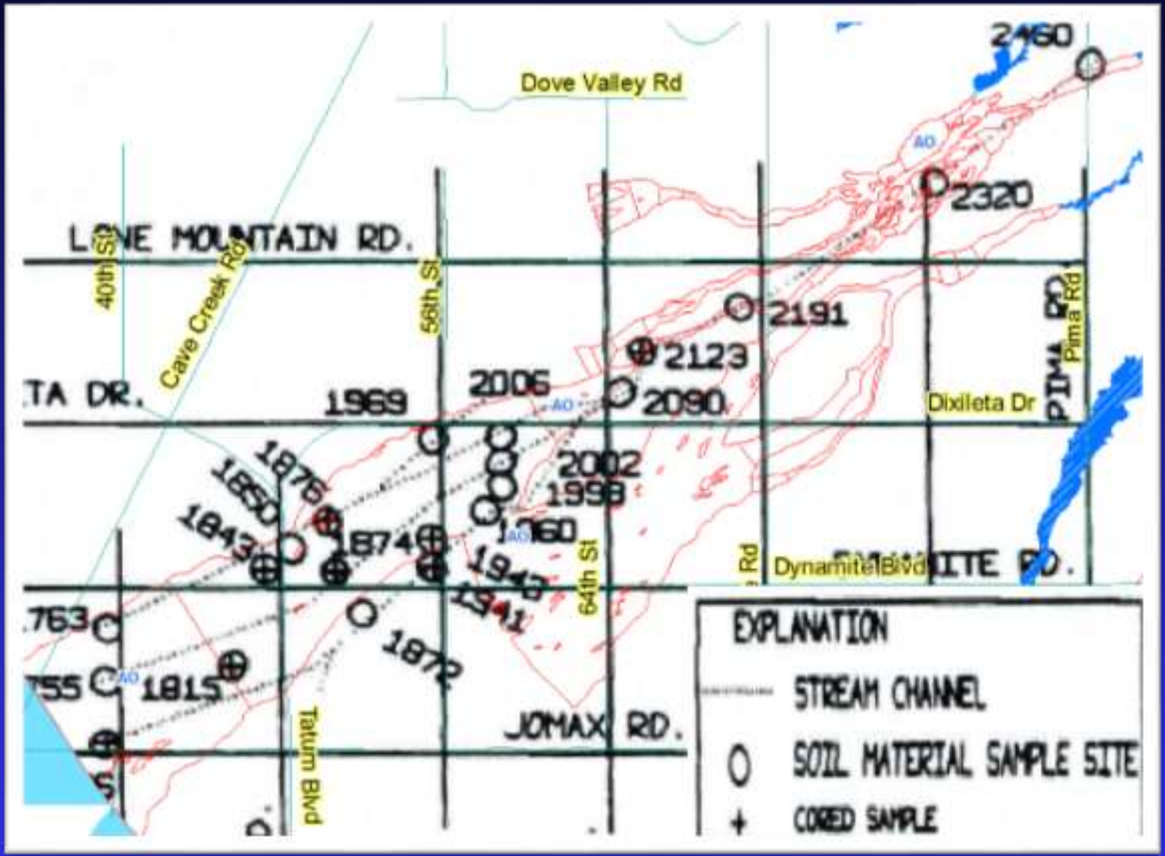
- There is no evidence of debris flow.
- The flow paths are confined by stable interfluves and there is little alluviation, there currently is no active flooding on Carefree fan.
- There are no areas on the Carefree fan where flow paths are expected to change.
- Flood flow typically is confined within and adjacent to the trench channels.

Stage 2 – Defining Active and Inactive areas of Erosion and Deposition

Step 1 Geomorphic Analyses

Step 2 Engineering Analyses

Soil Sample Sites Map



Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3rd, 1994)

The channels and flow paths of Fan 6A are found to be stable because:

Uniform distribution of particle size along the channels indicates that mobile bed material entering the distributary flow area is conveyed through the system of defined distributary channels (no deposition).

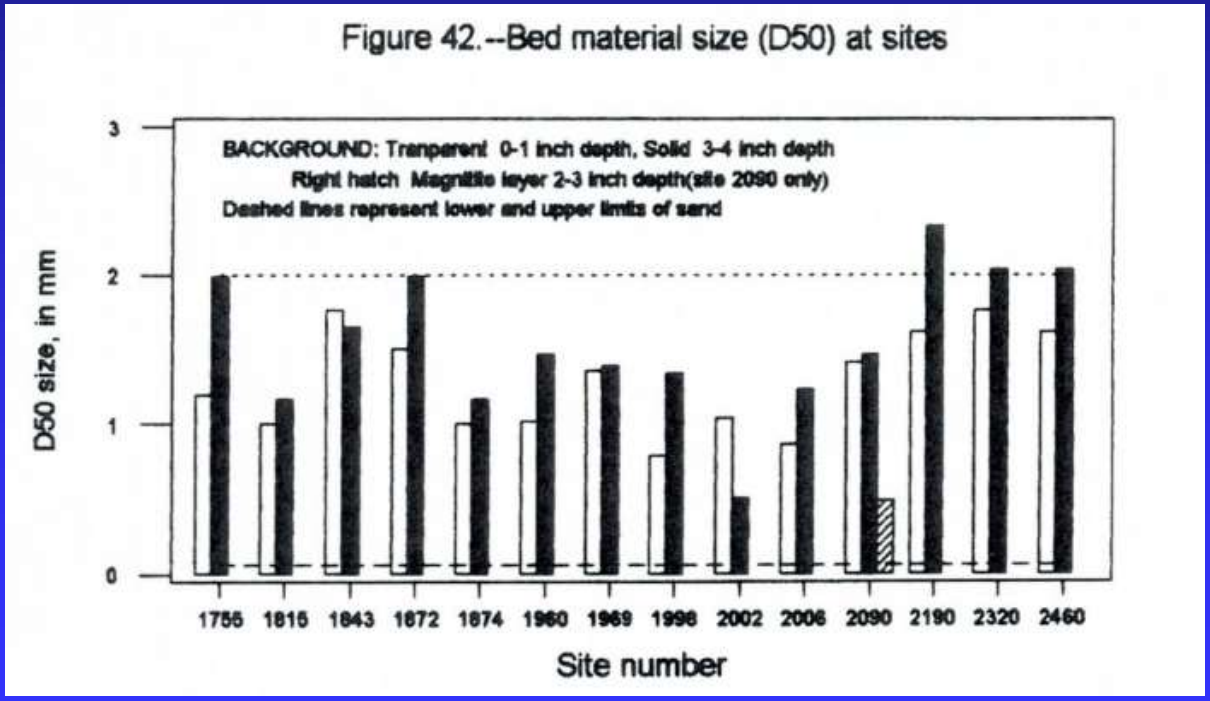
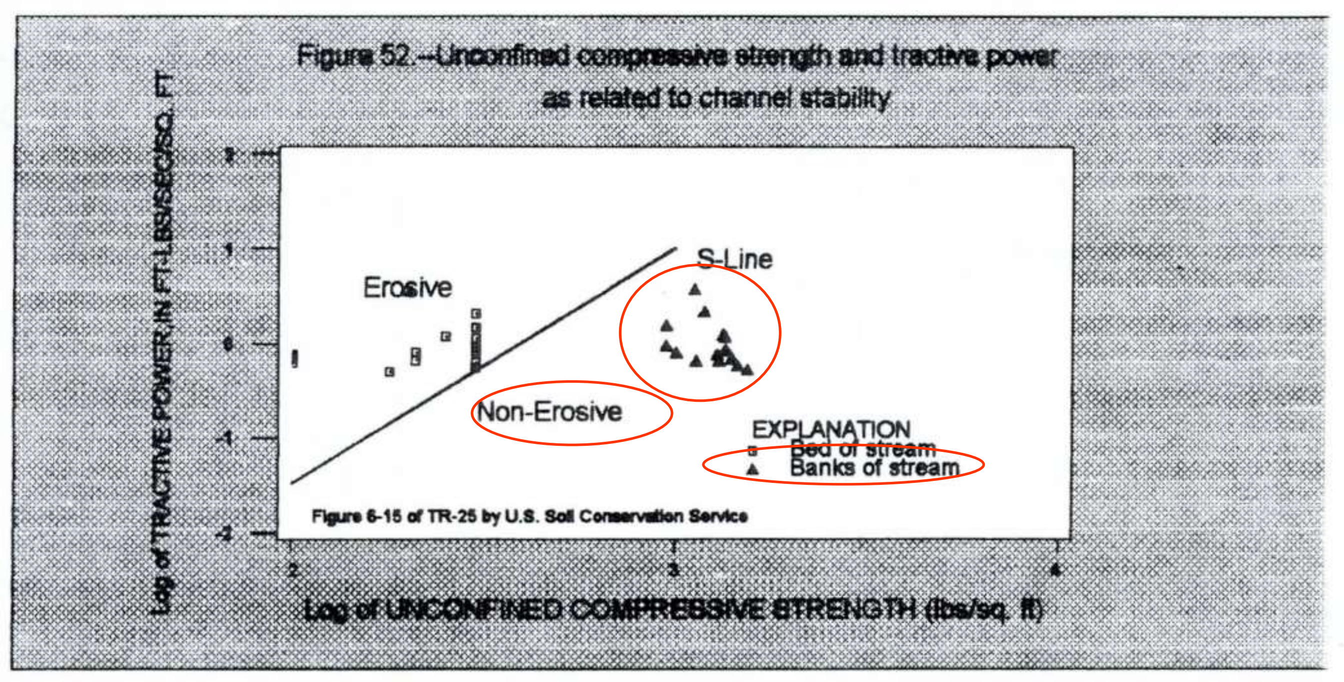


Figure 42.--Bed material size (D50) at sites

Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3rd, 1994)

The channels and flow paths of Fan 6A are found to be stable because:

Measurements of vane shear corresponding to computed tractive power at many cross sections show the channel banks are non-erosive or stable. The data consistently plotted in the non-erosive region of the relation of tractive power and unconfined compressive strength published in TR-25 by the U.S. Soil Conservation Service.



Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3rd, 1994)

The channels and flow paths of Fan 6A are found to be stable because:

Data from measurements of channel geometry and material samples at several cross sections were plotted on the relation between channel width-depth ratio and percent silt-clay along the wetted perimeter published in USGS Professional Paper 352C; and the data for site 6A plotted consistently in the stable region of the relation.

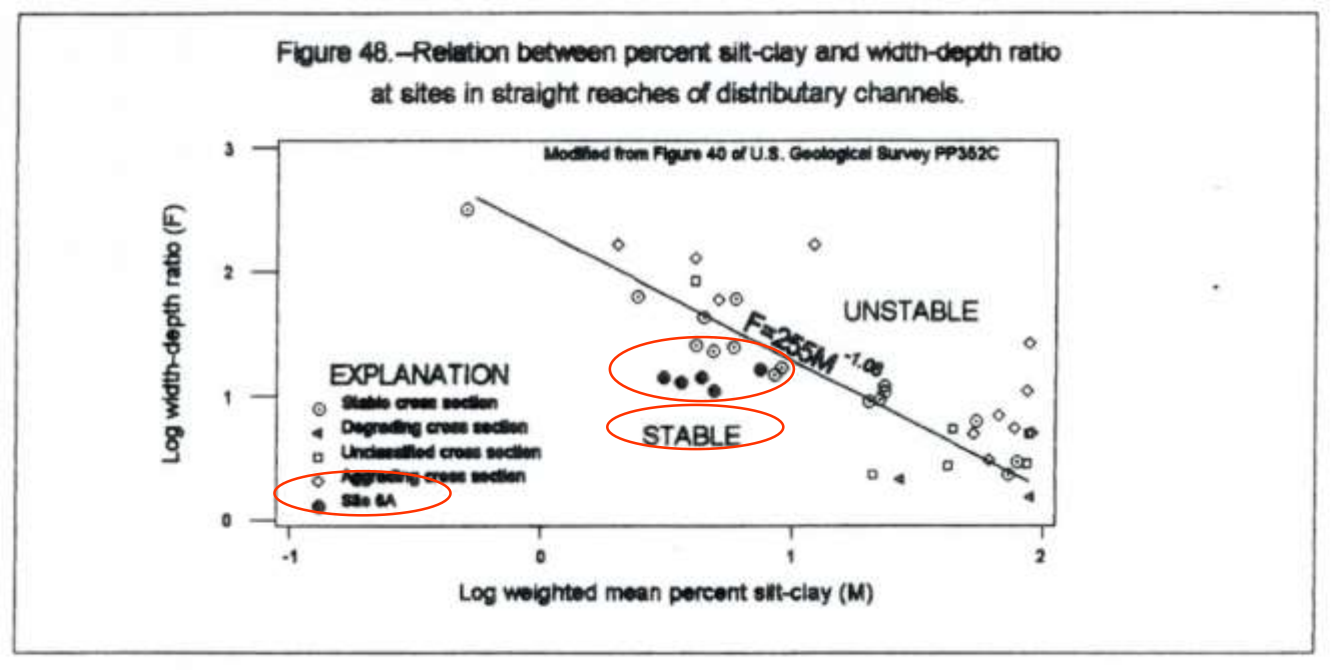


Figure 48.–Relation between percent silt-clay and width-depth ratio at sites in straight reaches of distributary channels.

Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3rd, 1994)

The channels and flow paths of Fan 6A are found to be stable because:

Data from measurements of vegetation size and channel geometry show the stream power at most cross sections is insufficient to lay over or remove larger trees along the channel banks.

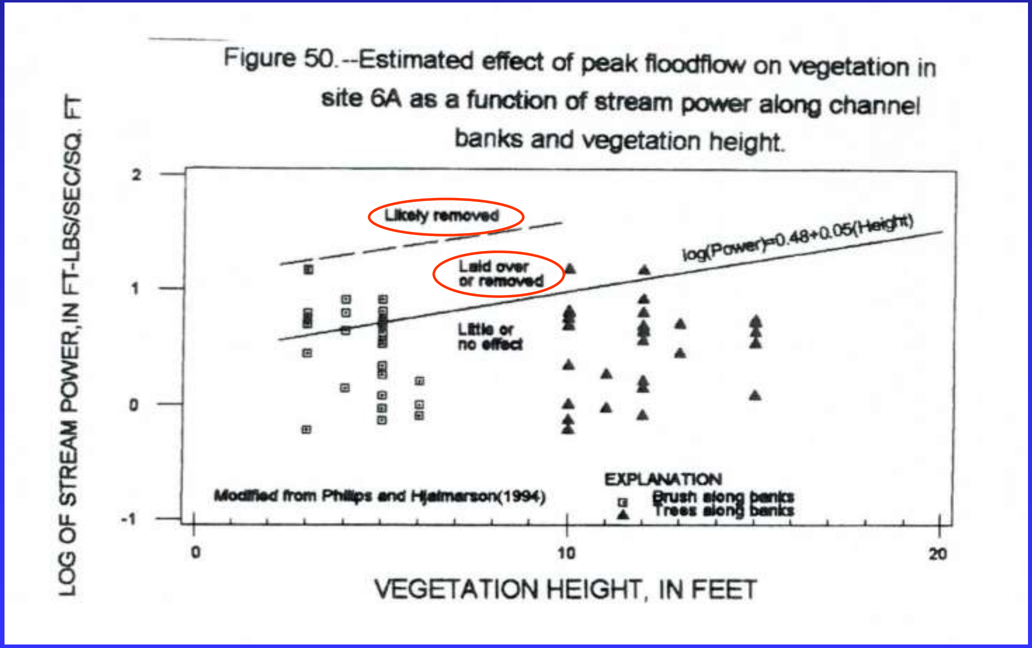


Figure 50.--Estimated effect of peak floodflow on vegetation in site 6A as a function of stream power along channel banks and vegetation height.

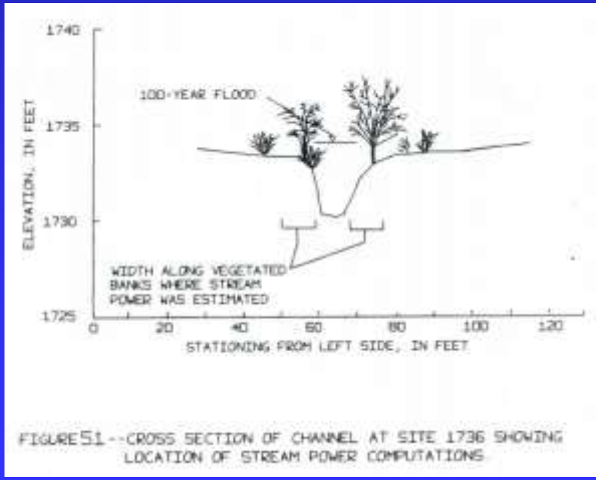


FIGURE 51--CROSS SECTION OF CHANNEL AT SITE 1736 SHOWING LOCATION OF STREAM POWER COMPUTATIONS

Flood Characteristics of FEMA Site 6A (Hjalmarson, June 3rd, 1994)

Stage 2 – Defining Active and Inactive areas of Erosion and Deposition

Step 1 Geomorphic Analyses

Step 2 Engineering Analyses

Summary of Stage 2 Analysis

Fan 5 and Fan 6 are inactive. Therefore, a 2-dimensional hydraulic model can be used to delineate the floodplains in Stage 3.

Application of the Latest FEMA Methodology to Fan 5 and Fan 6

3-stage Approach

- Stage 1 – Identify Alluvial Fan Landforms;
- Stage 2 – Active or Inactive?
- Stage 3 – 100-year Floodplain Delineation

Presentation Outline

- ✓ **Alluvial Fan No. 5 and Fan No. 6 in Scottsdale and Phoenix**
- ✓ **Alluvial Fan Delineation Methodologies**
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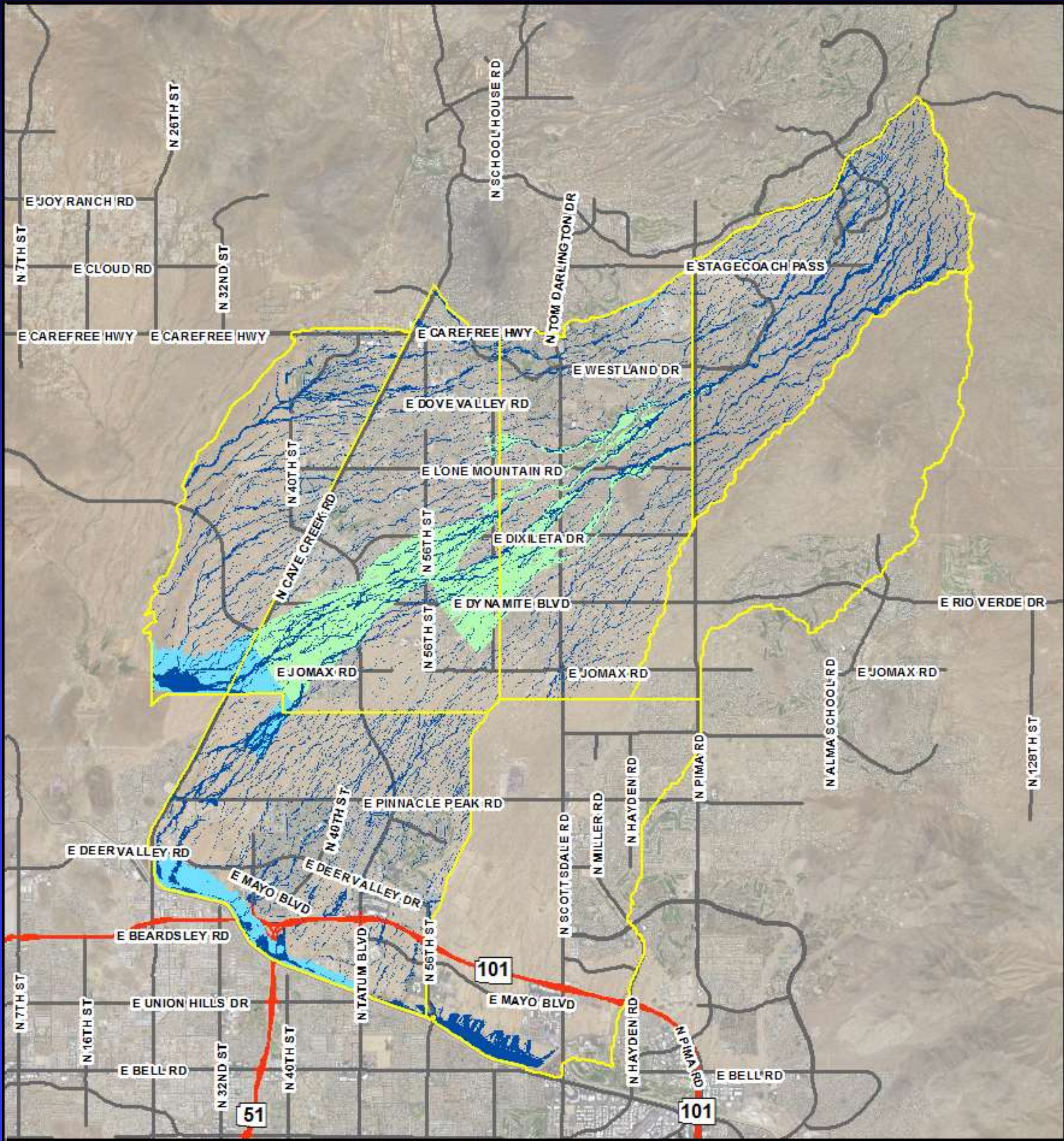
100-year Floodplain Re-delineation of Fans 5 & 6

- Part of Pinnacle Peak ADMS
- FLO-2D study
- 7 connected models
- 5 used for the delineation study
- Revising the Alluvial Fan AO Zone



Modeling Approach

- FLO-2D Pro
  - Hydrology & Hydraulics
- FEMA Approved for use in Maricopa County
- Followed the procedures in FLO-2D Verification Report
  - Spatially Varied Point Rainfall (NOAA 14)
  - Green-Ampt Infiltration
  - Hydraulic Structures
  - No walls
  - Limiting Infiltration Depths
  - Storm Event Verification

Drainage Policies and Standards for Maricopa County
Supplemental Technical Document
F.C.D. PCN 003.01.01

FLO-2D VERIFICATION REPORT

Prepared by:

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

2801 W. Durango Street

Phoenix, AZ 85009

(602) 506-1501

May 2016

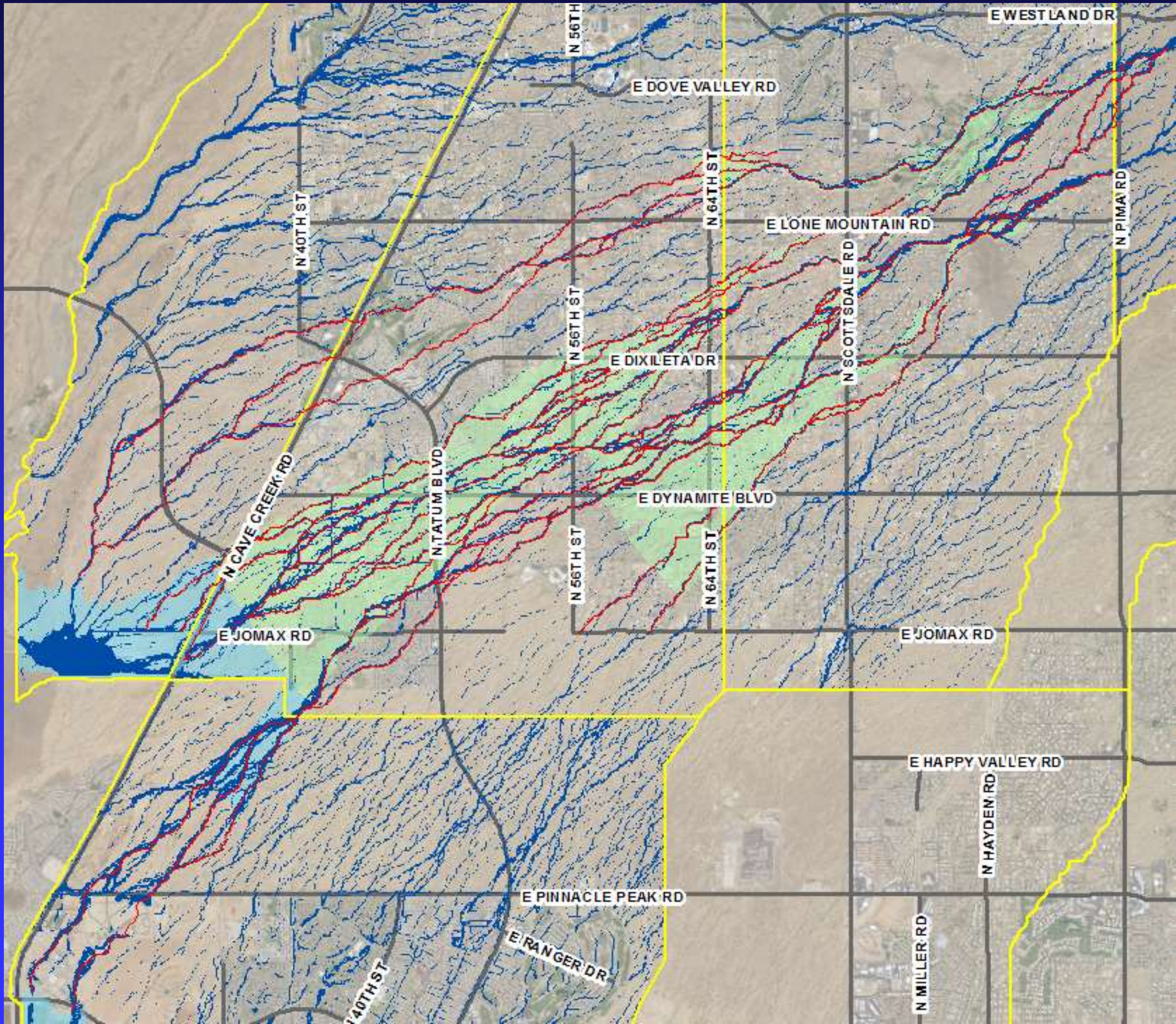
EXPIRES 06/30/2018

May 2016

Mapping Approach

Identify Corridors

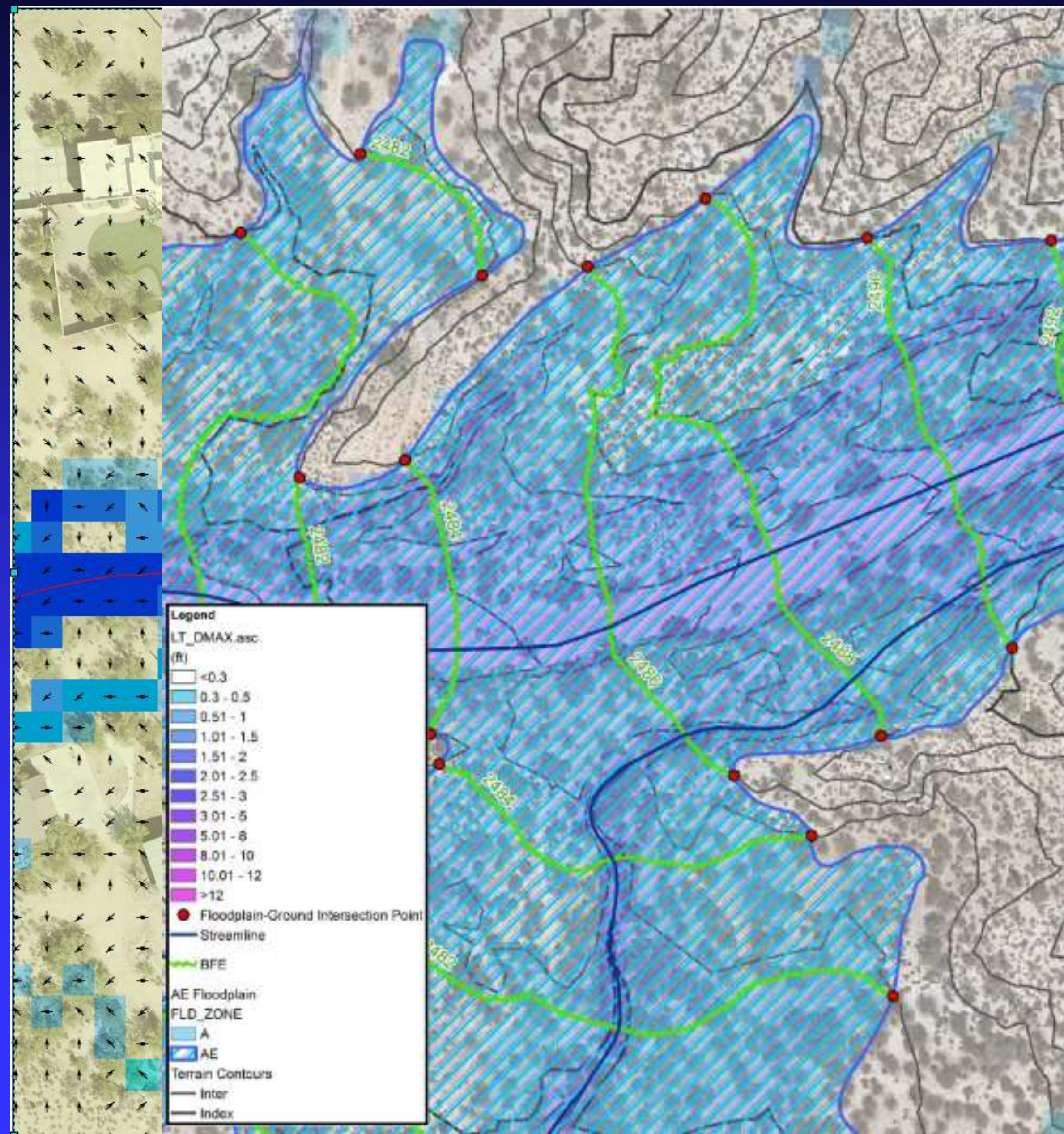
- Connection to upstream washes
- Consistent Flow Depth (>0.3 ft)



Mapping Approach

Lateral Boundaries

- Flow Direction Arrows
- WSEL contour lines compared to topographic contours
- Consistent Flow Depth (>0.3 ft)



Results

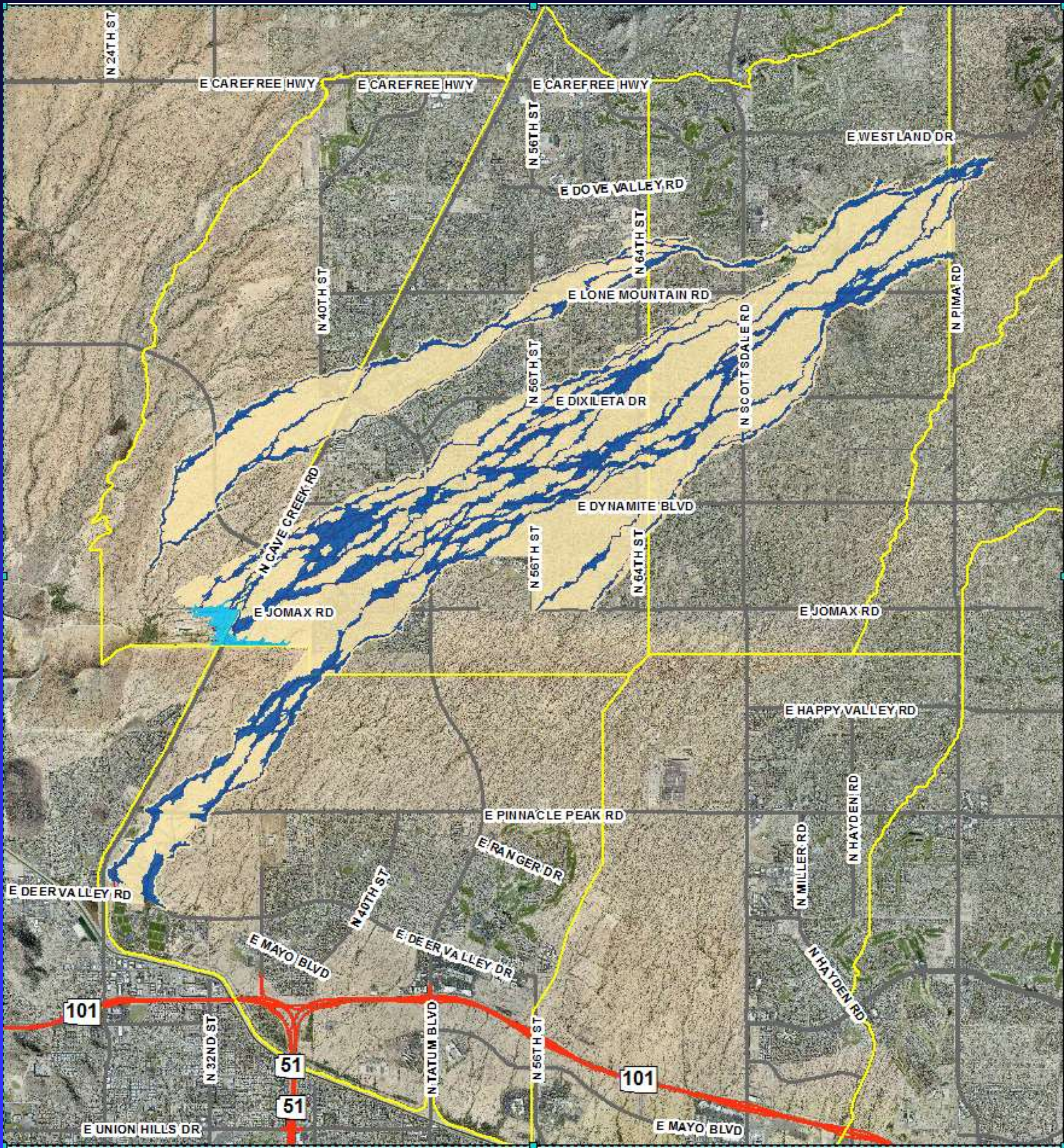
102 linear miles
73 washes

Zones:
- AE
- Shaded X
- A
- No Floodways

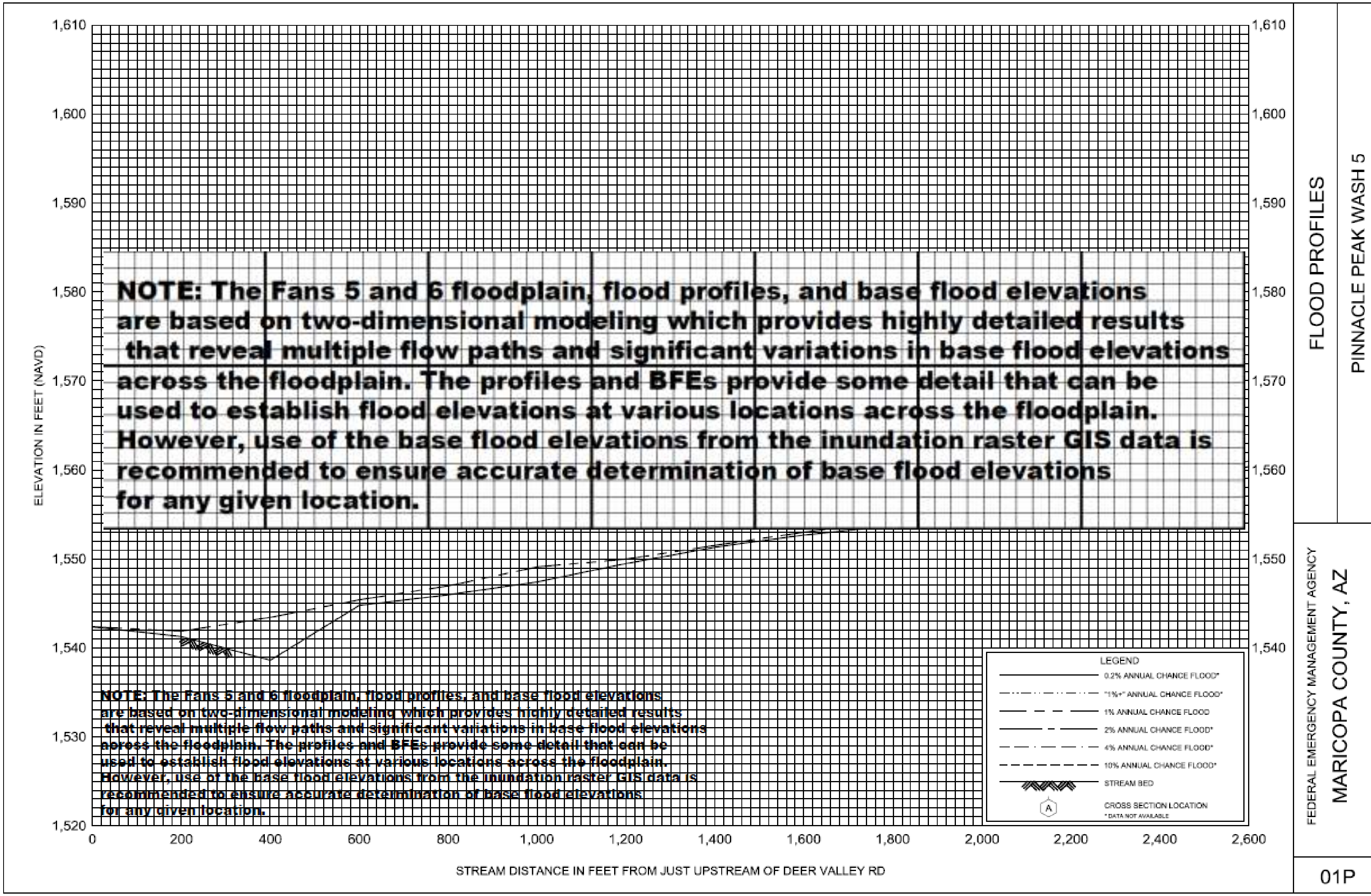
BFE versus Depths

Profile Sheets
- 245 pages

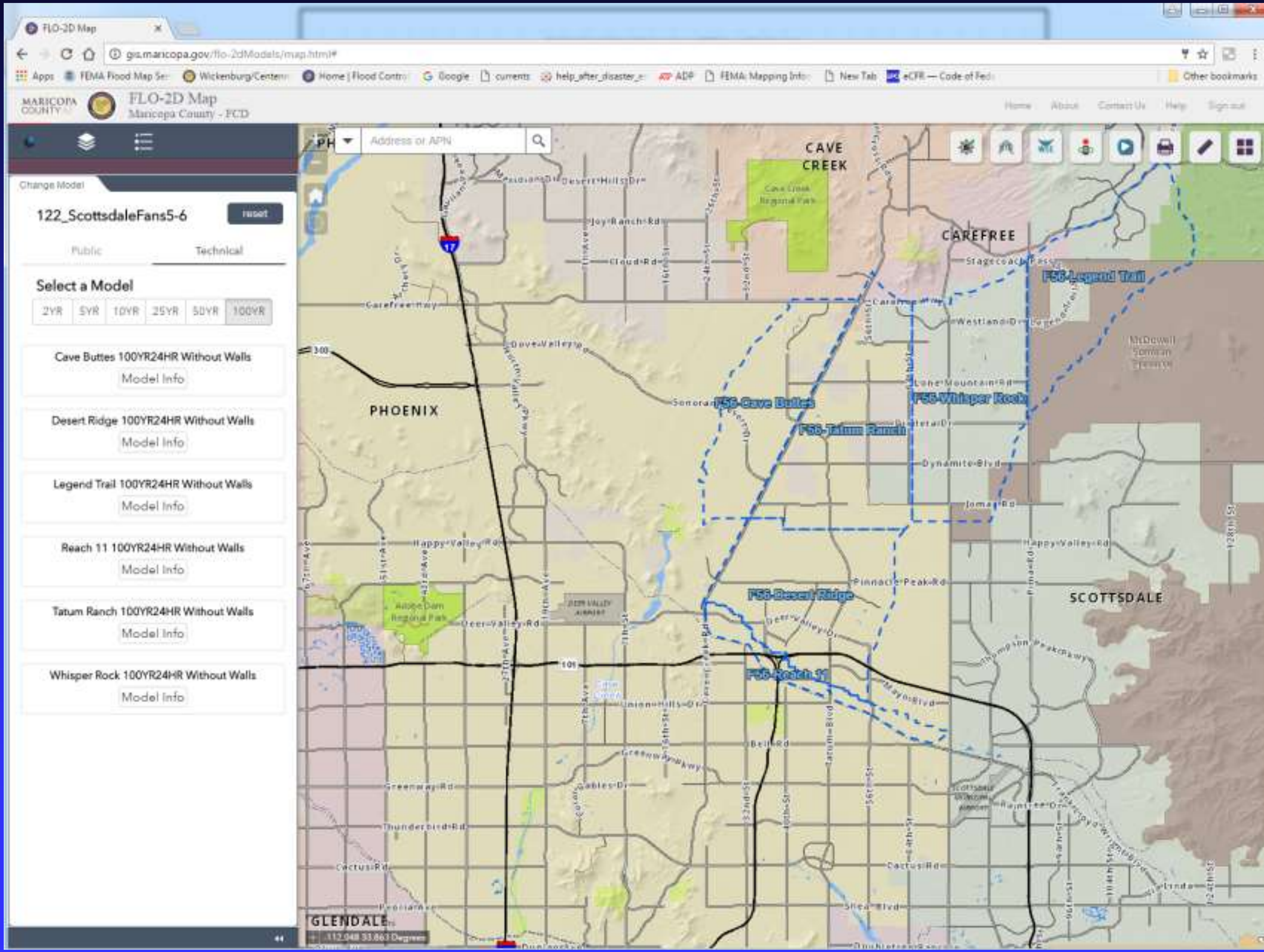
Summary of Qs



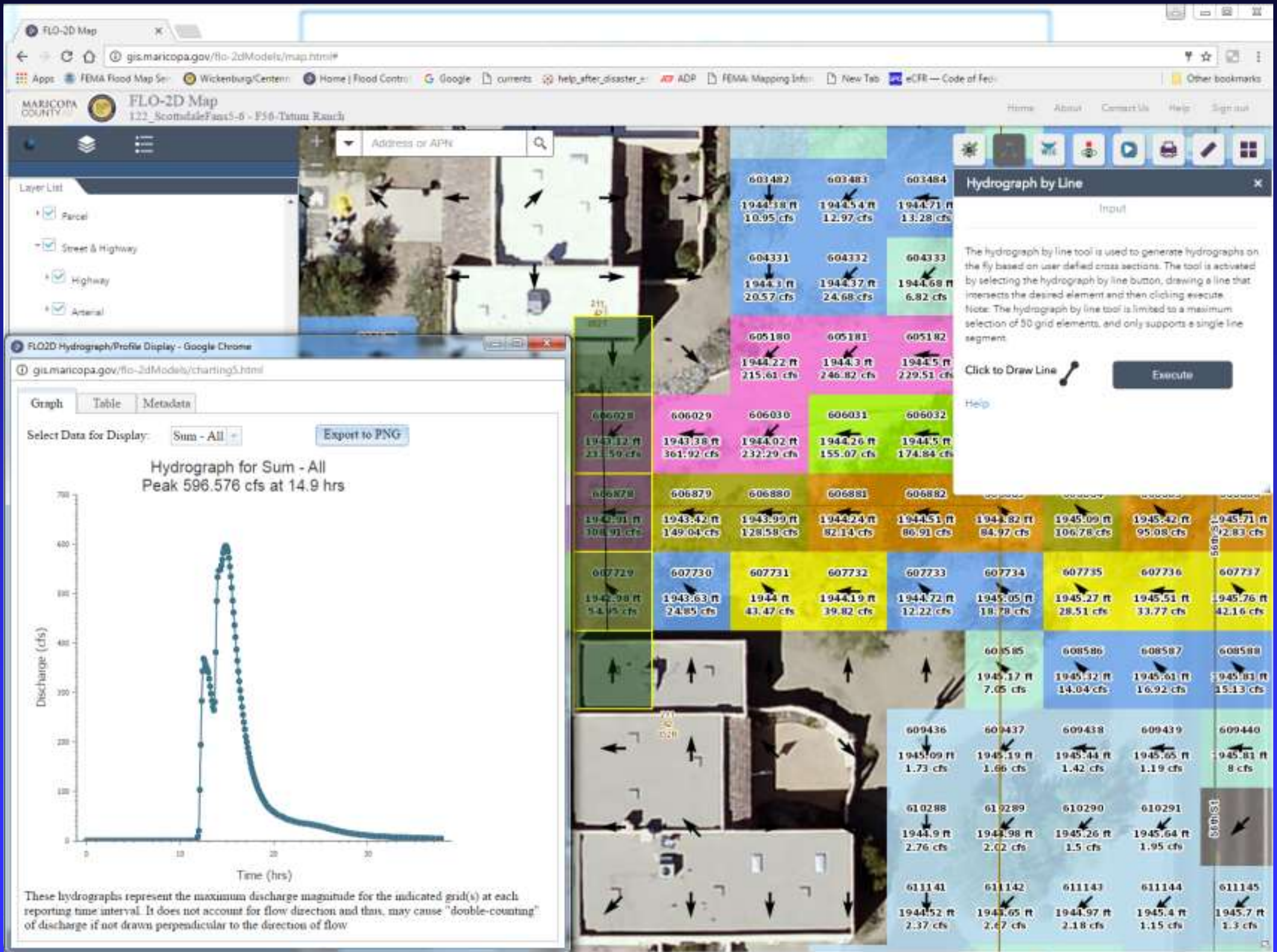
Profiles


NOTE: The Fans 5 and 6 floodplain, flood profiles, and base flood elevations are based on two-dimensional modeling which provides highly detailed results that reveal multiple flow paths and significant variations in base flood elevations across the floodplain. The profiles and BFEs provide some detail that can be used to establish flood elevations at various locations across the floodplain. However, use of the base flood elevations from the inundation raster GIS data is recommended to ensure accurate determination of base flood elevations for any given location.
ELEVATION IN FEET (NAVD)
1,610
1,600
1,590
1,580
1,570
1,560
1,550
1,540
1,530
1,520
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
STREAM DISTANCE IN FEET FROM JUST UPSTREAM OF DEER VALLEY RD
LEGEND
0.2% ANNUAL CHANCE FLOOD*
"1%+" ANNUAL CHANCE FLOOD*
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD*
4% ANNUAL CHANCE FLOOD*
10% ANNUAL CHANCE FLOOD*
STREAM BED
CROSS SECTION LOCATION
* DATA NOT AVAILABLE
FLOOD PROFILES
PINNACLE PEAK WASH 5
FEDERAL EMERGENCY MANAGEMENT AGENCY
MARICOPA COUNTY, AZ
01P

FLO-2D Web Application



FLO-2D Web Application



Next Steps

- FEMA Approved in early 2018
- Region IX going to prepare Preliminary Products
  - 1000 scale panels will become 500 scale
- Hoping for Preliminary in early 2019?
- Effective in 2020?
- In Interim, Communities regulate to most conservative of both products

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Questions?