Alluvial fan flood hazard assessment: A comparison of FEMA, NRCS, and surficial geological maps in Ivanpah Valley, Nevada

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ABSTRACT:

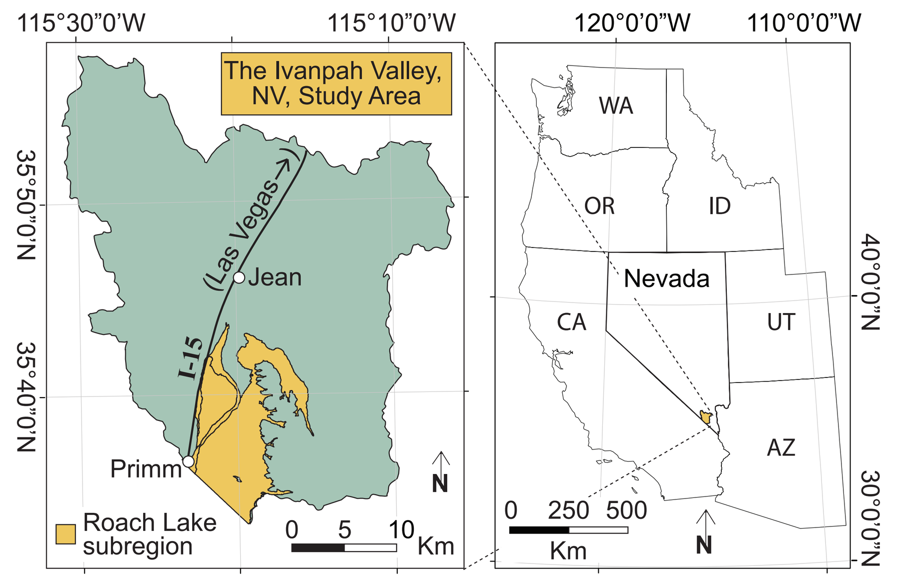
Alluvial fan flooding is increasingly important given the exponential urbanization of arid regions. However, flood behavior on alluvial fans in arid/semi-arid climates differs significantly from that of perennial rivers. Additionally, flood hazard maps differ widely depending on the methods, terminology, and spatial and temporal scales used. To improve understanding of arid system floods, and to ameliorate confusion for map users, we compared Federal Emergency Management Agency (FEMA) (CCRFCD, 2002), Natural Resource Conservation Service (NRCS) (Soil Survey Staff, 2007), surficial geology (House et al., 2006a; House et al., 2006b) and flood hazard (House, 2007) maps for the Ivanpah Valley, NV, the location of a planned new international airport. The FEMA map depicts areas that lie within the 100-yr flood hazard (Zone A) and those that do not (Zone X). The Order 3 NRCS survey shows 40 associations, each containing up to 5 distinct soil components and flood classes. The geologic map (1:50,000) contains 21 unique geomorphologic units. Of the 1,001.5 km2 study area, 3.4 percent lies within FEMA Zone A, compared to 21.9 percent within the House (2007) Very High flood class alone. Soil components within the NRCS map are correlative to the surficial geology units and if both are combined the result is nearly an Order 2 soil survey. The House (2007) map provides the most useful information on flood hazards for land-use planning. This map depicts active drainage systems, their flowpaths, and the locations of specific drainage divides, indicating that geomorphology is the most important and unifying criterion for alluvial fan flood hazard determination.

BACKGROUND:

- Urban expansion on alluvial fan piedmonts is rapidly increasing in the arid SW United States.
- Such development is inherently risky, as alluvial fan flooding is less predictable than flooding in perennial river systems.
- Flood hazard maps are often confusing to users, because numerous agencies create flood maps that differ in mapping methods, spatial scales, terminology, and temporal viewpoints.
- This study focused on the similarities and differences in FEMA flood hazard (CCRFCD, 2002), NRCS (Soil Survey Staff, 2007), and surficial geological maps (House et al., 2006a; 2006b; House, 2007) in the Ivanpah Valley, NV.

STUDY AREA:

Figure 1



- The study area is located in the Ivanpah Valley of southern Clark County, NV, 45 miles south of Las Vegas (Fig. 1).
- Roach Lake, a playa in Ivanpah Valley, is the planned site for a new international airport intended to serve the Las Vegas metropolitan area.

QUESTIONS:

- What are the key differences between the FEMA DFIRM, surficial geologic, and NRCS flood hazard assessments of Ivanpah Valley, NV?
- What is the percent correlation between flood class determinations for soil map units and geomorphological units?
- What do map differences, limitations of source data, and mapping methods mean for map users?
- What are the implications for flood hazard assessment in Ivanpah Valley, NV?
- What are the broader implications for flood hazard assessment on fan piedmonts in the Great Basin, or in arid to semi-arid environments of the southwestern United States?

RESULTS: *GIS Analyses*

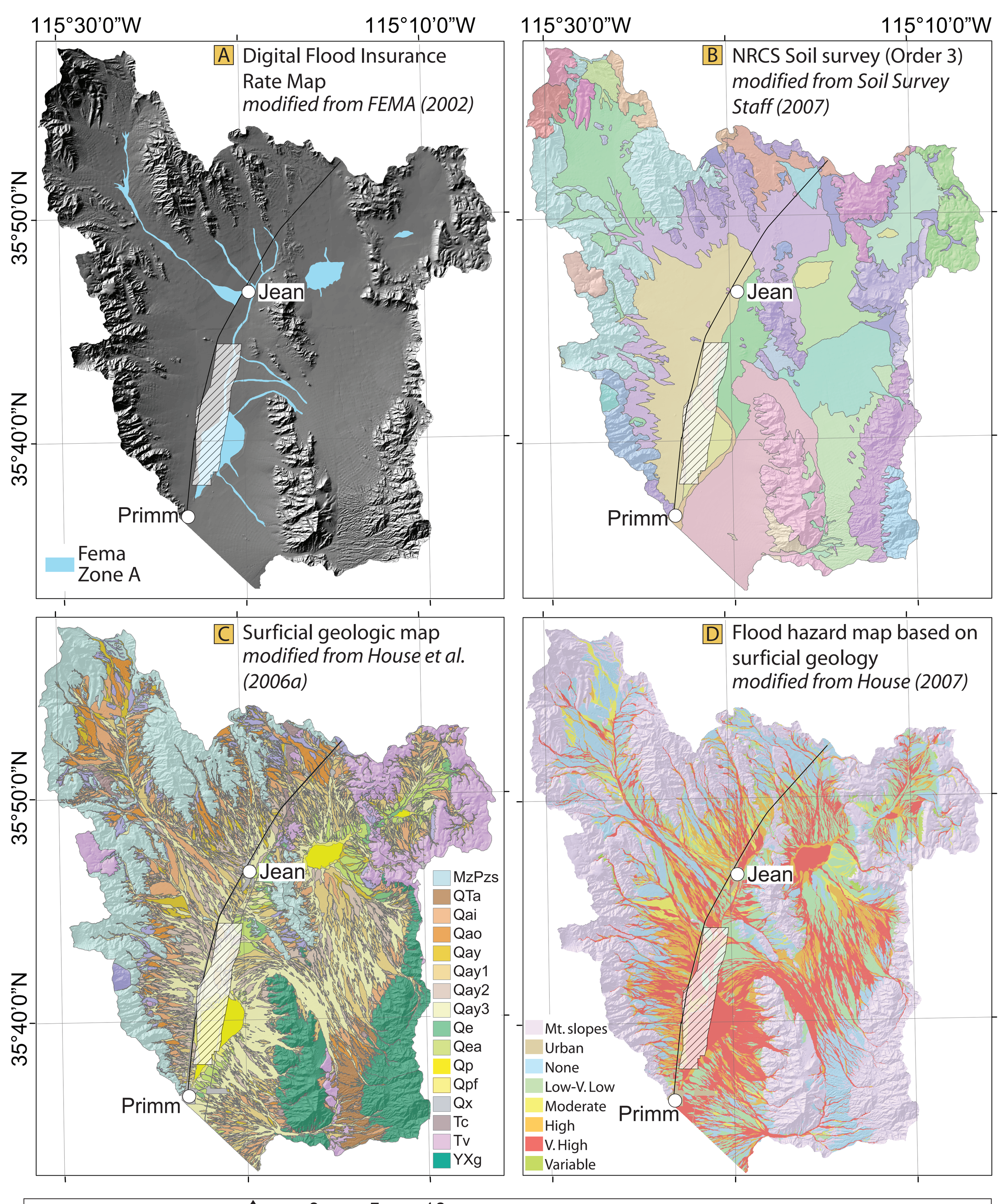


Figure 2: Comparison of flood hazard assessments of Ivanpah Valley, Nevada. The reader is referred to the primary map data sources for full map unit descriptions.

Figures 1-3 prepared by Colin Robins

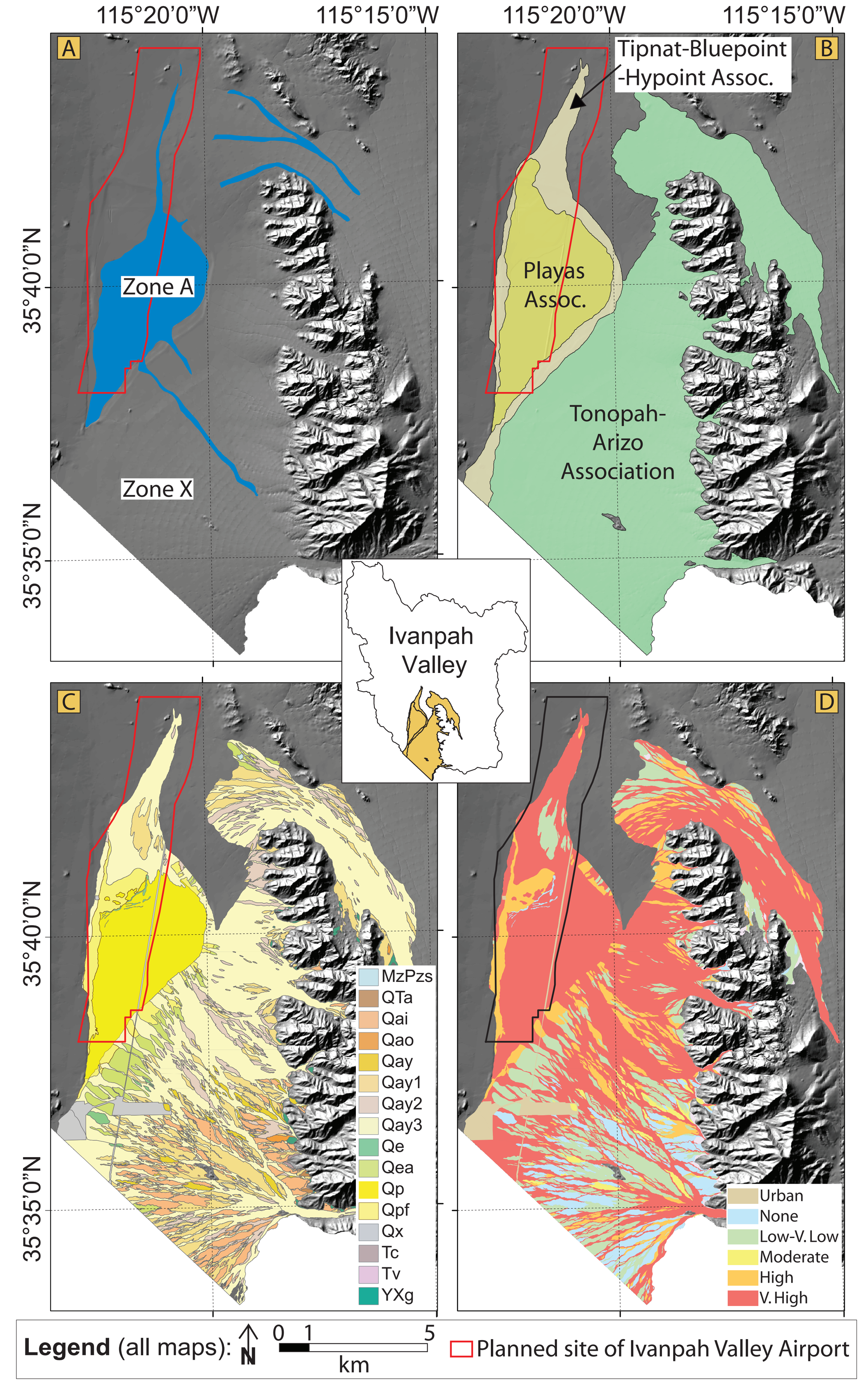


Figure 3: Roach Lake Subregion of Ivanpah Valley selected for qualitative comparison. (**A**) DFIRM modified from FEMA (2002); (**B**) Soil Survey Map modified from Soil Survey Staff (2007); (**C**) surficial geologic map modified from House et al. (2006a); (**D**) Geomorphological Flood Hazard Map modified from House (2007).

Table 1: GIS Comparison of House (2007) and FEMA (2002) flood hazard assessments for the entire study area

House (2007) Flood Class	FEMA Flood Zone	Extent (km²)	% of flood class comprised by each FEMA zone	Percent of total field area
None	A	0.7	0.5	0.1
	X	150.3	99.5	15.0
Low	A	3.0	2.4	0.3
	X	123.3	97.6	12.3
Moderate	A	0.3	1.2	0.0
	X	24.2	98.8	2.4
High	A	2.9	3.6	0.3
	X	78.1	96.4	7.8
Very high	A	26.3	12.2	2.6
	X	189.3	87.8	18.9
Variable	X	2.9	100.0	0.3
Urban Areas	A	0.4	4.0	0.0
	X	10.6	96.0	1.1
Mntn sideslopes	A	0.2	0.1	0.0
	X	389.0	99.9	38.8
Summary				
Total area of the Ivanpah Valley study region				1001.5 km²
Total FEMA (2002) flood hazard area (zone A)				33.9 km²
Total FEMA (2002) non-hazard area (zone X)				967.7 km²
Total House (2007) very high flood risk area				215.6 km²

Table 2: GIS comparison of House (2007) and FEMA (2002) flood assessments for the Ivanpah Valley Airport subregion

House (2007) Flood Class	FEMA Flood Zone	Extent (km²)	% of flood class comprised by each FEMA zone	Percent of total field area
None	A	0.15	1.9	0.1
	X	7.75	98.1	7.0
Low	A	0.52	2.7	0.5
	X	18.50	97.3	16.7
Moderate	A	0.02	1.4	0.0
	X	1.52	98.6	1.4
High	A	0.69	5.8	0.6
	X	11.23	94.2	10.1
Very high	A	16.52	24.5	14.9
	X	50.97	75.5	45.9
Urban Areas	A	<0.01	0.4	<0.01
	X	0.79	99.6	0.7
Mntn sideslopes	A	0.27	11.0	0.2
	X	2.15	89.0	1.9
Summary				
Total area of the subregion studied here				111.06 km²
Total FEMA (2002) flood hazard area (zone A)				18.16 km²
Total FEMA (2002) non-hazard area (zone X)				92.9 km²
Total House (2007) very high flood risk area				67.48 km²

Table 3a: Playas Association

Component Soil Series	Taxonomy	CaCO3 Morphology (NRCS derived)	NRCS Landform Classification	NRCS Flood or Ponding Class	House et al. (2006) Geomorphic Unit	House et al. (2006) Flood Class
Playas	None Assigned	N/A	Playa	None/ Frequent Ponding	Qp	Very High
Tipnat	Typic Natriargid	Stage I - II	Alluvial Flat	Rare	Qpf	High
Hypoint (Gravelly Loamy Sand)	Thermic Typic Torri-orthent	N/A	Fan Skirt	Rare	Qay3	Very High

Table 3b: Composition of the Playas Association, by geomorphologic unit

House et al. (2006) unit	Extent (km2)	% of Soil Association
Qp	13.4	75.7
Qay3	2.4	13.8
Qpf	1.4	8.1
Qx	0.3	1.5
Qe	0.2	1.0
Qay1	<0.01	0
Qay2	<0.01	0

Table 4a: Tonopah-Arizo Association

Component Soil Series	Taxonomy	CaCO3 Morphology (NRCS derived)	NRCS Landform Classification	NRCS Flood or Ponding Class	House et al. (2006) Geomorphic Unit	House et al. (2006) Flood Class
Tonopah (extremely gravelly sandy loam, 8% slopes)	Thermic Typic Haplocalcid	Strong Stage 1 to incipient Stage 2	Fan Remnant	Very Rare	Qay1	Low
					Qay2	High
Arizo (very gravelly)	Thermic Typic Torriorthent	N/A	Fan Apron/ Drainage	Very Rare	Qay3	Very High
					Qea	Variable
Typic Haplodurid	Typic Haplodurid	Stage III - IV	Fan Remnant	None	Qai	None
Arizo (extremely gravelly)	Thermic Typic Torriorthent	N/A	Drainage	Frequent	Qay3	Very High
Typic Torriorthent	Typic Torriorthent	N/A	Fan Skirt	None	Qay3	Very High
					Qay2	High
					Qea	Variable

Table 4b: Composition of the Tonopah-Arizo Assoc., by geomorphologic unit

House et al. (2006) unit	Extent (km2)	% of Soil Association
Qay3	45.7	55.3
Qay1	14.2	17.2
Qay2	7.7	9.3
Qai	7.1	8.6
Qea	3.6	4.3
Qay	1.5	1.9
Qx	1.1	1.3
YXg	0.7	0.8
Qpf	0.3	0.4
Qe	0.3	0.4
Qao	0.2	0.3
QTa	0.1	0.1
Tcs	0.1	0.1
MzPzs	<0.1	0
Tv	<0.1	0

METHODS:

- GIS Spatial Overlay
  - % Overlay between flood hazard units
  - % Overlay of soil and geomorphic surfaces
  - % Mapping area at risk for flooding
- Conceptual Comparison of Mapping Units (Surficial Geological vs. NRCS Soil Units)
  - Landform type
  - Soil characteristics (i.e. diagnostic horizons, texture, stage of carbonate development, soil structure, parent material)
  - Surface age, landform type, and, surface stability
  - Vegetation

RESULTS: *Conceptual & Quantitative Comparisons*

- Due to the limitations of Order 3 Survey, direct correlations could not be made between NRCS flood hazard classes and those of the other datasets. Instead, conceptual comparisons were made between attributes of the Soil Association Components (Soil Survey Staff, 2007) and attributes of the Surficial Geologic map units (House et al., 2006a,b). These results are summarized in Tables 3 and 4, below, for two NRCS soil association polygons mapped within the IVP subregion.
- Spatial relationships and discrepancies between map data sets (e.g., % overlap of map units, (dis)agreement on flood hazard designation, etc.) were determined in GIS and are summarized in Table 1 for the entire Ivanpah Valley area (612.3km piedmont, 389.2km mt.sideslopes), and Table 2 for the Ivanpah Valley Airport subregion.

DISCUSSION:

- Each map has inherent strengths and weaknesses that should be understood by map users.
  - NRCS maps include information concerning the major soil association units, restrictive layers, vegetation, soil properties, soil development, and land management interpretations (including flood hazard estimates) (USDA, 2005).
  - FEMA maps focus on flood hazard determination; however, within the study area it appears that FEMA has not yet followed its own guidelines for flood hazard delineation (FEMA, 2000). At this time, the mapping techniques have not been specified and cannot be therefore be critically analyzed
  - Surficial geologic maps focus on geomorphologic features to determine landform age and amount of time since surface disturbance (House et al., 2006a; 2006b).
- Variations in map unit delineations are a result of differences in mapping methods, spatial scales, terminology, and temporal viewpoints.
  - NRCS and FEMA designates flood hazards based on the frequency and percent chance of flooding for 100- and 500-year time periods – *human time scales* (FEMA, 2000; USDA, 2005).
  - The surficial geologic map was also used as the basis for a flood hazard map that delineated flooding potentials on the order of 100s to 1,000,000s of years – *geologic time scales* (House, 2007).

CONCLUSIONS:

- FEMA largely underestimates the flooding hazards in the Ivanpah Valley; within the subregion, FEMA maps 5% of the piedmont as Zone A, compared to the 21.9% mapped as Very High flood class by House (2007).
- NRCS Order 3 mapping (association level) is not an appropriate scale for local flood hazard delineation; field verification is needed to apply flooding designations for land-use planning.
- Integration of detailed surficial geological maps can essentially create an Order 2 map from an Order 3 map, making land-use interpretations more straightforward.
- Flood hazard assessment methods based on perennial systems are not appropriate for the alluvial fan flooding of the desert SW.
- The surficial geological maps (House et al. 2006a; 2006b; House, 2007) depict active drainage systems, modern flowpaths, and drainage divides. In particular, soil-geomorphology is one of the most important and unifying criterion for alluvial fan flood hazard determination.
- Surficial geological data are most effective for determining flood hazard potential in arid regions and could enhance arid flood hazard mapping.

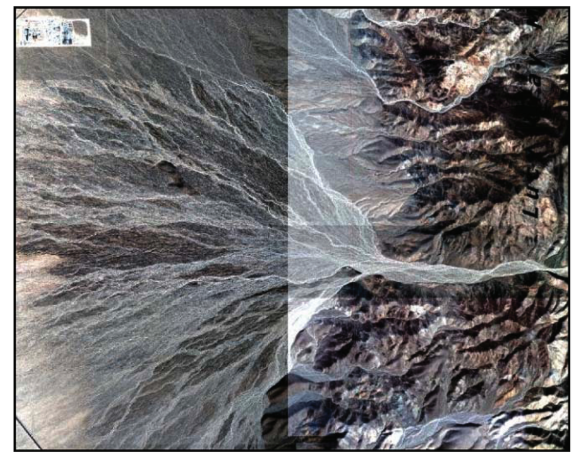


Figure 4: Large alluvial fan eminating from the Lucy Gray Mts at the S end of the study area (Quickbird® imagery)(House et al., 2006b)

Figure 5: View of Roach Lake, site of the planned Ivanpah Valley International Airport (Photo courtesy of Jim Faulds, NBMG)

REFERENCES:

CCRFCD (Clark County Regional Flood Control District). 2002. Digital FIRM Data for Clark County, Nevada. Available at ftp://www.ccrfcd.org/Shapefiles/dfirm02.shp [Accessed July 2007] Clark County Regional Flood Control District, Las Vegas, NV.

FEMA (Federal Emergency Management Agency), 2000. Guidelines for Determining Flood Hazards on Alluvial Fans. http://www.fema.gov/pdf/fhm/ft_afgd.pdf. [Accessed February, 2007].

House, P.K., Ramelli, A.R., and Buck, B.J., 2006a, Surficial geologic map of the Ivanpah Valley area, Clark County, Nevada. Nevada Bureau of Mines and Geology Map 156, 1:50,000.

House, P.K., Buck, B.J., and Ramelli, A.R., 2006b, Geologic assessment of piedmont and playa flood hazards in the Ivanpah Valley Area. Clark County, Nevada.

House, P.K., 2007. Assessment of piedmont and playa flood hazards in the IvanpahValley area, Clark County, Nevada. Nevada Bureau of Mines and Geology Map 158, 1:50,000.

Soil Survey Staff, 2007. Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey of the Clark County Area, NV. Available URL: http://soildatamart.nrcs.usda.gov/Survey.aspx?State=NV [Accessed March, 2007].

United States Department of Agriculture (USDA), Natural Resources Conservation Service. 2005. National Soil Survey Handbook. Title 430-VI. Mifflin Company, Boston.