The Flood Control District of Maricopa County presents a two-day symposium

Alluvial Fan

Flood Hazard Management Symposium

Optional Field Trip

Skyline Wash,

April 20, 2005

2801 West Durango Street, Phoenix, Arizona 85009

www.fcd.maricopa.gov

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...rd Management Symposium
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Alluvial Fan Symposium Agenda April 20-22, 2005 – Phoenix, Arizona					
Day	**Time**	**Duration**	**Topic**	**Speaker**	**Affiliation**
Day 0	9:00-5:00	7 hrs	Field Trip to White Tank Fan #36	Jon Fuller, PE	JE Fuller/H&G, Inc.
Day 1	8:00-8:15	15 min	Introduction & Symposium Overview	T. Phillips, PE	FCDMC
	8:15-8:55	40 min	Alluvial Fan Primer	Jon Fuller, PE	JE Fuller/H&G, Inc.
	8:55-9:35	40 min	Alluvial Fans in Maricopa County	P. Pearthree, PhD	
	9:35-10:00	25 min	Maricopa County Regulations - PFHAM	Ted Lehman, PE	JE Fuller/H&G, Inc.
	10:00-10:15		Break		
	10:15-10:50	35 min	FEMA Alluvial Fan Regulations	Unknown	M Baker Corp
	10:50-11:25	35 min	Basic Design Issues for Alluvial Fans - Hydrology	Dick French, PhD, PE	Univ. Texas San Antonio
	11:25-12:00	35 min	Basic Design Issues for Alluvial Fans - Hydraulics	Gary Freeman, PhD, PE	River Research & Design
	12:00-1:00		Lunch - Catered		
	1:00-1:30	30 min	Assessing Impacts to Adjacent Properties	Bill Spitz, RG	Ayres & Associates
	1:30-1:50	20 min	Non-Structural Approaches for Fan Management: Hazard Avoidance	Doug Plasencia, PE	M Baker Corp
	1:50-2:30	40 min	Non-Structural Case Histories	Felicia Terry, PE Andy Seiger, PE	FCDMC PCFCD
	2:30-2:45	15 min	Structural Approaches for Fan Management: Hazard Modification	Jon Fuller/JEF	JE Fuller/H&G, Inc.
	2:45-3:00		Break		
	3:00-4:30	90 min	Structural Approaches Case Histories	Phil Shaller, PhD, PE Bruce Phillips, PE Kevin Eubanks, PE	Exponent PACE CCRFCD
	4:30-5:00	30 min	Facilitated Discussion	P. Quinn/JEF	JE Fuller/H&G, Inc.
Day 2	8:00-8:15	15 min	Day 1 Overview	Jon Fuller, PE	JE Fuller/H&G, Inc.
	8:15-8:45	30 min	Environmental Permitting Issues	Sallie McGuire	USACE
	8:45-9:15	30 min	Land Owner Perspective	Bob Spiers	Stardust
	9:15-9:45	45 min	Case Histories: Lessons Learned on Alluvial Fan Designs	Jim Schall, PE Dick French, PhD, PE	Ayres & Associates Univ. Texas San Antonio
	10:00-10:15		Break		
	10:15-12:00	105 min	Panel Discussion #1 – Planning Exercise: White Tank Piedmont	R. Arrowsmith, PhD	ASU – Geology
	12:00-1:00		Lunch - Catered		
	1:00-1:15	15 min	Summary of Panel Discussion #1	R. Arrowsmith, PhD	ASU – Geology
	1:15-3:00	105 min	Panel Discussion #2 – Maricopa County Fan Development Policy	R. Arrowsmith, PhD	ASU – Geology
	3:00-3:15		Break		
	3:15-3:30	15 min	Summary of Panel Discussion #2	R. Arrowsmith, PhD	ASU – Geology
	3:30-3:45	15 min	Symposium Wrap Up –Identify Action Items & Working Groups	Valerie Swick, PH	FCDMC
	3:45-4:30	45 min	Working Group Formulation	T. Phillips, PE	FCDMC

Speaker Biographies

J Ramón Arrowsmith received a Ph.D. in Geological and Environmental Sciences from Stanford University in 1995 and is currently Associate Professor of Geological Sciences at ASU. His research centers on the interaction between tectonic and climatically modulated and human-influenced surface processes in the development of the landscape. In addition, he has considerable interest in the value of high quality data about the urban and surrounding natural environment for optimization of economic, planning, resource, and hazard mitigation systems. He has broad interests in geospatial tools and analysis and has recently been part of research teams supported by the NSF for the development of cyber-infrastructure for the geosciences. He has been involved in many interdisciplinary cross-campus efforts, including the Greater Phoenix 2100 project: an effort to bring the best possible scientific and technical information to the decision-making process that will shape the region during the next 100 years. He has regularly served at the national level on proposal review panels for the USGS Earthquake Hazards Reduction Program, and as a member of the National Science Foundation-American Geophysical Union Geoinformatics interim steering committee. At the state level, he served as an external review for California's earthquake prediction evaluation program, and now acts as an advisor for the Arizona Council on Earthquake safety. He also currently serves as the Associate Chairman of the Geological Sciences Department.

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Pat Quinn is a Project Manager with JE Fuller/Hydrology & Geomorphology, Inc. She has served as a project manager and project engineer for a wide range of water resources engineering, floodplain management, flood control, drainage master planning, and water policy studies and projects in Arizona. Her specialties include arid lands hydrology/hydraulic analysis, sediment transport analysis, flood insurance studies, flood control/drainage design, flood warning/flood response plans, flood disaster emergency response, water resources studies/policy development, and litigation support. She has a B. S. (Civil Engineering) from the University of New Hampshire. Pat is a member of the Arizona Floodplain Management Association, having served on the Flood Warning Committee. She also is a member of the Arizona Statewide Flood Warning Task Force.

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Kevin Eubanks joined the staff of the Clark County Regional Flood Control District in July 1991 and was appointed Assistant General Manager in January of 1994. He attended the University of Arizona and is currently a registered professional engineer in both Arizona and Nevada. Kevin manages flood control master planning, flood map revisions, flood plain management and storm water quality programs for the district.

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Gary E. Freeman, P.E. Ph.D, Esq., is the President of River Research & Design, Inc. Gary has extensive experience in hydraulic, floodplain, and sediment transport modeling, and has served as a project manager for projects throughout the United States. He served as a member of the White House teams (SAST and Galloway Committee) evaluating and making recommendations regarding floodplain policy for the United States after the 1992 Mississippi and Missouri River Floods. Gary has a B.S.C.E. and M.S.C.E. from Utah State University, and his PhD from Texas A&M University. He worked for the U.S. Army Corps of Engineers at what is now the Engineering Research and Development Center in Vicksburg, Mississippi for 7 years, for two years in West Africa working on an irrigation development project, and four years with WEST Consultants. He currently teaches the ASCE course entitled "Introduction to Streambank Investigation, Stabilization and Restoration."

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Richard French received his Ph.D. in civil engineering from the University of California, Berkeley in 1975 and is a registered civil engineer in Arizona, Nevada, and California and is a Diplomate of the American Academy of Water Resources Engineers. He has more than 25-years experience in hydrologic and hydraulic engineering in semi- and arid environments. Dr. French is the author of two technical books regarding open-channel hydraulics and one regarding hydraulic processes on alluvial fans. In 1991, he received ASCE's Arid Lands Hydraulic Engineering Award; has been a member of ASCE's Water Resources Division Executive Committee, and chaired the ASCE/EWRI Hydraulics and Waterways Council. He is currently Professor of Civil and Environmental Engineering at the University of Texas at San Antonio. Professor French serves and has served as a consultant to the Flood Control District of Maricopa County, Clark County (NV), the U.S. Departments of Energy and Defense, and numerous consulting firms.

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Jon Fuller is the President of JE Fuller/ Hydrology & Geomorphology, Inc., a small consulting firm with offices in Tempe and Tucson, Arizona. He has served as a project manager, project hydrologist, project geomorphologist, and project engineer for studies and projects in Arizona, Nevada, Utah, California, Colorado, and Montana. His specialties include arid land hydrology, applied fluvial geomorphology, sediment transport, erosion hazard analysis, floodplain management, bridge hydraulics, and alluvial fan analyses. Jon has a B.S. (Geology) from Calvin College in Grand Rapids, Michigan and a M.S. (Geomorphology) from the University of Arizona, and is a registered civil engineer in Arizona, Utah, Nevada, Colorado, Texas and Oregon, a registered Professional Hydrologist (American Institute of Hydrology), a Registered Geologist, and a Certified Floodplain Manager. Jon is active in the Association of State Floodplain Managers, ASCE, and served on the Board of the Arizona Floodplain Management Association from 1988 to 1998.

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Ted Lehman is a Hydrologist/Geomorphologist for JE Fuller/Hydrology & Geomorphology, Inc. Ted has served as project hydrologist/geomorphologist for water resource and flood control projects throughout Arizona. His specialties include fluvial geomorphology, arid land hydrology, alluvial fan studies, GIS, flood insurance studies, area drainage master plans, flood warning, hydrometeorological data collection and ALERT Systems operation and maintenance. Ted has a B. A. (Mathematics/Earth Science) from Willamette University in Salem, Oregon, and an M. A. (Geography/Fluvial Geomorphology) from Arizona State University. He is a registered Professional Engineer in the state of Arizona.

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Sallie McGuire has worked in the Corps of Engineers Regulatory Branch for seven years as a project manager. Her background is in biology and her job is helping the public comply with Section 404 of the Clean Water Act. The majority of projects she has managed are residential developments, utility line construction and flood control projects. Each project requires some knowledge of biology, as well as engineering, archaeology, environmental regulations, and diplomacy. Before working for the Corps of Engineers she taught high school chemistry, but realized only saints can do that.

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Phil Pearthree, Ph.D. has been a Research Geologist with the Arizona Geological Survey in Tucson, Arizona, since 1988. In this position, he is responsible for research and investigations in applied and environmental geology, Quaternary geology, and geomorphology by the AZGS in Arizona. Pearthree received his B.A. in Geology and History from Oberlin College in 1977, his M.S. degree in Geosciences from the University of Arizona in 1982, and his Ph.D. in Geosciences from the University of Arizona in 1990. He has held a position of Adjunct Associate Research Scientist in the Dept. of Geosciences, University of Arizona, since 1989.

Phil has been involved in the use of geologic and geomorphic data to define flood-prone areas, and integration of these data into the floodplain management process, since the late 1980's. He has collaborated with the Flood Control District of Maricopa County, the Pima County Flood Control District, and the Arizona Dept. of Water Resources in these efforts. His other research interests include mapping and dating of Quaternary alluvial surfaces and deposits; paleoflood investigations on streams of various sizes; historical geomorphology and channel changes along large rivers; factors controlling occurrence of debris flows; and paleoseismic analysis of young fault and evaluation of seismic hazard.

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Bruce Phillips. As the manager of the stormwater portion Pacific Advanced Civil Engineering (PACE), Mr. Phillips is responsible for the technical preparation and production of urban storm drain systems, regional flood control facility plans, watershed hydrology analysis, river engineering, sediment transport, stormwater quality assessment studies, detailed hydraulic structure analysis and design, urban drainage facility master plan development, floodplain analysis, and watershed modeling. He has developed specialized experience in river engineering and geomorphic studies, including design of river stabilization and stream restoration programs, and also erosion prediction. Past projects completed include improvement plans for variety of flood control channel, retention/detention basins and storm water pump station design, floodplain mapping, diversion/bifurcation structures, channel stabilization, levee design, side weir, spillway and outlet structure design, grade control structures, regional flood control channels, "river-walk system", wetland mitigation features, architectural water features, dam break analysis, and contract specification preparation. Mr. Phillips is a **lecturer** in the Civil Engineering department at California State University of Long Beach, University of California at Irvine, and University of California at Riverside. Mr. Phillips has an M.S. in Civil Engineering from Long Beach State University, and M.S. in Petroleum Engineering and a B.S. in Civil Engineering from the University of Southern California. Mr. Phillips is a registered engineer in Arizona and California.

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Tim Phillips, is the Acting Chief Engineer and General Manager for the Flood Control District of Maricopa County, and has over 25 years of water resources experience in the irrigation and flood control fields. Mr. Phillips received a Bachelors Degree in Civil Engineering from Arizona State University in 1980 and is a registered professional civil engineer in the State of Arizona. He further has a Masters of Arts in Organizational Management and a Masters of Strategic Studies.

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Doug Plasencia, CFM, PE recently joined Baker as an assistant Vice President and is the Practice Leader for the Western United States Water Resources Program. Doug will be primarily focusing on the growth of Baker's Water Program in the west and will be working with Baker Water Resource Professionals on serving new and existing clients. Doug has over 21-years of experience in water resources and is a recognized expert in floodplain management and policy. He is the co-developer of the NAI (No Adverse Impact) floodplain management strategy. He has served on and supported several committees of the National Academy of Sciences. In addition he is a past Chair of the Association of State Floodplain Managers, and the Arizona Floodplain Management Association.

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Steve Roberts was born in Oregon, and moved across the United States with his family to four states before graduating from high school in Pinedale, Wyoming in 1974. He attended Georgia Institute of Technology and Colorado State University, earning a Bachelor of Science degree in Civil Engineering in 1978. Steve is a registered professional engineer in Colorado and Nevada, and is a member of American Society of Civil Engineers and Association of State Dam Safety Officials.

Mr. Roberts works for Clark County Regional Flood Control District as Engineering Director. His principal responsibilities include project management of District funded flood control projects financed by a $30 million per annum capital improvement program and a $200 million tax-exempt commercial paper program and Tropicana & Flamingo Washes Project, a $280 million network of flood control projects being funded, designed and constructed in partnership with the US Army Corps of Engineers, Clark County, and District. Prior to joining the District in 1994, Steve was employed with Black & Veatch for 15 years. B&V is a large engineering and construction firm specializing in power, water, wastewater, transportation and industrial projects. He worked for Power and Environmental Divisions and Construction Management Services on design and construction management of power plants, dams, flood control facilities, and sewage treatment plants.

Mr. Roberts is married to Jean Cline, PhD, who is a geology professor at University of Nevada-Las Vegas, and has two sons, Jonathon and Kenji, ages 18 and 16.

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Jim Schall is Vice President of Water Resources in the Fort Collins office of Ayres Associates Inc. He has worked for over 25 years as a water resource consulting engineer, specializing in fluvial systems analysis and design. He has authored a number of publications including the "Design Manual for Engineering Analysis of Fluvial Systems" (Arizona Department of Water Resources), "Introduction to Highway Hydraulics" (FHWA HDS-4), "Stream Stability at Highway Structures" (FHWA HEC-20) and Bridge Scour and Stream Instability Countermeasures" (FHWA HEC-23). Dr. Schall is a certified instructor for the National Highway Institute and regularly teaches short courses on urban drainage, scour and sediment transport throughout the country. He earned his B.S. degree from Purdue University (1976), his M.S. (1979) and Ph.D.(1983) degrees from Colorado State University, and is a registered professional engineer in Colorado, California and Nevada.

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Andrew D. Seiger, P.E. BSAE, MSCE New Mexico State University, Las Cruces. Past experience includes engineering work in the areas of hydraulics and hydrology in both private and public sector, including 2 years with the State of New Mexico, 14 years with the Federal Government, and 2 years with the Tohono O'odham Nation. Employed by Pima County Regional Flood Control District since April 2004.

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Philip J. Shaller, Ph.D., Registered Geologist and Certified Engineering Geologist (CA). A.B., Occidental College; M.S. Montana Tech; Ph.D. Caltech (Geology). His doctoral thesis studies at Caltech concentrated on the mechanics of debris flows and large-scale landslides. He has worked as a consulting engineering geologist since 1991, at Woodward-Clyde Consultants (later URS Corporation), Bing Yen and Associates, and Exponent, Inc. He has performed a wide variety of engineering geologic investigations, both for design purposes and for geologic hazard evaluations in several western states, as well as in New Zealand and Venezuela. Since joining Exponent in 2000, he has worked with Doug Hamilton on numerous flood and debris flow hazard evaluations in California, Nevada and Arizona, in which he has evaluated historical air photos, performed geologic mapping and interpreted fluvial and tectonic landforms.

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Bob Speirs is a Senior Vice President with Stardust Companies, a major residential land developer in the Phoenix Metropolitan Area. He has been with Stardust since 1993. Bob has been working in residential land development locally since 1984. His educational background includes a BS in Geography from Northern Arizona University, and an MBA from the University of Oregon.

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Bill Spitz is a Project Geomorphologist with Ayres Associates in Fort Collins, Colorado and is a registered professional geologist in the state of Arizona and Wyoming. Mr. Spitz has 19 years of experience working on a wide variety of fluvial systems throughout the United States with extensive experience on stable and unstable fluvial systems and landforms in the southwest. He is currently conducting the Geomorphic Evaluation and Landform Stability Assessment task of the Buckeye/Sun Valley Area Drainage Master Study for the Flood Control District of Maricopa County, Arizona.

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Felicia Terry, P.E., CFM currently works for the Flood Control District of Maricopa County as a Regional Area Planning Manager. She has over 20 years experience in floodplain management and stormwater management in both the public and private sector. She graduated with a BSCE from Georgia Tech and is a Registered Professional Civil Engineer in Arizona. She is also a Certified Floodplain Manager.

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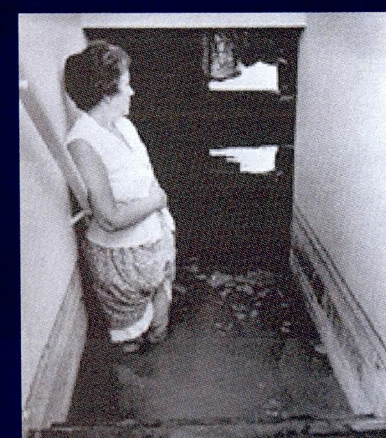
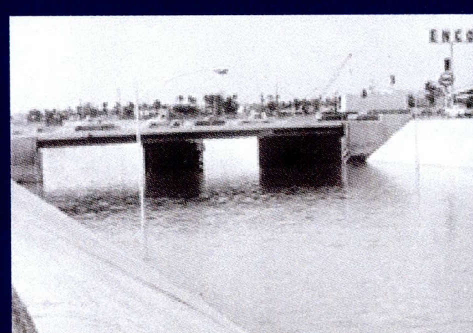
Our Mission is to provide flood hazard identification, regulation, remediation and education to the people of Maricopa County so that they can reduce their risks of injury, death, and property damage due to flooding while enjoying the natural and beneficial values served by floodplains





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www.fcd.maricopa .gov

Alluvial Fan Flood Hazard Management Symposium

Phoenix, AZ

April 20-22, 2005

Flood Control District of Maricopa County

Alluvial Fan Flood Hazard
Management Symposium

Introduction

- Objectives
  - Understand Issues for Fan Development
    - Technical
    - Regulatory
    - Planning
    - Permitting
    - Property Rights
  - Review Floodplain Management Options Used in Other Communties

Alluvial Fan Flood Hazard
Management Symposium

Introduction

- Objectives
  - Identify Floodplain Management Needs for Maricopa County
  - Develop Tools Needed for Effective Floodplain Management of Alluvial Fans

Alluvial Fan Flood Hazard Management Symposium

Overview

- Day 1: Lecture
  - Background/Educational
  - Discussion & Questions Encouraged
- Day 2: Panel Discussion
  - Brainstorming
  - Problem Solving
  - Action Items

Alluvial Fan Flood Hazard Management Symposium

Rules of Engagement

- Ask Questions After Lecture
  - 5-10 Minute Block Reserved for Discussion
- Disagree (Politely)
  - Avoid Group Think
- Breaks & Lunch
  - Return Promptly – Full Schedule
  - Lunch is Provided
- See JEFuller Staff for Problem Resolution

Alluvial Fan Flood Hazard
Management Symposium

Alluvial Fan Primer

Alluvial Fan Flood Hazard
Management Symposium
April 21, 2005

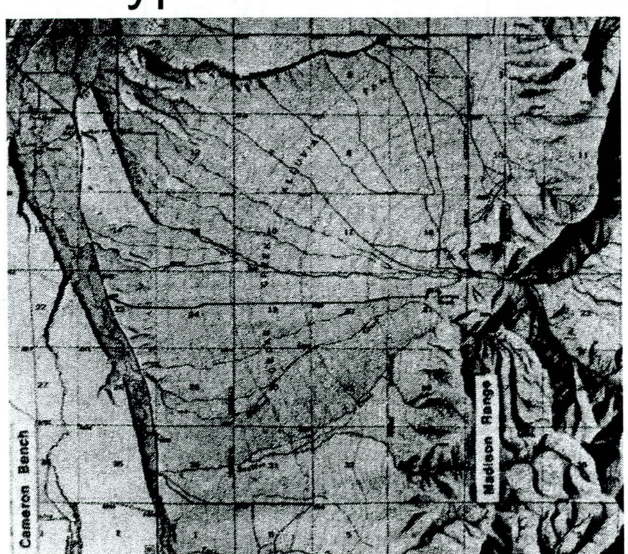
What is an Alluvial Fan?

- Geologic Definition
  - An alluvial deposit with a semi-conical, downstream-broadening shape formed where the topographic gradient reduces and the transporting capacity is diminished as the width of flow increases, such as along a mountain front, fault scarps, valley sides and glacier margins.
    - New Penguin Dictionary of Geology

"Typical" Alluvial Fan

Alluvial Fan Flood Hazard
Management Symposium

"Typical"Alluvial Fan



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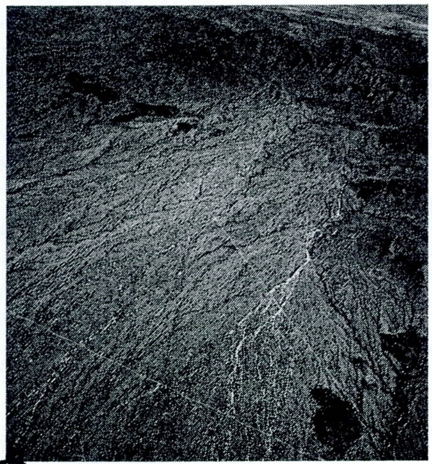
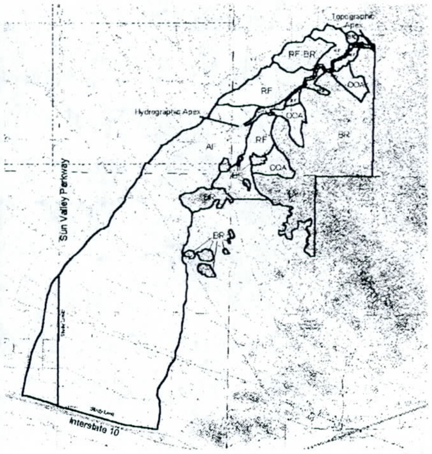
Alluvial Fan in Maricopa County





Alluvial Fan Flood Hazard
Management Symposium

What is an Alluvial Fan?

- NRC Landform Definition
  - A sedimentary deposit located at a topographic break, such as the base of a mountain front, escarpment, or valley side that is composed of fluvial and/or debris flow sediments and which has the shape of a fan either fully or partially extended.
    - National Research Council, *Alluvial Fan Flooding*, 1996

Alluvial Fan Flood Hazard
Management Symposium

What is an Alluvial Fan?

- FEMA Definitions (NRC, 1996)
  - **Alluvial Fan Flooding** -- Flooding occurring on the surface of an alluvial fan. Active alluvial fan flooding is a type of flood-hazard that occurs only on alluvial fans. It is characterized by flow path uncertainty so great that this uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard.

What is an Alluvial Fan?

- FEMA Definitions
  - **Active alluvial fan flooding hazard** is indicated by
    - a) Flow path uncertainty below the hydrographic apex
    - b) Abrupt deposition and ensuing erosion of sediment as a stream or debris flow loses its competence to carry material eroded from a steeper, upstream source area,
    - c) An environment where the combination of sediment availability, slope, and topography creates an ultra-hazardous condition for which elevation on fill will not reliably mitigate the risk.

Alluvial Fan Flood Hazard
Management Symposium

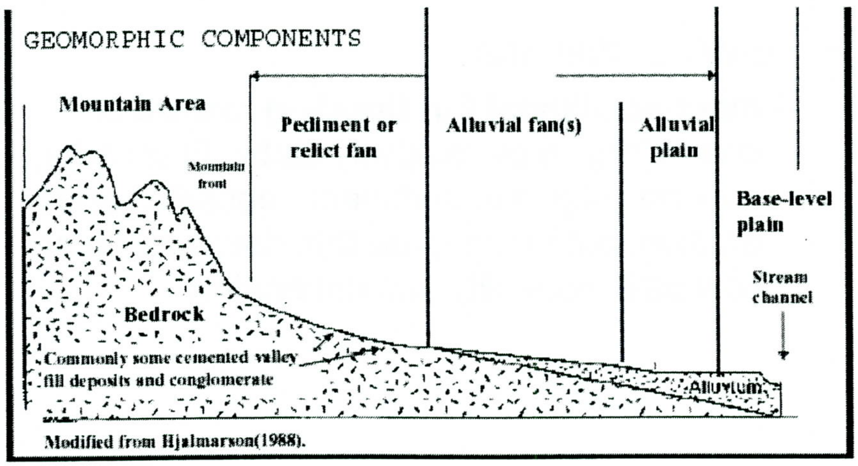
What is an Alluvial Fan?

- FEMA Definitions
  - **Inactive alluvial fan flooding hazard** is characterized by relatively stable flow paths, may be subject to sediment deposition and erosion, but to a degree that does not cause flow path instability and uncertainty.

Definitions

- **Piedmont** – an area, plain, slope or other feature at the base of a mountain. A generic term inclusive of several landform types.
- **Pediment** – a broad, flat or gently sloping, rock-floored erosion surface or plain of low relief. Key characteristics include shallow bedrock, thin alluvial mantle, concave up profile.

Piedmont & Pediment



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Management Symposium

Definitions

- **<u>Bajada</u>** – A broad, continuous alluvial slope or gently inclined detritus surface, extending along and from the base of a mountain range out into and around an inland basin, formed by the lateral coalescence of a series of separate but confluent alluvial fans. Bajadas occur most commonly in semiarid and desert regions. A bajada is a surface of deposition, as contrasted with a pediment (a surface of erosion that resembles a bajada in surface form).

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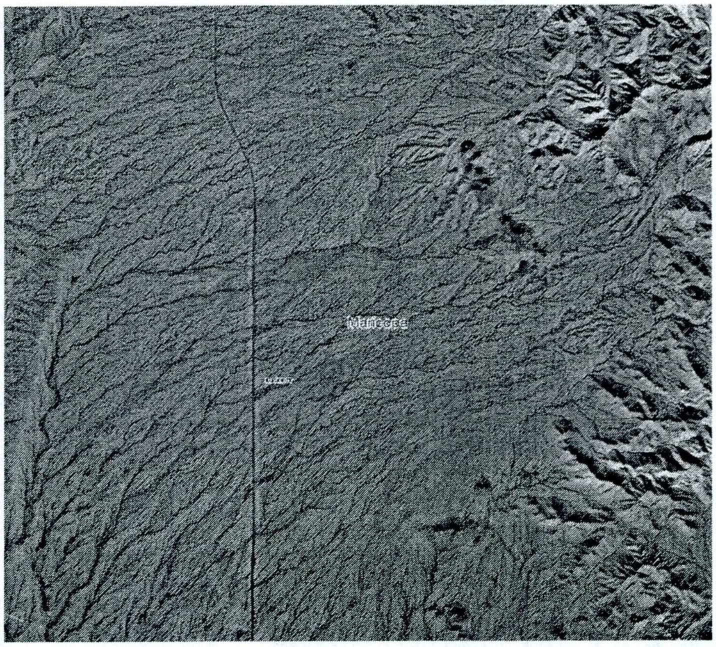
Bajada



White Tank Piedmont, Maricopa County

Alluvial Fan Flood Hazard
Management Symposium

Definitions

- **Apex**
  - **Hydrographic apex** The head or highest point on an active alluvial fan. The point where flow path uncertainty begins.
  - **Topographic apex** The highest point on an alluvial fan and some granite pediments in Maricopa County where flow is last confined. Often located at the mountain front or mountain front embayment.

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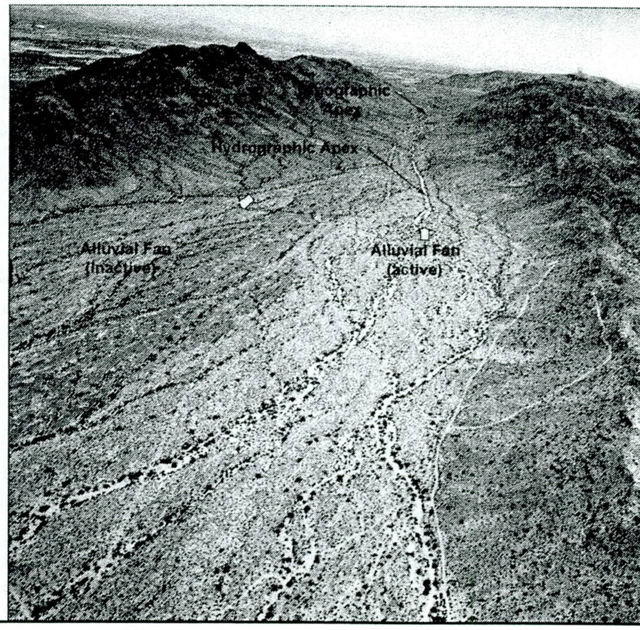
Management Symposium

Hydrographic & Topographic Apex



an Flood Hazard
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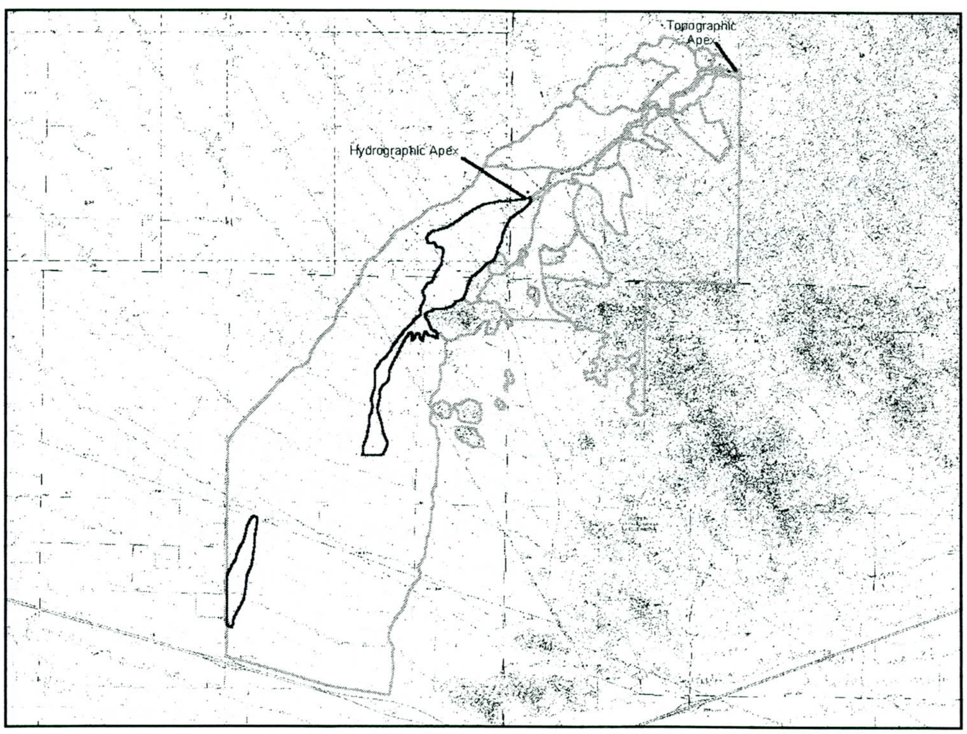

Definitions

- **<u>Distributary Flow</u>**. Diffuse flow where there is a distinct channel fork at an out flowing branch of a stream. Areas with distributary flow typically are composed of channel forks, joins and outlets. Active alluvial fans and pediments typically are often characterized by distributary flow.

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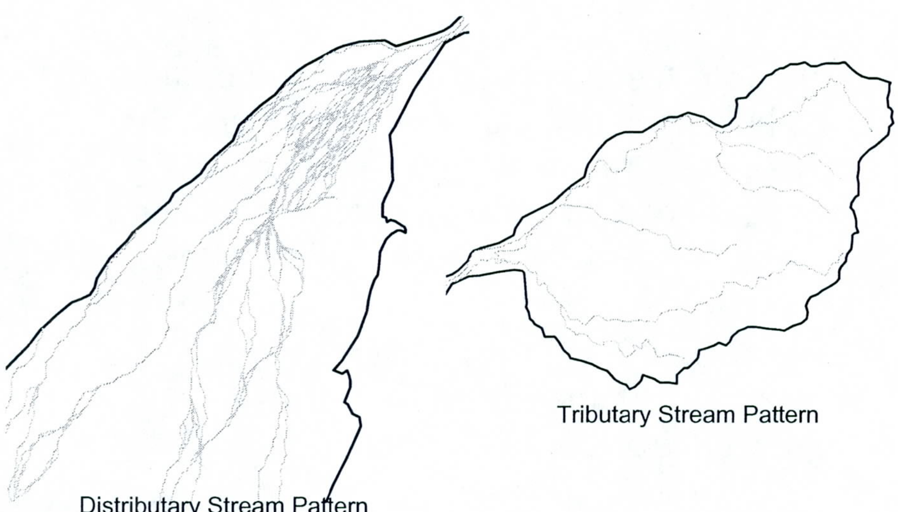
Management Symposium

Tributary & Distributary Flow



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Management Symposium

Distributary Stream Pattern

White Tank Fan 36

Alluvial Fan Flood Hazard Management Symposium

Definitions

- **Avulsion**. A sudden cutting off or separation of land by a flood or by an abrupt change in the course of a stream, as by a stream breaking through a meander or by a sudden changes in current, whereby the stream deserts its old path for a new one.
- **Stream Capture/Piracy**. Diversion from one stream into another by erosion, usually by headward erosion & extension.

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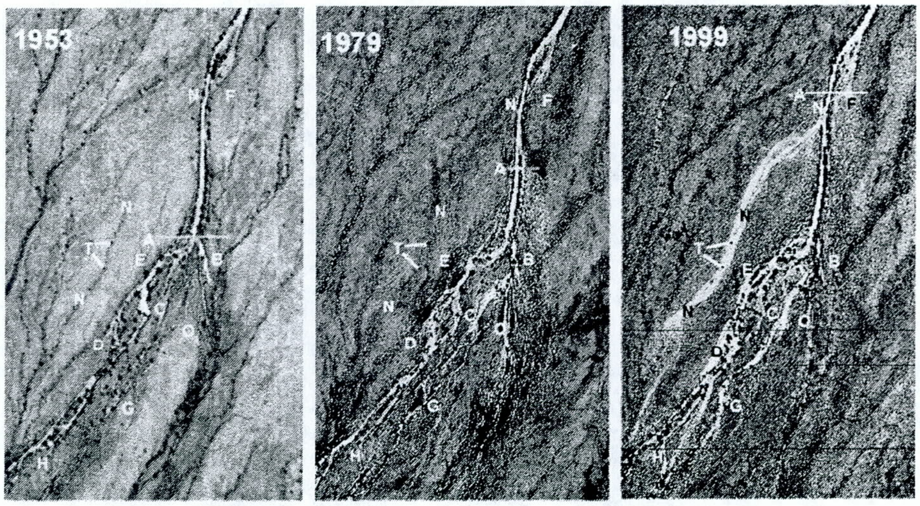
Avulsion



Tiger Wash, Maricopa County

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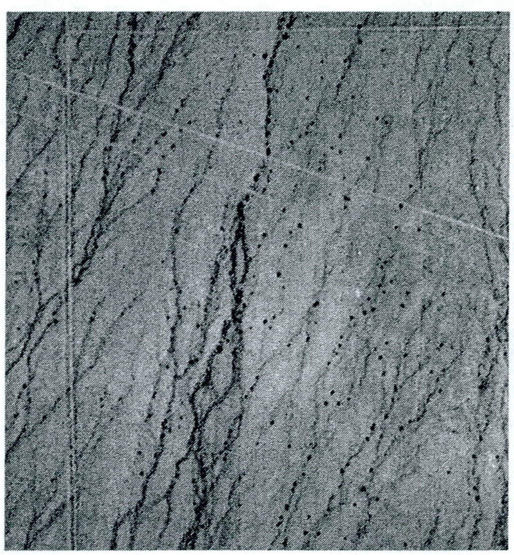
Channel Avulsion (1949-1997)



White Tank Fan 36, Maricopa County

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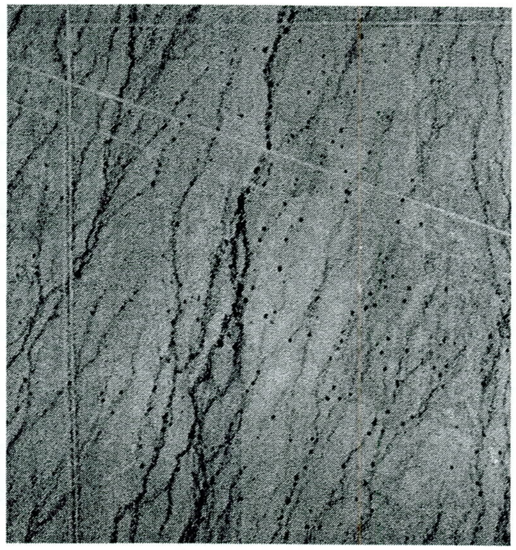
Channel Avulsion (1949-1997)



White Tank Fan 36, Maricopa County

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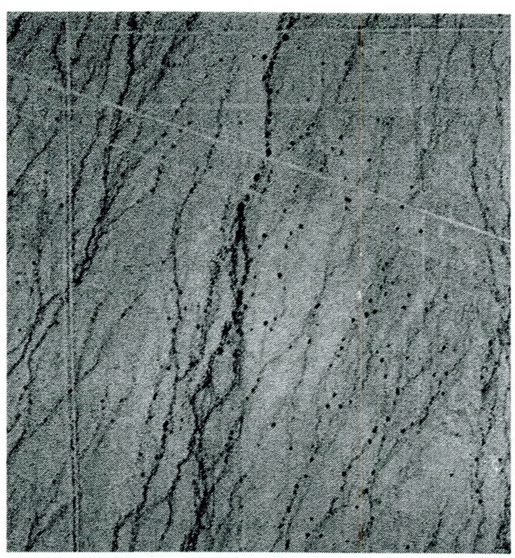
Channel Avulsion (1949-1997)



White Tank Fan 36, Maricopa County

Alluvial Fan Flood Hazard Management Symposium

Definitions

- **Debris Flow**. A mass movement involving rapid flowage of debris of various kinds under various conditions; specifically, a high-density mudflow containing abundant coarse grained materials and resulting almost invariably from an unusually heavy rain.

Alluvial Fan Flood Hazard Management Symposium

Debris & Mud Flows

Alluvial Fan Flood Hazard Management Symposium

Definitions

- Alluvial Plain. A level or gently sloping tract or a slightly undulating land surface produced by extensive deposition of alluvium, usually adjacent to a river that periodically overflows its banks; it may be situated on a flood plain, a delta, or an alluvial fan (usually at the toe).
- Alluvial Plain Flooding. A type of flood hazard that occurs only on alluvial plains. It is characterized by sheet flow (Arizona State Standard 4-95), sediment deposition and channel erosion where the base-level stream has lowered.

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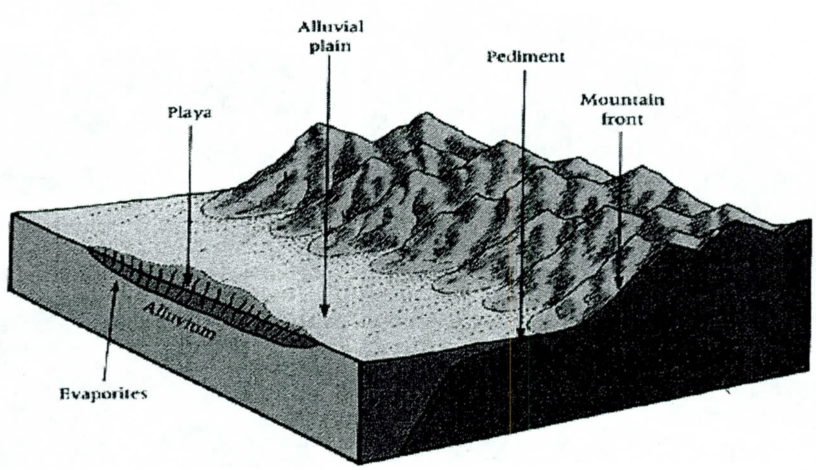
Management Symposium

Pediment



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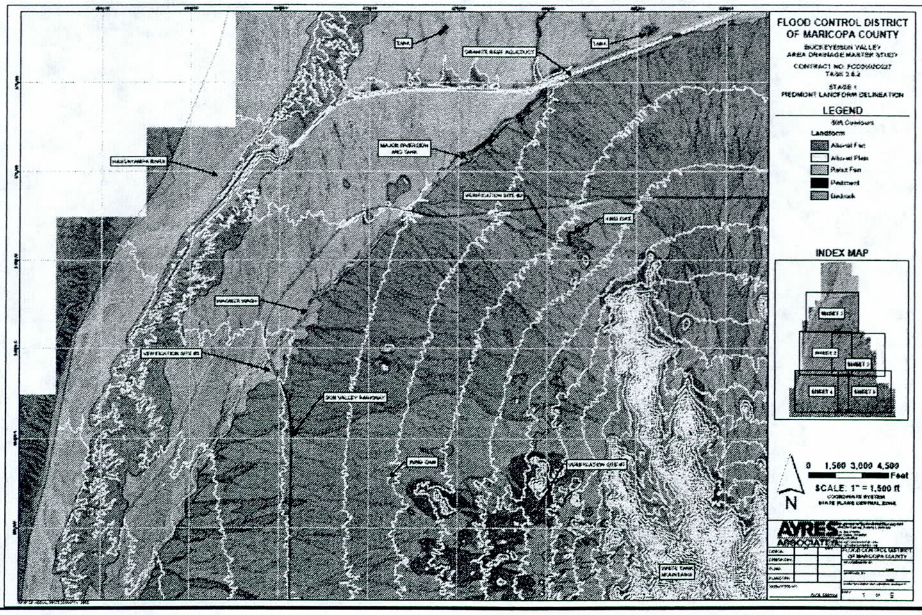
White Tank Piedmont



Definitions

- **<u>Sheet flood.</u>** A broad expanse of moving, storm-borne water that spreads as a thin, continuous, relatively uniform film over a large area in an arid region and that is not concentrated into well defined channels; its distance of flow is short and its duration is measured in minutes or hours. Sheet floods usually occur before runoff is sufficient to promote channel flow, or after a period of sudden and heavy rainfall. According to Hogg (1982) a sheet flood is simply a sheet of unconfined floodwater moving down a slope. This definition implies a sheet flood is less frequent than a sheet flow.

  See also: Blair and McPherson, 1994 & McGee, 1897. Arizona State Standard 4-95.

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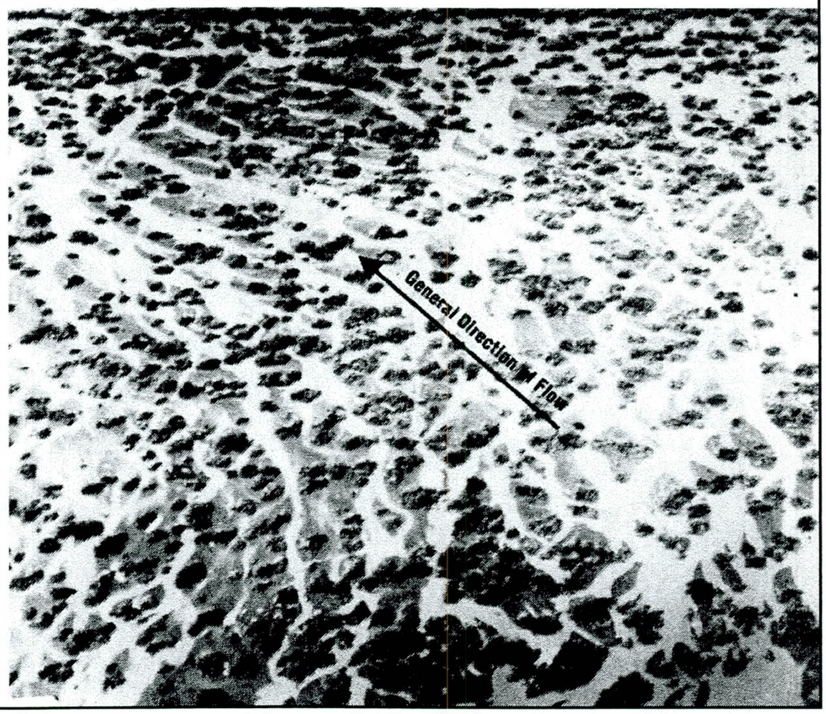
Sheet Flood

Maricopa County 1954



Sheet Flow Definitions

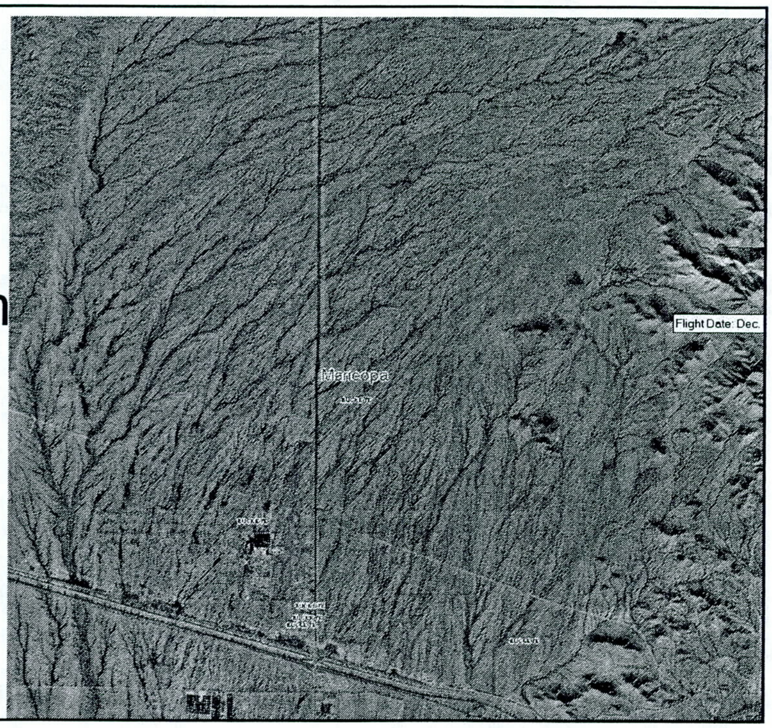
- **Sheet Flow** An overland flow or down slope movement of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces and not concentrated into channels larger than rills.
- **Sheet Runoff** (FEMA 2002) The broad, relatively unconfined down slope movement of water across sloping terrain that results from many sources, including intense rainfall and/or snowmelt, overflow from a channel that crosses a drainage divide, and overflow from a perched channel onto deltas or plains of lower elevation. Sheet runoff is typical in areas of low topographic relief and poorly established drainage systems.
- **Shallow Flooding** (FEMA 2002) Unconfined flows over broad, relatively low relief areas, such as alluvial plains; intermittent flows in arid regions that have not developed a system of well defined channels; over bank flows that remain unconfined, such as on delta formations; overland flow in urban areas; and flows collecting in depressions to form ponding areas. For National Flood Insurance Program purposes, shallow flooding conditions are defined as flooding that is limited to 3.0 feet or less in depth where no defined channel exists.

Definitions

- **Axial Drainage**. A watercourse usually located along the center of a valley floor into which runoff from the bajada flows. The riverine outfall for an alluvial fan drainage system.

Alluvial Fan Flood Hazard
Management Symposium

Axial
Stream



Where are Alluvial Fans Found?

- Everywhere
- Arid West
- Glacial Outwash
- Construction Sites
- Not Within Political Boundaries

How Do Fans Form?

- Sediment Excess: Supply > Transport
  - Lack of topographic confinement
  - Slope break, velocity decrease
  - Loss of flow to infiltration or attenuation
- Time
  - Geologic time v. Engineering time

Alluvial Fan Processes

- Sediment deposition – aggradation
- Avulsion
- Stream capture
- Debris flow (mud flow, hyperconcentrated, rock fall)
- Distributary flow
- Sheet flow – unconfined flooding
- Flash flooding
- Local scour
- Lateral erosion
- High velocity flow
- Infiltration & recharge

Alluvial Fan Flood Hazard
Management Symposium

Differences from Riverine Floodplains

- Aggrading landforms – net deposition
- Uncertain flow path
  - Channel movement with time
- Uncertain flow distribution
  - With or without channel movement
- Debris & mud flows
- Less obvious inundation areas
- Unconfined & distributary flooding
- Percent of flow outside defined channel is high

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Why Are Special Management Strategies Required?

- High hazards (see above)
- Sensitive to development impacts
  - Roads, walls, channelization
- Adjacent property impacts
  - Changes in flow distribution
  - Sedimentation & erosion
- Limited engineering experience on fans
- 404 permitting issues

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Summary & Discussion

- Active & Inactive Alluvial Fans
- Flow Path & Flow Distribution Uncertainty
- Hazard & Risk Varies With Landform Type
- Hazard & Risk Varies Within Landform
- Areas of Sediment Deposition
- Areas of Sediment Transport
- Areas of Sediment Erosion
- Management Strategy Must Vary

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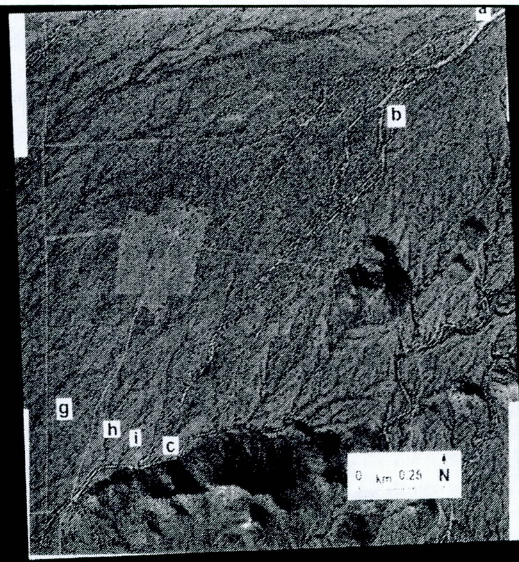

lazard
osium

Overview of Fan Characteristics and Flood Processes in Maricopa County

Phil Pearthree
Arizona Geological Survey
www.azgs.gov

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Active Alluvial Fans Characteristics & Processes Central and Southern Arizona

- How can we tell fluvial systems are active fans and where do they exist?
- What processes occur on our fans?
- What flood hazards associated with those processes?
- Illustrations and examples from central and southern Arizona

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Distributary Drainage Network Does Not Equal Active Fan

- Location & extent of active alluvial fans determined by interpreting the surficial geology & geomorphology of piedmonts
- Dominance of water flooding on low-gradient alluvial fans in Arizona
  - Different from some other areas
- Hazardous processes and flood characteristics on active fans of Arizona

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Surficial Geology and the Age Structure of Piedmonts

- Surficial geology and geomorphology of piedmonts tell us much about how fluvial systems behave
- Existing conditions record past behavior

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Fans are Depositional Landforms

- Deposits record fan activity
- Drainage patterns & connections to mountain watersheds
- Various indicators of recent of fluvial activity / surface stability
- Mapping surfaces of different ages shows where young deposits exist & thus where fluvial systems have been active recently
- Analysis of drainage networks and surficial geologic mapping together outline active alluvial fans and more stable areas on piedmonts

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Particular Characteristics of Alluvial Fans in Maricopa County

- Active fans vs. distributary drainage networks
- Apexes of classic alluvial fans typically at steep, abrupt linear mountain fronts
- Active fan apexes in Maricopa County typically are well out on the piedmont
- Active fans are a limited subset of very common distributary drainages in Maricopa County
  - Hydrographic apexes within distributary systems

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Elements of Stability and Instability in Distributary Drainage Systems

- Many parts of many distributary systems are topographically confined and relatively stable
- Limited strips of young deposits indicative of this
- Active fans – distributary channel networks and extensive young deposits

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Intensity of Rainfall Events and Flood Hydrology

- Equal or greater than other locations with classic fans
- Less chance for prolonged rainfall & soil saturation
- Flood hydrology at top of distributary network same as for other watershed, but more complex within distributary network
- Importance of duration as well as peak discharge to perform work on alluvial fans

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Debris Flows not an Important Factor

- Sediment supply to fans is less
- Drainage basins less steep and more stable
- Less storage and slower removal of hill slope sediment in drainage basins
- Vegetative cover on hill slopes relatively sparse, not subject to catastrophic burning
- Soil mantle is thin and patchy
- Thin hill slope sediment mantles do not provide large slugs of sediment
- Channel slopes near mountain front and fan slopes are low – debris flows lose momentum

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"Typical" Characteristics of Distributary Drainage Systems In Maricopa County

- Incised distributary area
  - Flow distribution
  - Higher channel position stability
  - Some avulsions
  - More topographic confinement
  - Not aggrading

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"Typical" Characteristics Maricopa County Alluvial Fans

- Active Fan Area
  - Distribution of flow
  - Infiltration and recharge
  - Net aggradation, sediment storage
  - Downstream-branching channel networks, lateral erosion, change in channel networks
  - Channel capacity not sufficient to contain large floods
  - Sheet flooding between channels

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"Typical" Characteristics Maricopa County Alluvial Fans

- Sheet Flow Areas
  - Very extensive shallow flow
  - Few or no large channels
  - Sensitive to flow concentration
  - Low rates of aggradation

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“Typical” Characteristics Maricopa County Alluvial Fans

- Lower Margin of Fan
  - Re-entrenchment zone
  - Axial stream floodplain
  - Base-level controls

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Flood Processes on Maricopa County Alluvial Fans

- Lateral erosion & scour along channels
  - Widespread along channels during floods
  - Areas of downcutting
    - Narrow channel reaches alternate with areas of deposition (expansion reaches)
  - Lateral bank erosion and deposition may “prime the system” for more dramatic changes in large floods

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Flood Processes on Maricopa County Alluvial Fans

- Shallow Sheet Flooding
  - By far the most extensive process downstream of the fan apex
  - Extremely shallow flooding (<1 ft deep) very common
  - Areas covered by fine sediment indicative of sheet flooding
  - Sensitive to perturbations, potential to develop narrow, deep gullies

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Flood Processes on Maricopa County Alluvial Fans

- Aggradation
  - Deposition makes fans
  - Aggradation must shift around over time to make fan shape
  - Aggradation creates relatively high areas that facilitate shifts in channel position
  - Associated with channel expansions, downstream diminution of channels

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Flood Processes on Maricopa County Alluvial Fans

- Development of New Channels - Avulsions
  - Most dramatic and potentially devastating process
  - Very localized and possibly predictable (?)
  - May have significant implications down fan
  - Major deposition at channel expansions
  - Potential for incorporation of tributary channels into distributary system
  - Overflow at channel bends
  - Deep overbank flow where channel capacity decreases

Summary

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Maricopa County Alluvial Fan
Regulations & Policies

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Maricopa County Regulations

- Piedmont Flood Hazard Assessment Manual
  - (PFHAM)
  - NRC *Alluvial Fan Flooding* Procedure
    - Three Stage Analysis

- FEMA Guidelines and Specifications
  - Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping

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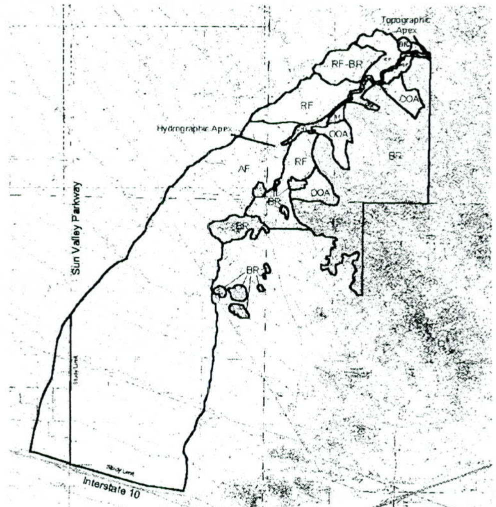
Stage 1 - Recognize and Characterize Piedmont Landforms

- Composition
- Morphology
- Location
- Boundaries



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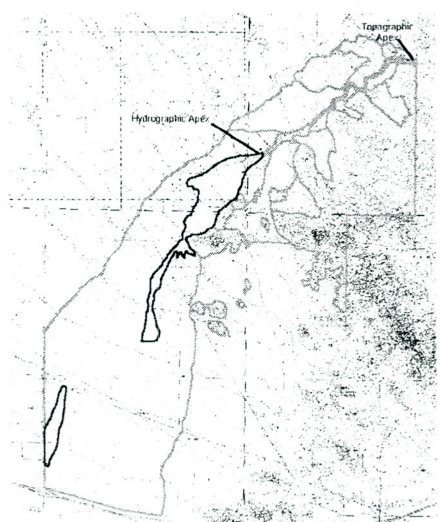
Stage 2 – Identify Stable and Unstable Areas

- Soil development
- Surface characteristics
- Drainage texture
- Topography
- Historical flow path movement
- Potential water and sediment delivery from basin



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Stage 3 – Define 100-year Flood Hazards

- Flooding on Stable Channels
  - Upstream of hydrographic apex
  - Inactive alluvial fans
  - Often within entrenched distributary flow systems
  - "Normal" hydraulic methods
  - Potentially complex split flow accounting - uncertain flow distribution

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Stage 3 (cont.)

- Sheet Flooding
  - Broadsheets, completely unconfined flow
  - Might be where several shallow, distributary channels join together near toe of fan and gradient is low
  - Active alluvial fan flooding
  - (New) FEMA Guidelines & Specifications, Appendix E, Shallow Flooding

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Stage 3 (cont.)

- Unstable Flow Path Flooding
  - Where single channel splits into multiple channels
  - Subject to deposition and bank or bottom erosion causing channel migration, avulsion and/or formation of new channels
  - Characterized by shallow, braided or distributary sand and gravel bed channels

Flood Control District of Maricopa County

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Recommend: Composite Methods

Combination of:

- Geomorphic Methods
- 1-D Hydraulic Methods
- 2-D Hydraulic Methods
- Sheetflow Analysis Techniques
- FEMA Fan Model

Flood Control District of Maricopa County

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Flood Hazard Zones for Alluvial Fans in Maricopa County, AZ

- **A** – FEMA *approximate* floodplain
- **AO** – FEMA *sheet flooding* area
- **AE** – FEMA *riverine* floodplain with BFE
- **AFHH** – Alluvial fan *high hazard* zone
- **AFUFD** – Alluvial fan *uncertain flow distribution* zone
- **AAFF** – Approximate alluvial fan *floodway*
- **AFZA** – Alluvial fan zone A

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Flood Hazard Zones For Alluvial Fans in Maricopa County	
Zone Name	Description
AFHH	Alluvial fan *high hazard*, community to *treat as a floodway* district
AFUFD	Alluvial fan *uncertain flow distribution* area; transitional area downstream of AFHH zone characterized by channelized and sheet flooding generally becoming more stable and less uncertain with increasing downstream distance from the AFHH zone; community to *treat as a floodway* district

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Flood Hazard Zones For Alluvial Fans in Maricopa County (cont.)	
Zone Name	Description
AAFF	*Approximate* alluvial fan *floodway*; corridors for conveyance of water and sediment on a stable alluvial fan surface downstream of the AFHH and AFUFD; community to *treat as a floodway* district

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Flood Hazard Zones For Alluvial Fans in Maricopa County (cont.)	
Zone Name	Description
AFZA	Alluvial fan zone A; areas within the 100-year floodplain on an *inactive* alluvial fan characterized by shallow channelized flow and sheet flooding in stable channels; zone is considered approximate because no base flood elevations are provided; *flood hazards within this zone are not necessarily equal throughout*, that is, the frequency and magnitude of flooding with respect to depth and velocity of flow may vary within the AFZA zone; floodplain managers should consult available aerial photographs and topographic maps for more detailed evaluation of site specific flood hazard within this zone; *development will be allowed in this zone* given demonstration of adequacy of site and/or design which addresses safety from inundation and sedimentation hazards

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Flood Hazard Zones For Alluvial Fans in Maricopa County (cont.)	
Zone Name	Description
A	Approximate 100-year floodplain; stable riverine reaches with predictable discharges
AE	Detailed study 100-year floodplain; stable riverine reaches with predictable discharges
X (shaded)	Areas flooded between 100-yr and 500-yr discharge; <u>or</u> areas of flooding with depth of 100-year flood less than 1 foot; <u>or</u> drainage area less than 1 square mile
X (unshaded)	Areas outside the 500-year floodplain; shown only on rocky hills
D	Area not studied

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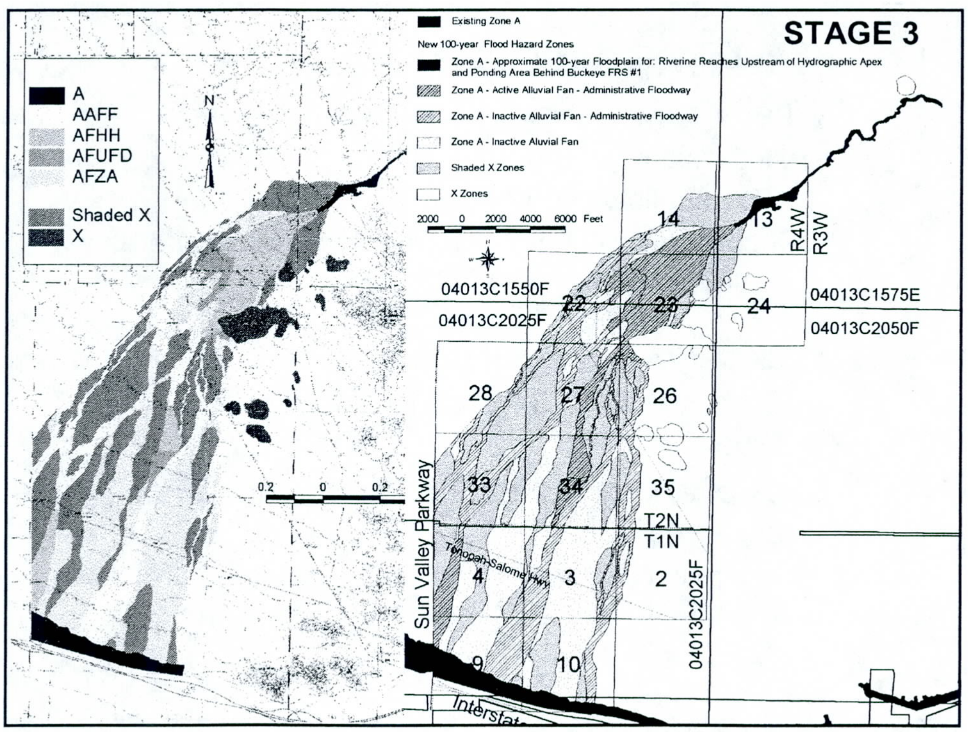

Maricopa County Floodplain & Drainage Regulations

- Drainage Regulations
  - Include no reference to alluvial fans
  - Minimum floor elevation
- Floodplain Regulations
  - Article III – Definitions
  - Article XIII – Alluvial Fans
    - Oriented toward single lot development
    - "The (site) plan may include engineering analysis to mitigate all hazards associated with Alluvial Fan flooding including inundation, ground erosion, scour around structures, debris and sediment flow and accumulation in addition to aggradation and degradation of conveyance systems. The plan shall also include building pad and lowest floor elevations." *minimal guidance as to what the analysis should look like or include is provided e.g. what Q do I use?*

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- Floodplain Management Issues
  - Where do we want to regulate (as fans)?
    - High hazard zones (AFHH)
    - NOT shallow flooding zones
    - Incorporation of development impacts on alteration of hazard location and magnitude (e.g. concentration of flow)
  - Lack of development guidelines
    - State Standards for Shallow Flooding Areas
    - Other fan areas…
  - Lack of approved technical procedures for design analysis
    - e.g. asking for an analysis without criteria of what's acceptable, adequate, sufficient, etc.

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BASIC DESIGN ISSUES - HYDROLOGY

Richard H. French, Ph.D., P.E., D.WRE
Professor
Department of Civil & Environmental Engineering
University of Texas at San Antonio
San Antonio, TX
&
Research Professor Emeritus
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Las Vegas & Reno, NV

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PRESENTATION TOPICS

THE GOAL
TRADITIONAL CHALLENGES
- **Identification of the Appropriate Design Precipitation Event**
- **Quantifying Precipitation Losses**
- **Choosing the Appropriate Unit Hydrograph**
- **Get the Above Apex Hydrology Right**
- **Get the On-Fan Hydrology Right**

MODERN CHALLENGES
- **Design Precipitation Event**
- **Abstraction, Infiltration, Transmission Losses**
- **Lumped Versus Distributed Modeling**

CONCLUSION
- **What Has Been Accomplished**
- **What Remains to be Accomplished**

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THE GOAL

Estimate peak flood discharges and associated volumes for events with a specified return periods and durations for

The watershed above the apex of the alluvial fan

The watershed on the alluvial fan

Identify and design appropriate alluvial fan flood hazard mitigation strategies

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TRADITIONAL CHALLENGES

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Identification of the Appropriate Design Precipitation Event

Depth-Duration-Frequency

- General winter storms
- General summer storms
- Local storms

Depth-Area reduction

Distribution of precipitation in time

Correlation between precipitation and runoff event return periods

Quantifying Precipitation Losses

- Holtan infiltration equation
- Exponential loss rate
- SCS curve numbers (CN)
- Green and Ampt infiltration equation
- Initial loss plus uniform loss rate

Choosing the Appropriate Unit Hydrograph

Clark Unit Hydrograph

S-Graphs

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Get the Above Apex Hydrology Right

- Estimate Q2, Q10, Q100
- Check regional ($LP3_R$) skew vs. synthetic ($LP3_S$) skew
- If ($LP3_R$) ⑤ ($LP3_S$): Adjust hydrologic parameters
  - Check validity of Q2 and Q10
  - Adjust abstraction and infiltration
  - Continue to adjust until ($LP3_R$) ❿ ($LP3_S$)

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Get the Above Apex Hydrology Right

Why is this important?

- Important input to any hydrologic/hydraulic model for
  - On fan flood hazard identification
  - On fan flood hazard mitigation
- Critical input to probabilistic hydrologic/hydraulic model for
  - On fan flood hazard identification
  - On fan flood hazard mitigation

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GET THE ON-FAN HYDROLOGY RIGHT

Why is this important?

- Proper design of on-fan flood hazard mitigation

Considerations – fan types

- Active alluvial fan
- Distributary flow system
- FEMA alluvial fan
- Inactive alluvial fan

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GET THE ON-FAN HYDROLOGY RIGHT

Considerations – how does flow occur on alluvial fans?

- Sheetflow
  - What is it?
  - Does it happen?
- Distributary flow
  - One channel branches into two; two branch into four; etc. and the flow becomes?
- Defined flow channels
  - Do they branch?
  - Channel avulsions

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GET THE ON-FAN HYDROLOGY RIGHT

- Flow formed channels
  - Does it happen?
  - Shape
  - Formation conditions
  - Avulsions
    - Debris blockage
    - Sub-surface geology
    - Channel capture

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GET THE ON-FAN HYDROLOGY RIGHT

Modeling Approaches:

HEC-HMS coupled with HEC-RAS

Requires defined channel with splits and routing reaches

FLO-2D

Requires detailed topographic and other on-fan data but works well when channels are not incised

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GET THE ON-FAN HYDROLOGY RIGHT

Stochastic approaches

Assumes on-fan rainfall is negated by on-fan abstraction and infiltration

Geomorphologic approaches

Not an engineering approach supported by calculation

Provides data that should confirm engineering calculations and vice versa

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MODERN CHALLENGES

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Design Precipitation Event

Accounting for climatic variability

El Nino

La Nina

Storm movement

Have we properly correlated design precipitation and runoff events from the viewpoint of return periods?

What is the design event with a 100-year return period?

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Abstraction, Infiltration and Transmission Losses

On-fan surface age

- Geologically old surfaces (paved) - relatively impervious
- Geologically young surfaces - relatively pervious
- Geologically intermediate surfaces - depends
  - When wet - infiltration increases
  - When dry - infiltration is limited

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Lumped Versus Distributed Modeling

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HEC-HMS (HEC-1) - Lumped Approach

Traditional approaches to rainfall-runoff process modeling

- **Widely used**
- **Many options**
- **Excellent documentation**
- **Easy to use**
- **Good approach for watershed above the apex**
- **Free**

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HEC-HMS (HEC-1) - Lumped Approach

"Lumped approach"

One-dimensional routing

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FLO-2D – Distributed Approach

Quasi-two dimensional model

"Distributed approach"

Can address debris and mudflows

Widely used

Good approach for on-fan hydrology and hydraulics

Good approach for use in complex urban areas

Constant improvements being made

FLO-2D - Distributed Approach

Documentation limited

Steep learning curve

Constant improvements being made

Data intensive

Proprietary model

Model Selection

Select a model that fits the problem rather than try to fit the problem to the model.

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CONCLUSION

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- **Progress has been in dealing with flood hazard identification and mitigation on alluvial fans since the professional and regulatory communities became interested c. 1979**

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What Has Been Accomplished:

Recognition it does rain and flood in the desert

Standardization of of hydrologic and hydraulic engineering approaches to alluvial fan flooding

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Recognition that we do not yet have complete knowledge in terms of hydrometeorology, hydrology (including the vadose zone), hydraulic engineering, and geomorphology

Recognition that more needs to be done

What Remains to be Accomplished:

Integrate remote sensing into flood hydrology
- Satellite images
- NEXRAD radar

Integrate the abilities and skills of the civil engineering and geosciences communities to identify and mitigate flood hazard on alluvial fans

Developing and funding a regional research agenda and funding to conduct that agenda

Developing community awareness of the issues, complexities, uncertainties, and importance of alluvial fan flood hazard identification and mitigation

Break the disciplinary mind-set of the educational community

- Civil engineers do not need be able to identify rocks; but they do need to understand "environmental geology"
- Geosciences graduates do not need to understand hydrologic/hydraulic engineering, but they need to understand how their input can be a critical reality check

All taxpayers need to have a basic understanding of science and engineering and how it affects their taxes, property value and lives.

Basic Design Issues for Alluvial Fans

Hydraulics

Gary E. Freeman, PhD, PE
River Research & Design, Inc.

Hydraulic Data

- Needed for:
  - Determine Floodplain Limits
  - Estimate
    - Sediment Transport
    - Scour
    - Erosion
  - Design of Structures
  - Establish FFE's (??)
  - Assess Impacts of Projects

Floodplain Types

- Cross Sections
  - River – Well Defined Channel
    - Well defined flow path
  - Fan – Very low banks, if any
    - Vary wide/multiple flow paths

Channel Shape / Size

- Determined by Relationship between Sediment Transport and Flow Rate
  - Sediment Starved – Erodes / Incises
  - Sediment Rich – Balanced or Deposition

Estimating Sediment Transport

- Uncertain in Both Time and Space
- Two-Dimensional Problem at Best

Do FFE's Have any Meaning on Fans?

- NRC Report –
  - Alluvial Fan Flooding: Committee on Alluvial Fan Flooding, Water and Science Technology Board, Commission on Geosciences, Environment, and Resources, National Research Council, National Academy Press, 1996

NRC Report

- Alluvial fan flooding is a type of flood hazard . . . characterized by flow path uncertainty so great that this uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard. An alluvial fan flooding hazard is indicated by three related criteria: (a) flow path uncertainty below the hydrographic apex, (b) abrupt deposition and ensuing erosion of sediment as a stream or debris flow losses it competence to carry material eroded from a steeper, upstream source area, and (c) 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.

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FFE on Alluvial Fans

- Changing Flow Path
- Changing Flow Rate
- Changing Water Surface Elevation over Time
- Erosion Hazard

- How High Do I Build????

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Methods / Approaches

- Probabilistic Approaches
- Deterministic
- Geomorphic Approaches

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Approaches

- Probabilistic
  - Dawdy
    - Reference:
      - Flood Frequency Estimates on Alluvial Fans: ASCE Journal of Hydrology, 105(HY11) 1407-1413
  - French
    - Reference:
      - Estimating the Depth and Length of Sediment Deposition at Slope Transitions on Alluvial Fans During Flood Events: Journal of Soil and Water Conservation, V. 50, No. 5 p. 521-522
      - Estimating the Depth of Deposition (Erosion) at Slope Transitions on Alluvial Fans: ASCE Journal of Hydraulics, Vol 127, No. 9 Sep 2001 p. 780-782

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Dawdy

- Assumes Equal Probability of All Flow Paths
  - Number of Flow Paths
  - Width of Fan at that point
- Probability of any point on fan less than that at apex

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Dawdy Method

- Calculate Stable Depth
  - $D = 0.07\ Q^{0.4}$
- Calculate Stable Width
  - $W = 9.5\ Q^{0.4}$
- Use Bulletin 17A to Estimate Frequency
- Calculate Fan Width where probability is 0.01

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Dawdy Assumptions

- 1) Log Pearson III Distribution Applies to Flows at Apex
- 2) Each Event forms a Single Channel and Flow Remains in that Channel Throughout the Event (Avulsions?)
- 3) Flood Channels are Distributed Uniformly Across any Contour

Dawdy Method

- Implemented in FEMA FAN Program
- Called "simplistic and unrealistic" by Mays and Mushtaq in 1993 (Cazanacli et. al. 2002) because
  - Ignores Topography
  - Doesn't differentiate active and inactive

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French (Deterministic)

- Assumptions
  - Abrupt Longitudinal Slope Transitions Do Not Occur on Fans Without Geologic Controls
  - Slopes, geometries of conveyance channels, hydrograph, sediment size characteristics and other variables and parameters controlling sediment transport are known

French Methodology

- Also Assumes Smooth Curve between Upper (steeper) and Lower (flatter) Slopes

French Methodology

- Figure from RH French

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French Methodology

- Partition Hydrograph into small increments => pseudo steady flow
- Calculate equilibrium sediment transport for each pseudo steady flow rate
- Calculate deposition for each reach by subtracting downstream transport rate from upstream rate
  - Gives rate – multiply by time step for volume

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French Methodology

- Maximum Depth
  - $D_{max} = (S_1 - S_2)\ L / 8$

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Deterministic - Modeling

- One-Dimensional Modeling
  - HEC-RAS
  - HEC-6/HEC-6T
- Two-Dimensional Modeling
  - FLO-2D
  - Not RMA-2

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HEC-RAS / 1D

- Assumes all flow down channel
- WSE in all channels equal unless split flow
- Assumes rigid boundary

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FLO-2D / 2D Approaches

- Flow in x and y directions

- Assumes FIXED BED CONDITIONS
- Unless using sediment transport

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Geomorphic Approaches

- Eliminates need for Q
  - Old landforms = stable
  - Recent landforms = unstable / floodplain

  - Can back calculate flow rate from sediment sizes (velocity) / approx depth / slope

Uncertainty

- How to incorporate into design???
  - Flow Path
  - Flow Rate
  - Changing Bed Elevations

Consequences of Error

- If we err –
  - Result in Over or Under Design???
    - Dawdy
    - French
    - Risk Uncertainty
    - Geomorphic

Sediment Transport Issues

- Flow Concentration
- Flow Uncertainty
- Deposition Impacts
- Deposition & Maintenance
- Scour
- Obstructions
- Dynamic Equilibrium
- Flow Transitions

Assessing Impacts of Development on Fans

William J. Spitz, R.G.
Ayres Associates Inc

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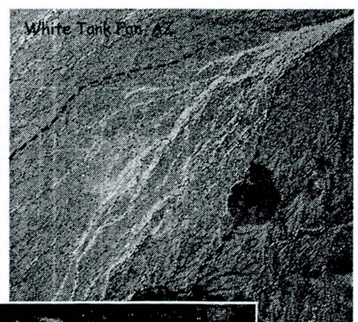
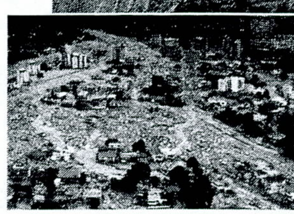
April 20-22, 2005

Introduction

- What are the potential impacts of development on alluvial fans?
- What is an acceptable impact?
- Tools for assessing the impacts





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Potential Impacts of Development on Alluvial Fans

- What are the potential impacts?
  - Changes in flow characteristics
  - Changes in sediment supply
  - Upstream and downstream impacts
  - Impacts from mitigation measures
  - Impacts on infrastructure

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Peak Flow

- Development can increase peak flows by:
  - Increasing impervious areas and reducing infiltration (increase runoff)
  - Concentrating flow
- Increased peak flows may result in:
  - Higher water surface elevations
  - Increased area of inundation
  - Increased risk of flooding and erosion

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Flow Frequency

- Development can increase frequency of smaller flows by:
  - Increasing impervious areas and reducing infiltration
    - *increased frequency of runoff*
- Increased flow frequency may result in:
  - Increased potential for erosion
  - Changes in vegetation type, distribution

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Flow Volume

- <u>Increases</u> in flow volume may result in:
  - Increased extent of inundation
  - Increased streambank erosion and scour
  - Channel degradation
  - Changes in vegetation characteristics

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Flow Volume (cont.)

- Decreases in flow volume may result in:
  - Decreased inundation and flood risk
  - Stream aggradation or narrowing
  - Reduction in vegetation health
  - Changes in vegetation distribution
  - Invasive species encroachment
  - Impacts on wildlife habitat

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Flow Distribution

- Changes in flow distribution include:
  - Reduced sheet flooding
  - Concentration of flow into few channels
  - Diversion into detention/retention basins
  - Diversion of flow into collector or interceptor channels
  - Containment within levees or berms
- Potential for concentrated flow at collection points

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Flow Distribution (cont.)

- Concentrated flow can result in:
  - Increased volume and peak of flows
    - *increases area and depth of inundation*
    - *increases risk of flooding and erosion*
- Concentrated flow in natural channels can:
  - Induce local degradation, scour, erosion
  - Create potential for downstream aggradation → increased flood risk

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Sediment Supply

- Causes of changes in sediment supply:
  - Diversions and channelization
  - Detention and retention
  - Bank erosion and channel degradation
- Changes that are proportional to water supply may be appropriate

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Sediment Supply (cont.)

- Increased supply can cause:
  - Aggradation and loss of capacity
  - Increased risk of flooding
  - Potential channel avulsions
- Decreased supply can cause:
  - Channel degradation (incision)
  - Bank erosion and scour

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Development Impact & Minimization

- Flow Concentration

  Response: degradation, headcutting, bank erosion, local scour

  Minimization: grade control, bank protection, channel lining
- Increased frequency of small flows

  Response: increased potential for erosion

  Minimization: detention and retention, diversion channels and floodways

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Development Impact & Minimization

- Increased flow volume

  Response: channel degradation, erosion, and scour; increased depth and area of inundation

  Minimization: detention and retention, channelization, flood walls, berms, levees, street alignment, build on elevation

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Development Impact & Minimization

- Increased sediment supply

  Response: aggradation and loss of channel capacity, increased risk of flooding, potential channel avulsions

  Minimization: debris basins, channelization

- Decreased sediment supply

  Response: channel degradation, bank erosion, and scour

  Minimization: grade control, bank protection, channel lining

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Impacts of Control Measures

- Debris basins at or below the hydrographic apex trap sediment and debris
  - Downstream sediment supply is severely curtailed
  - Can cause downstream degradation
    - *Can be countered by lining downstream channel or installing grade control and bank protection*
  - Requires maintenance plan and $$ for clean out

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Impacts of Control Measures

- Cross-fan collector/interceptor channels collect flow from multiple flow paths
  - Reduces number of downstream channels to maintain
  - Reduces area of downstream inundation, flooding
  - Needs to be appropriately engineered to carry water and sediment for wide range of events
    - *can get significant sediment deposition, flow ramping, avulsions*
  - Requires long-term plan and $$ for maintenance

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Impacts of Control Measures

- Detention/retention basins capture part or all of flow
  - Reduces peak and volume of flow in downstream reaches
  - Can reduce extent and duration of downstream flooding
  - Like debris basins, can also trap sediment and cause downstream degradation
  - Requires long-term plan and $$ for maintenance

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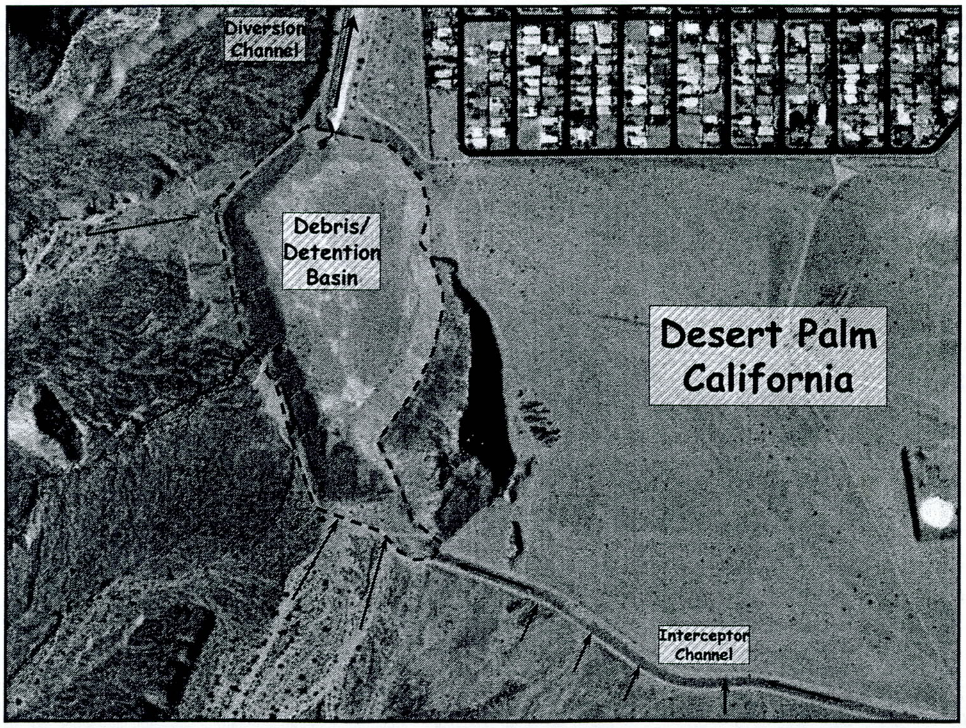

Impacts of Control Measures

- Diversion channels convey flood water (and sediment) down valley
  - Inlet can be collection point or basin outlet
  - Outlet must accommodate flows <u>and</u> sediment
  - Will need to be concrete lined or adequately protected with grade control and bank protection
  - Must be appropriately engineered to carry water and sediment for wide range of events
    - *significant in-channel sedimentation possible, flow ramping, avulsions, plugging of inlet with sediment*
  - Requires long-term plan and $$ for maintenance

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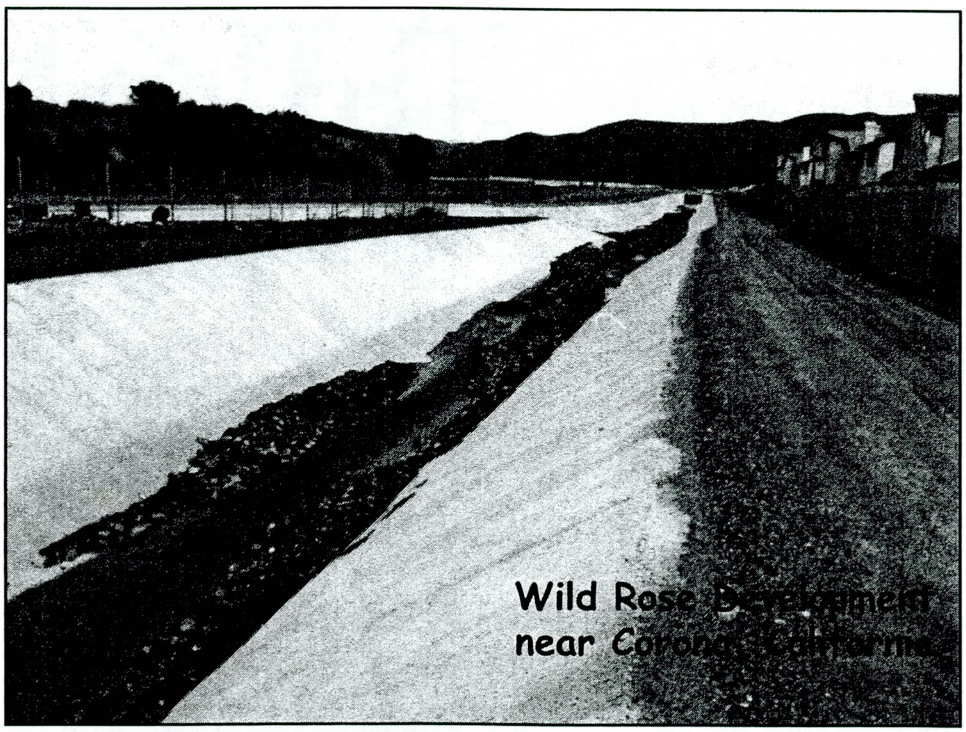

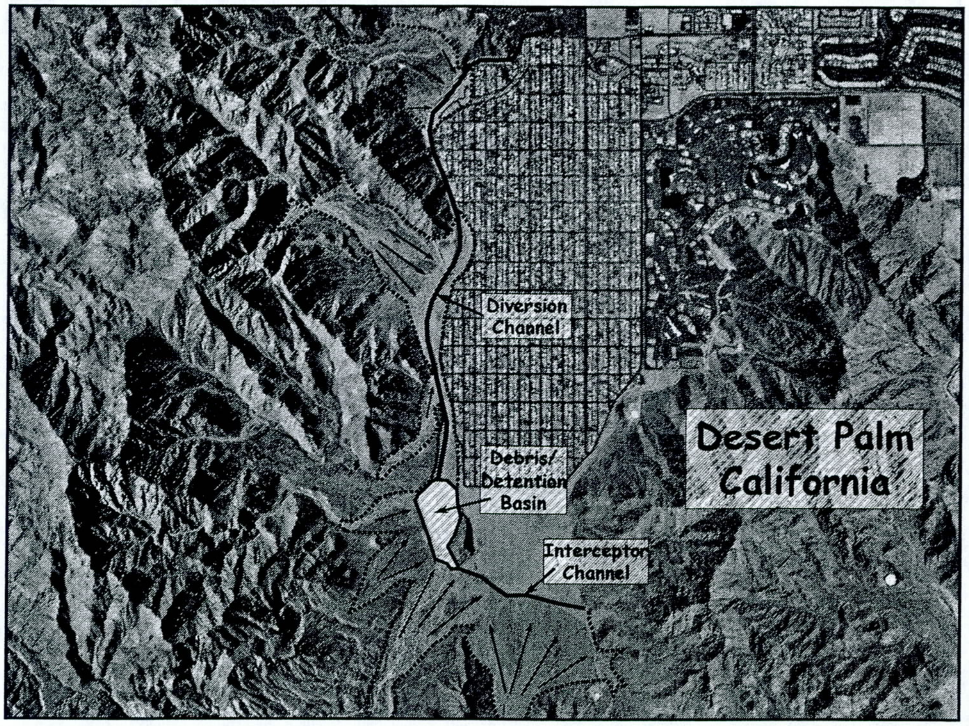

Impacts of Control Measures

- Lots with elevated pads and flood walls provide protection from shallow flooding
  - Lots with inadequate open space may not be able to accommodate flow paths
  - Design of elevated foundations and flood walls may not adequately address velocity/scour, sedimentation, and debris impact
    - *Unprotected pads and walls may be susceptible to erosion and other damages*
  - Potential impacts to adjacent property owners
    - *Large lots, elevated pads, and walls may deflect flow into other properties*

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Impacts of Control Measures

- Appropriately designed roadways can accommodate shallow flood flows
  - Street design may not adequately accommodate flow between residential developments
  - Street alignment may result in the formation of new flow paths or the relocation of existing paths because of poor alignment
    - *Streets running down-fan should be aligned parallel to flow*

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Impacts of Control Measures

- Road crossings, culverts, and bridges over natural channels should pass high sediment loads as well as flood flows
  - Low water crossing hazards and maintenance
  - Poorly designed crossings can become clogged with sediment
    - *Can get overtopping or avulsions due to loss of capacity*
  - Clogged crossing may result in downstream degradation due to reduced sediment loads
    - *Downstream incision and headcutting may threaten structure integrity*

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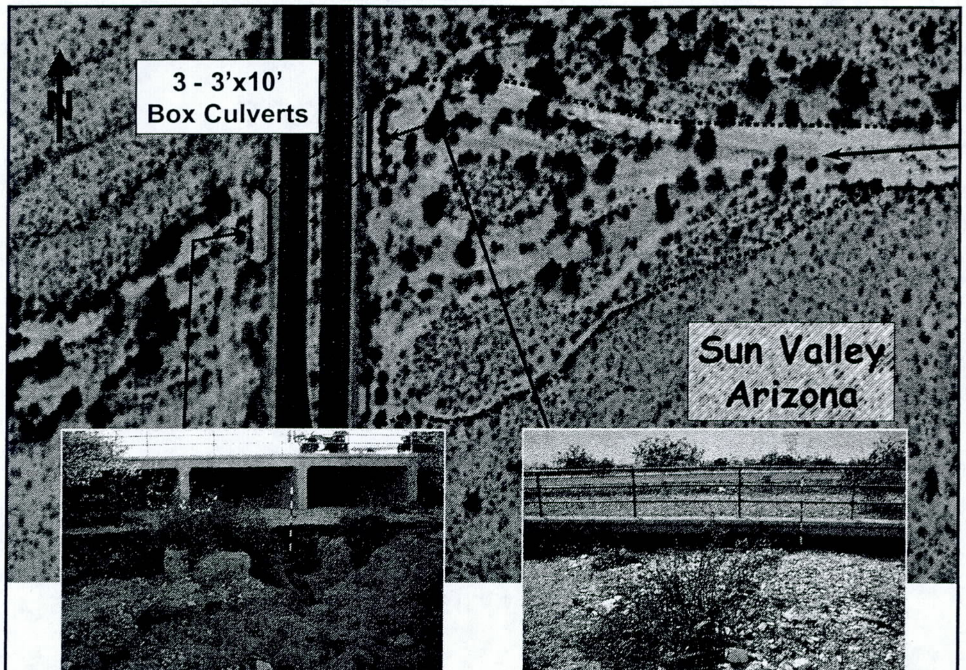

Downstream Side - Reduced sediment load, degradation, potential undermining of structure

Upstream Side - Aggradation, loss of capacity, potential overtopping

Impacts of Control Measures

- Floodways with berms, dikes, and levees can contain flood flows
  - Berms, dikes and levees susceptible to erosion if unprotected
  - Dense vegetation in floodway can reduce capacity and induce sediment deposition
  - Meandering channels within floodways can impinge on levees and dikes
    - *deposited sediment at impingement point can lead to sediment ramping and overtopping*

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What is Important in Assessing Impacts?

- Not just Q_{100} is important
  - All discharges have impact
  - Should use combination of discharges to evaluate flow and sediment impacts
    - *Q_2 through Q_5*
  - Sediment bulking of flows should be included in design considerations
  - Maintenance plan and costs should consider range of discharges and sediment loads

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Assessment Tools

- Tools include:
  - Geomorphic Assessments
  - Landform Stability and Hazards Mapping
  - Hydrologic and Hydraulic Modeling
  - Sediment Transport Modeling
  - Engineering Design
- Tools require considerable expertise to use and apply

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Conclusions

- No such thing as "little or no impact"
  - Development and infrastructure must account for all alluvial fan processes
  - Developing on alluvial fans also influences fan processes
- All discharges should be evaluated
- Tools are available for assessing impacts
  - require high degree of knowledge to use and apply
- Use "whole-fan" approach to management and control
  - Coordination and cooperation are key

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Questions or Comments?

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Alluvial Fan Symposium

A Proposed Non-Structural Management Framework

Doug Plasencia, P.E. CFM
Michael Baker Corporation

Baker

What this Talk Is

- A potential framework for using a non-structural management strategy on alluvial fans.

What this talk is NOT

- These are not the concepts of any organization or person other than my own.
- This is not an ending- rather it is intended to provoke and be a catalyst for discussion

Alluvial Fans are Inherently Risky

- High Sediment Levels
- Uncertainty of flow paths
- Extent of potential flooding
- Lack of Risk Awareness by Public

Alluvial Fan Flood Hazard Management Symposium

Non Structural Approaches

- Non Structural Compliance with Floodplain Management Standards (Apex is not controlled)
  - Avoidance
  - Flow Through
  - Combined Approach
    - Non-Structural Floodplain
    - Partially Structural Drainage Infrastructure

Step 1- Risk Identification

- Frequency
- Depth
- Velocity
- NEW – Sediment and Debris

Step 2- Risk Mapping

- POTENTIAL RISK MANAGEMENT ZONES
  - AFH- Alluvial Fan High Hazard
  - AFM- Alluvial Fan Moderate Hazard
  - AFL – Alluvial Fan Low Risk Hazard

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AFH- High Hazard

- Conceptually much like a floodway or coastal velocity zone
- Defined by Depth x Velocity and Sediment Severity
- Very Low Densities (No Critical Facilities)
- Maximum D x V for ingress/egress
- Special Construction Standards?
  - Would a Coastal Beach House approach Work?

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AFM – Moderate Hazard

- Conceptually, similar to the flow through concepts employed in Valley- Could include structural elements.
- Defined by Depth x Velocity and Sediment Severity
- Low to Moderate Density
- Police and Fire Sub-Stations, Neighborhood Schools, but limit other Critical Facilities.
- Construction Standards- freeboard, infrastructure considerations

Alluvial Fan Flood Hazard Management Symposium

AFL- Low Risk Zone

- Conceptually a mix of floodplain lowest floor requirements and drainage design practices.
- Based on not exceeding a D x V criteria
- No restriction on use
- Allows flow through of upland areas
- Special infrastructure construction standards

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Step 3. Sediment Management

- Access
- Clean Up and Restoration (Potentially Significant Expense)
- Individual Safety

Paying for Debris Removal and Restoration?

- Existing Government?
- By Development Community (HOA)?
- Special Service Utility or District?

Step 4. Infrastructure and Lifelines

- Special Design Standards for Roads, Culverts, dip crossings?
- Are the proposed lifelines susceptible to flooding, erosion or sediment damages? Are the consequences of shutdown significant? Can this be mitigated by location and flood proofing ?

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Step 5. Continual Risk Communication

- The alluvial fan environment is different and most do not recognize or understand the risk

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Risk Communication

- The Public Perception " This area won't flood, THEY would not allow someone to build here if it was a problem"

Risk Communication

- Public Reaction –"The last time it rained water came over the top of the road and there was mud on my street, who screwed up?"

Risk Communication

- Due to the potential geographic extent of hazard there is a need for:
  - Hazard Specific Real Estate Disclosure
  - Reminders about driving, personal emergency action plans, and individual safety
  - Encourage the purchase of flood insurance

Summary and Discussion

- Step 1- Risk Identification
- Step 2 –Risk Management Zones
- Step 3- Sediment Management Strategies
- Step 4- Infrastructure Design and Location
- Step 5- Ongoing Risk Communication

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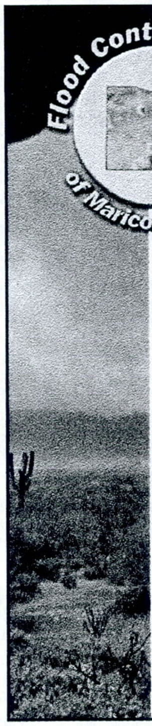
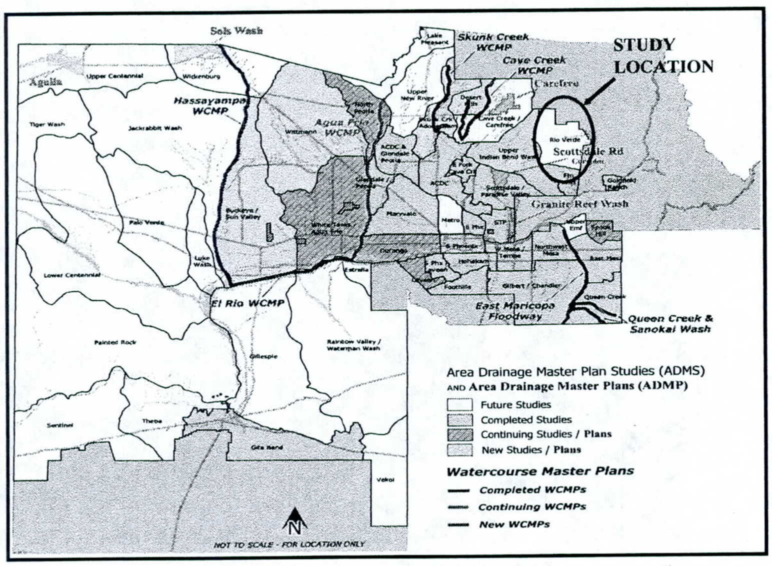


Regulating Development on a Distributary Flow Area Using Drainage Guidelines

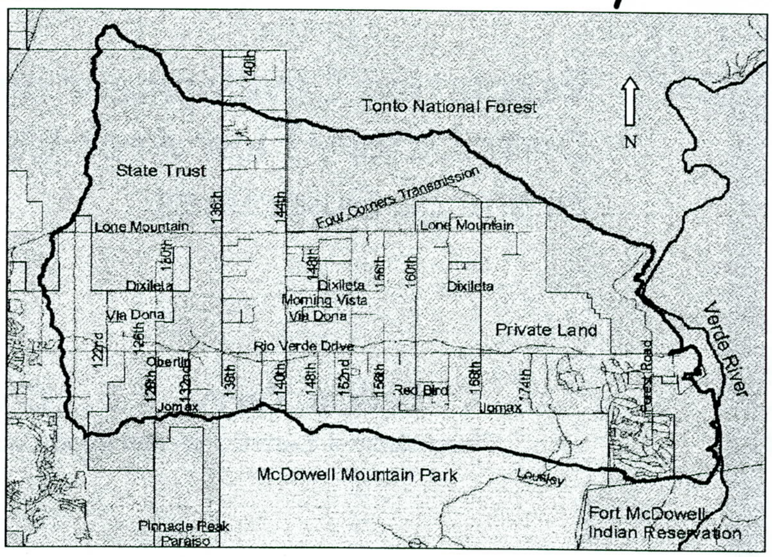
Felicia Terry, P.E., CFM.

Flood Control District of Maricopa County

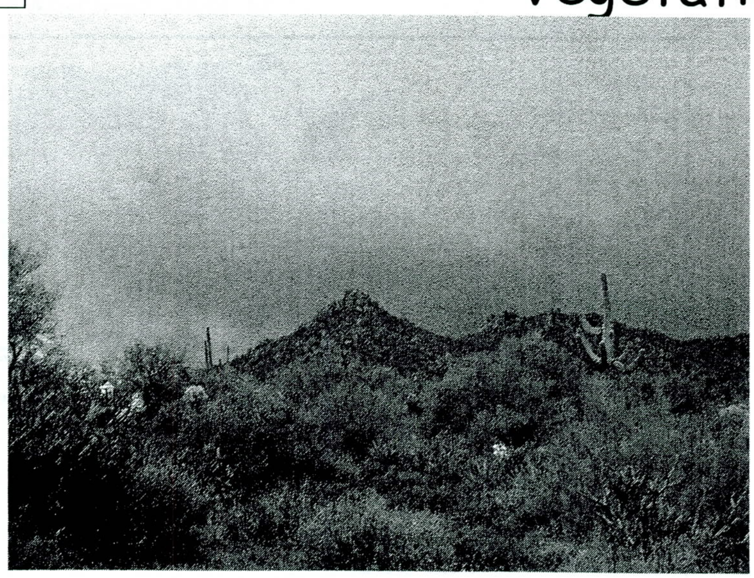
Rio Verde Study Area Location



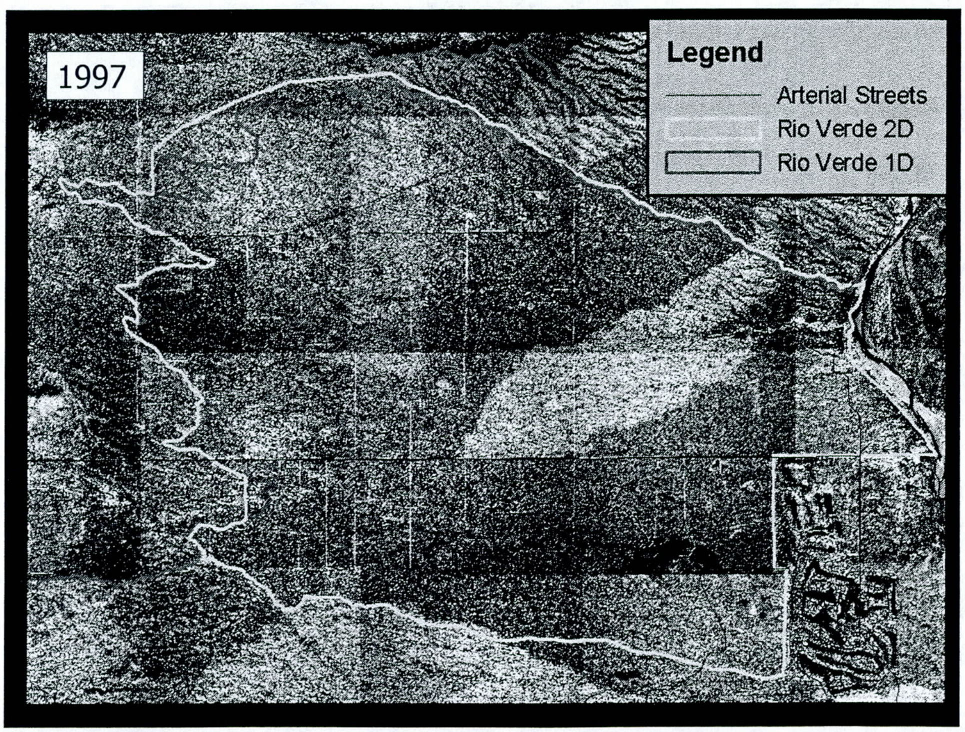
Rio Verde Study Area

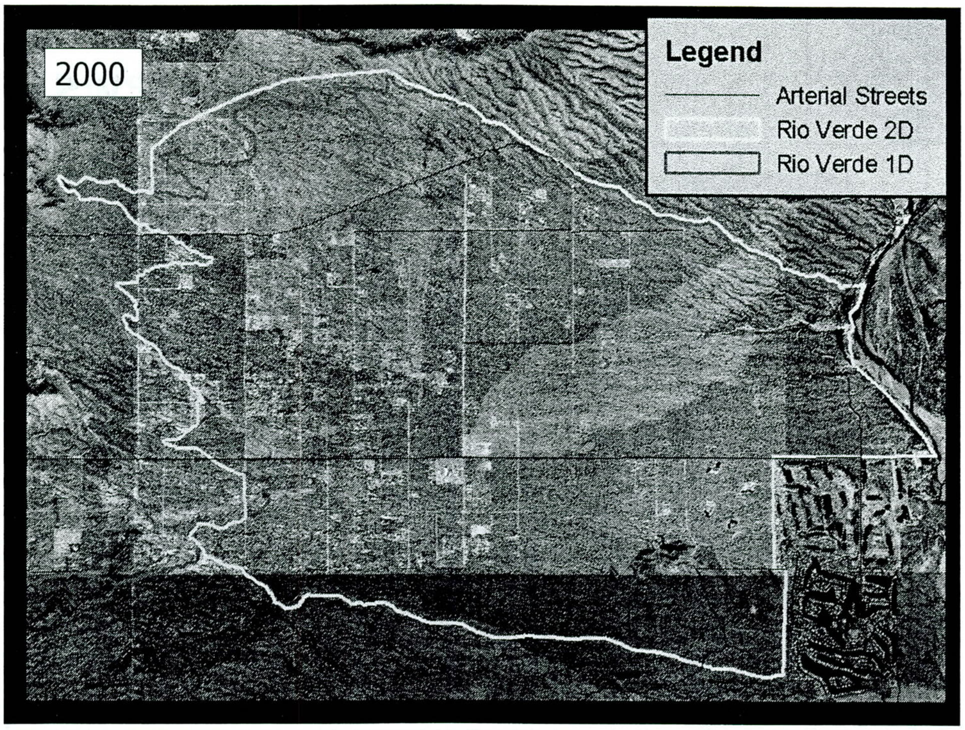


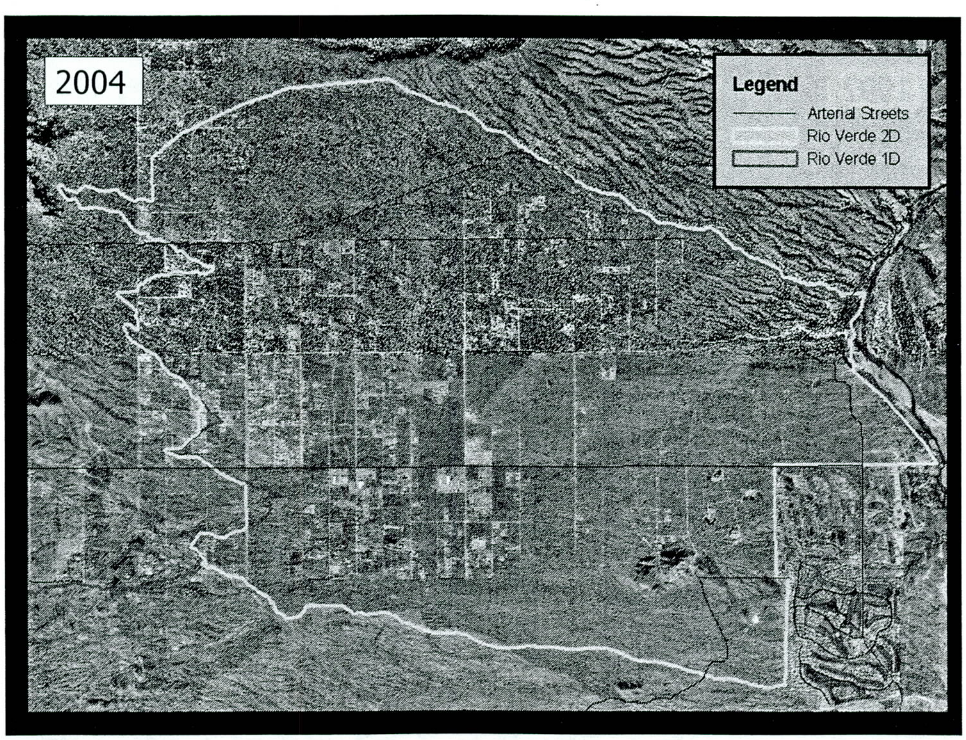
Beautiful Desert Vegetation

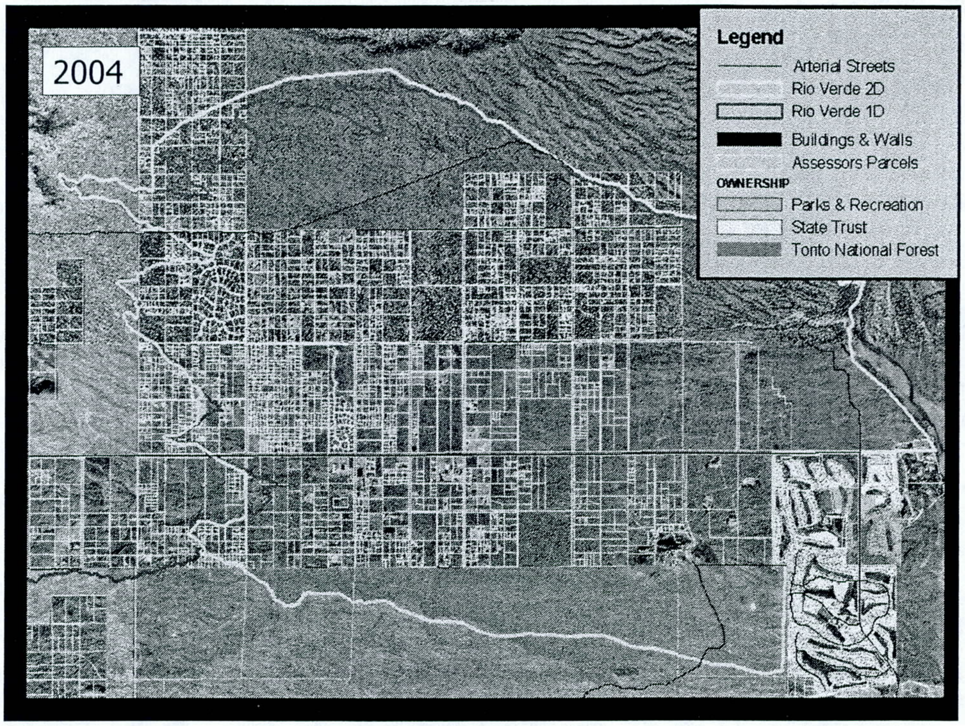


Scenic Views




2000
Legend
Arterial Streets
Rio Verde 2D
Rio Verde 1D


2004
Legend
Arterial Streets
Rio Verde 2D
Rio Verde 1D

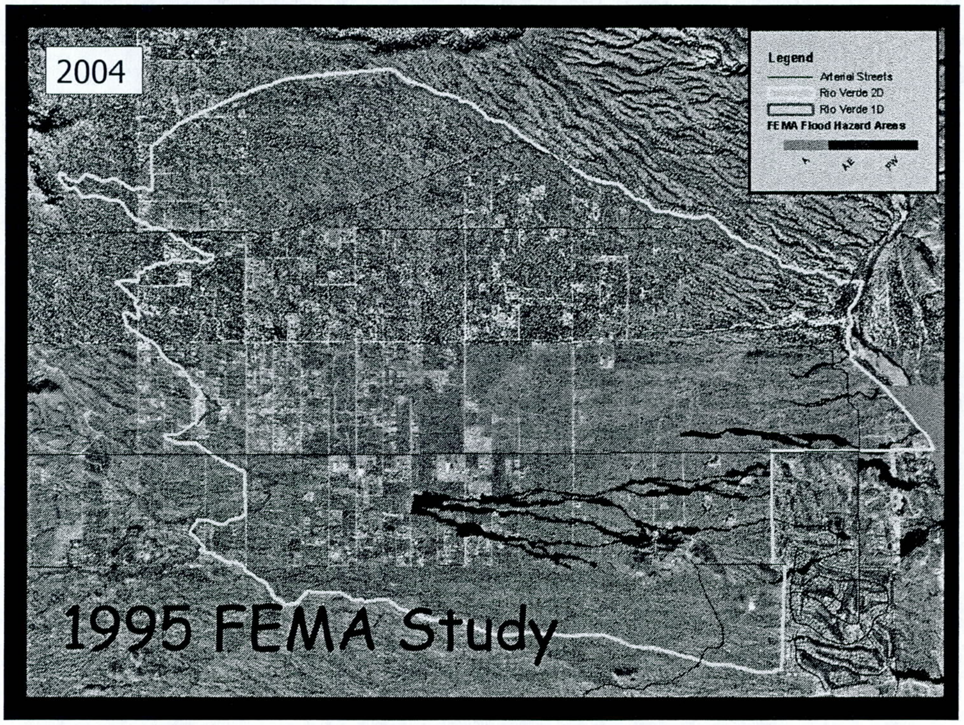


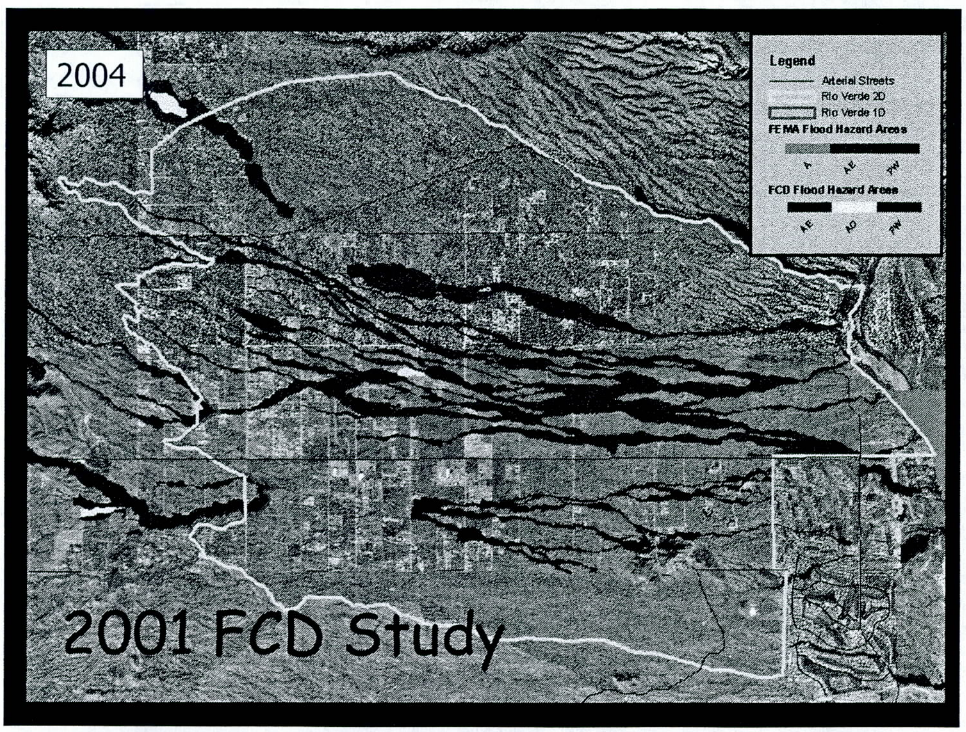
Unique Conditions in Rio Verde Area

- Steep Slopes
- Fine-grained Sediments
- Distributary Stream Networks
- Shallow Sheet Flooding
- Lateral Erosion & Gullying
- Natural Debris Diversions & Flow Splits

Drainage Patterns - 1953

Drainage Patterns - 2003


2004
Legend
Arterial Streets
Rio Verde 2D
Rio Verde 1D
FEMA Flood Hazard Areas
A
AE
FW
1995 FEMA Study


2004
Legend
Arterial Streets
Rio Verde 2D
Rio Verde 1D
FEMA Flood Hazard Areas
A
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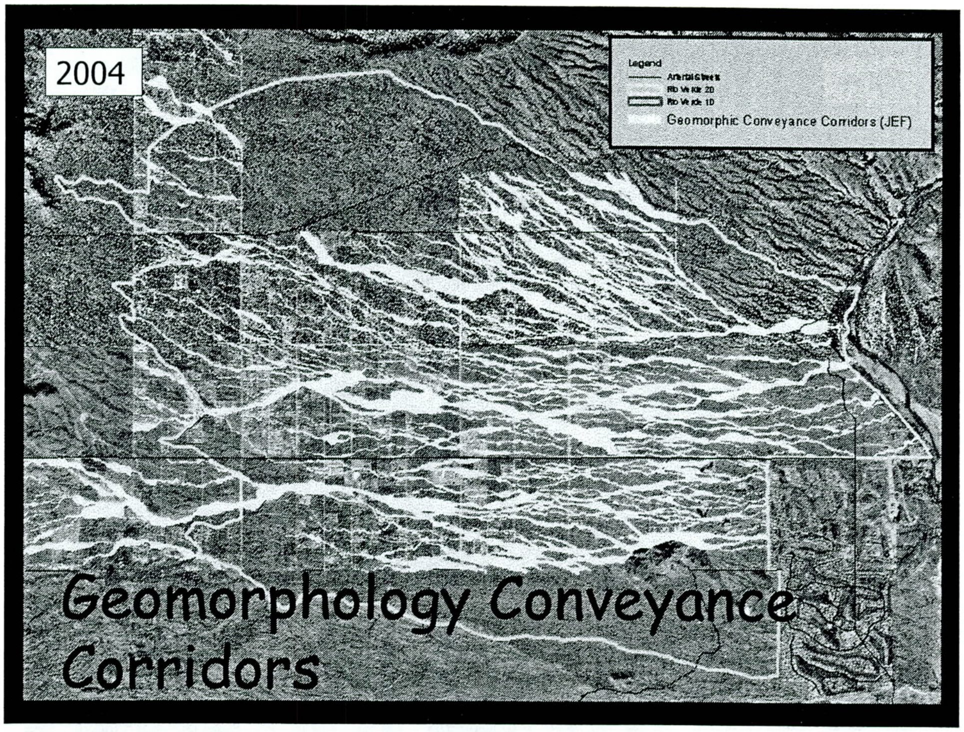
FCD Flood Hazard Areas
AE
AO
FW
2001 FCD Study



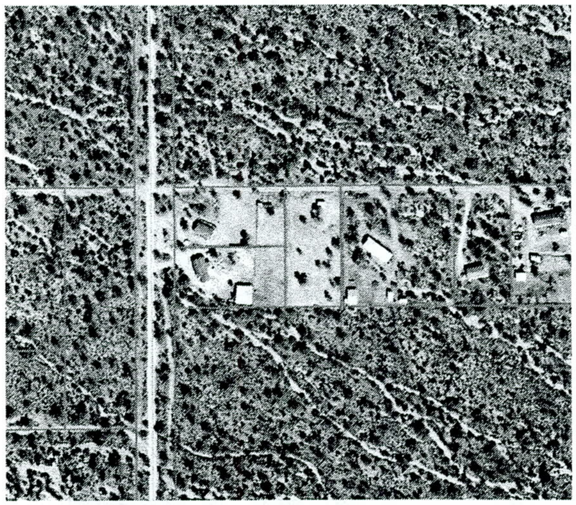
Drainage Guidelines

Were developed based on the best technical information and experience at the time.

Maintain Existing Natural Washes

Washes 5 ft wide or greater should not be disturbed.

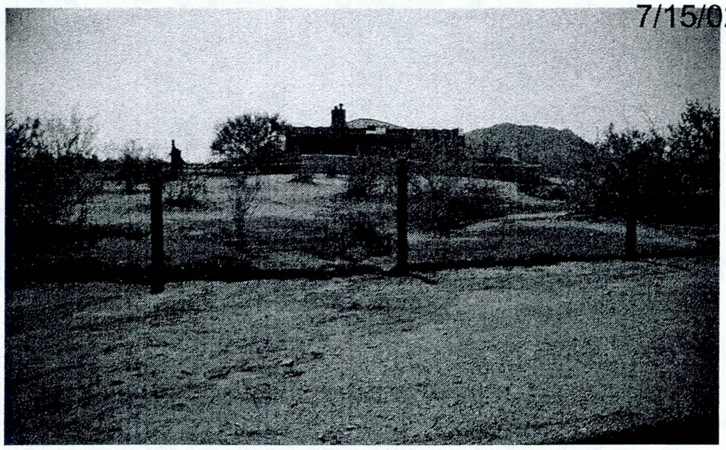
Minimize the Area of Disturbance



- Disturb 40% Maximum
- If disturb More than 40 % need retention

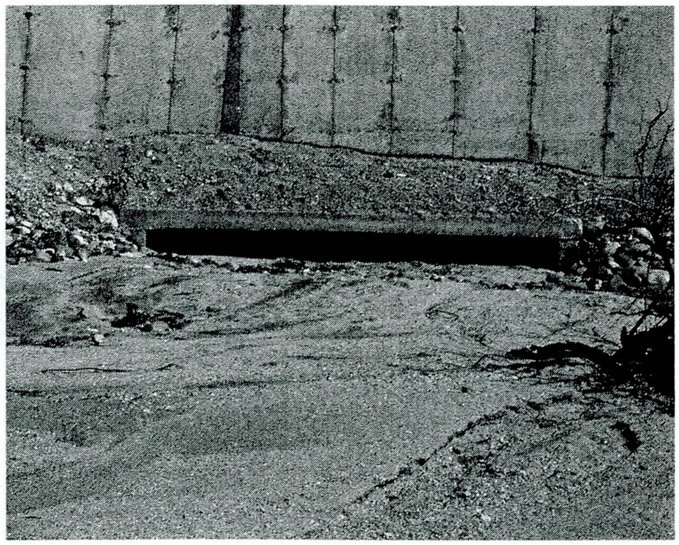
Discourage Perimeter Walls and Fencing

Mesh fencing should not be used for perimeter fencing



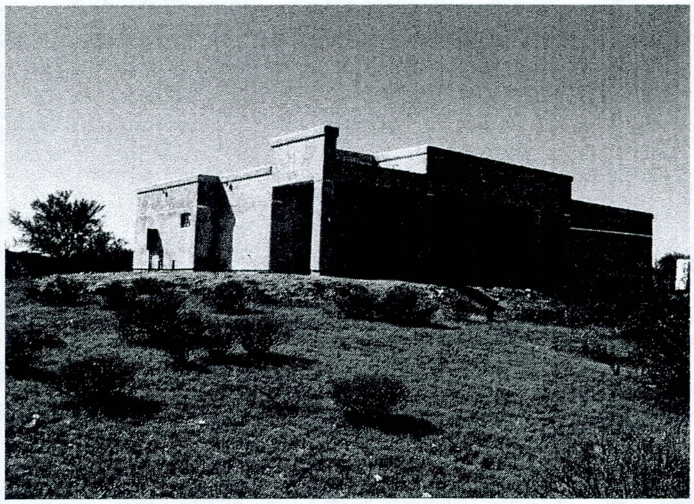
Block Walls should not be used around the Perimeter

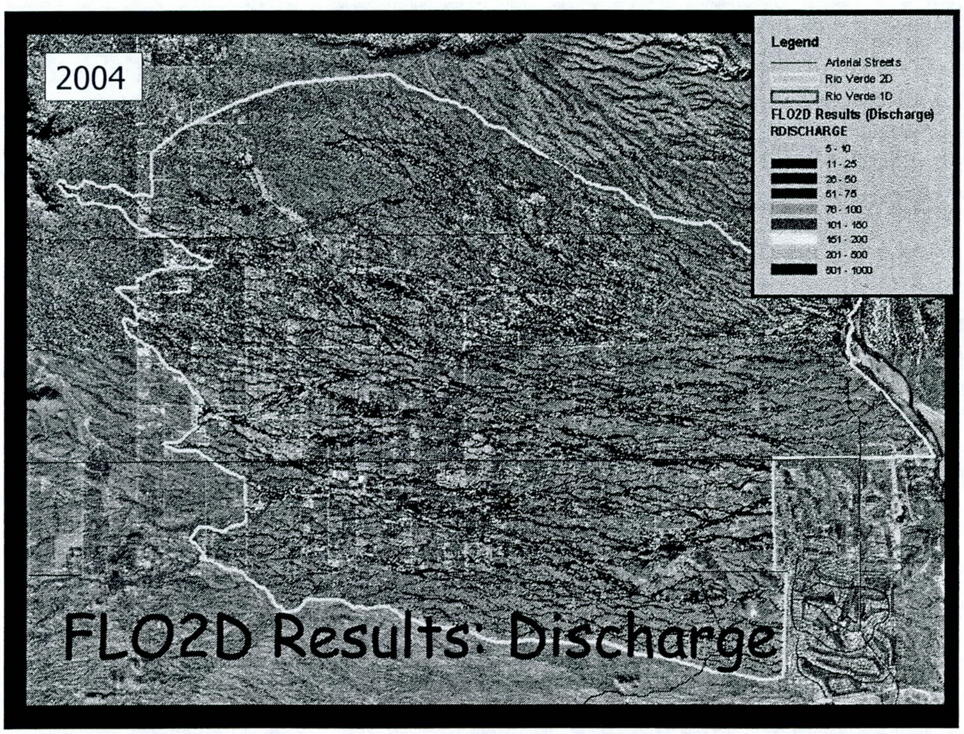
Block Wall Openings become Clogged

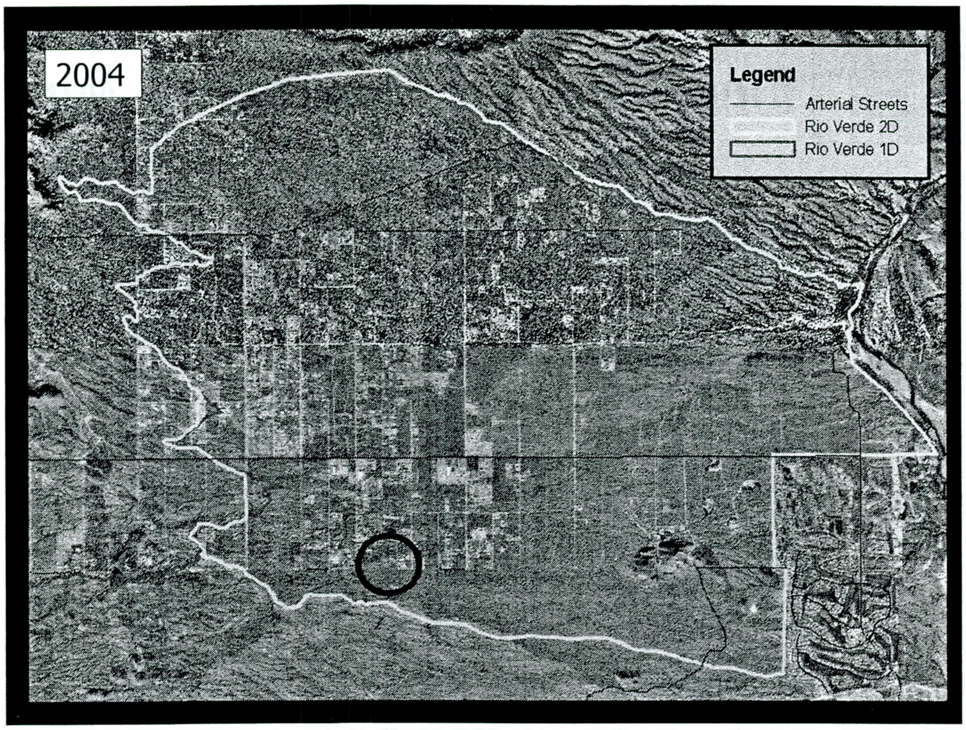


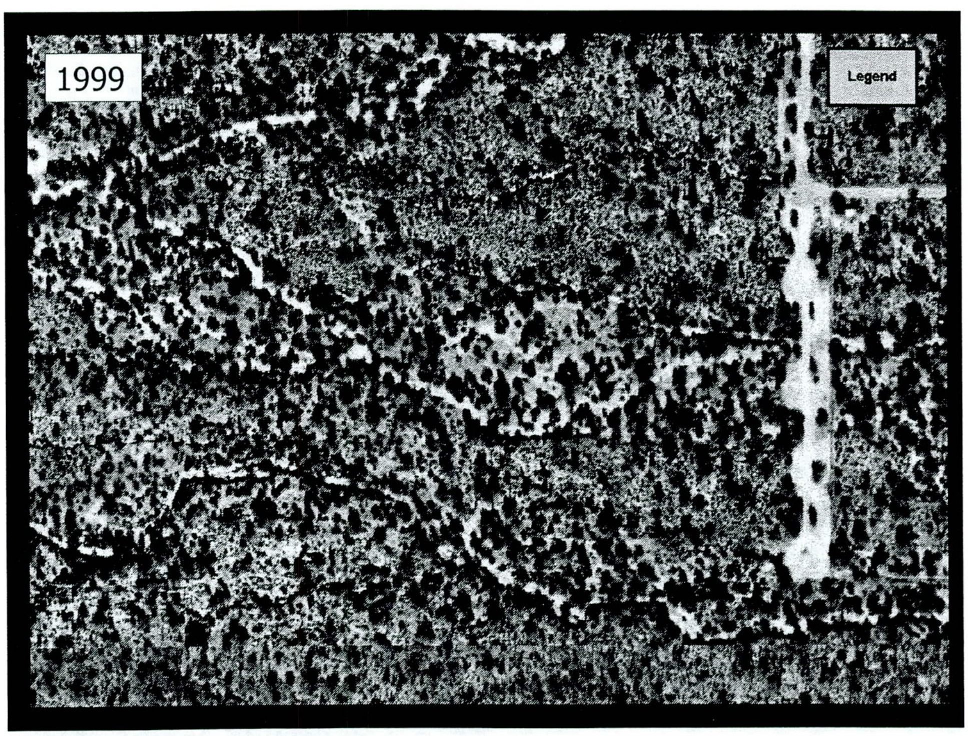
When is a Drainage Opening not a Drainage Opening?

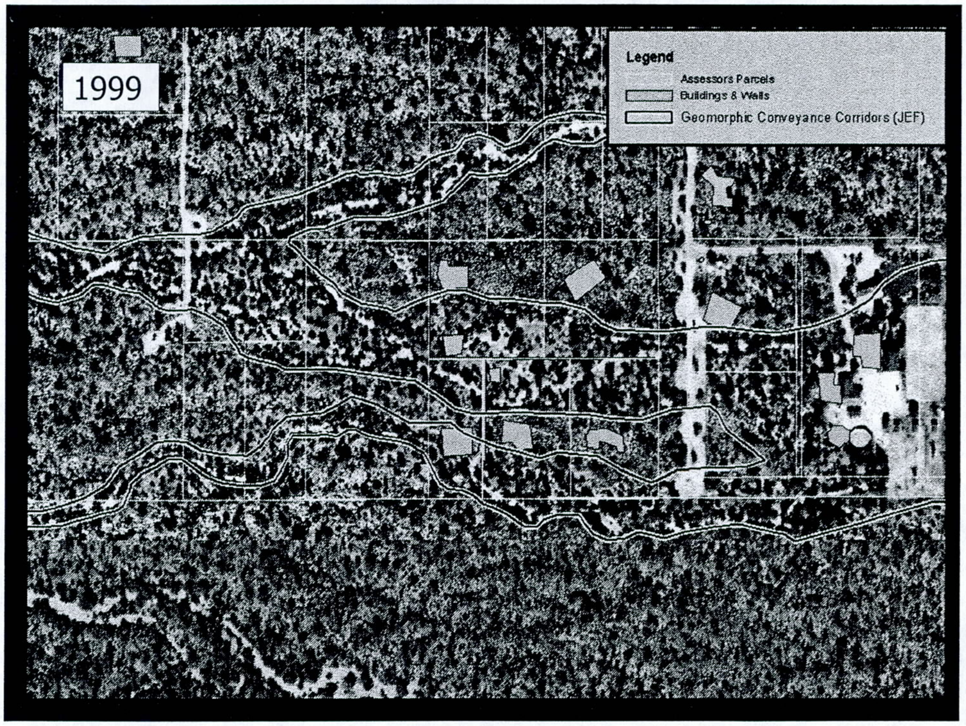
Finished Floor Elevations – Min. 18" Above Natural Grade



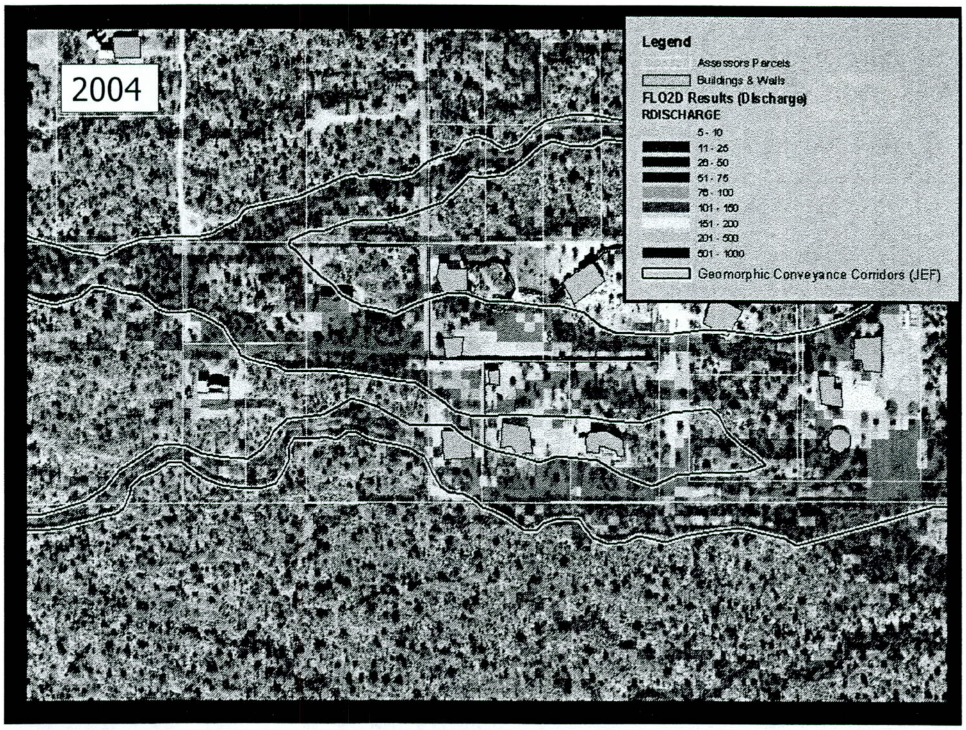



2004
Legend
Arterial Streets
Rio Verde 2D
Rio Verde 1D


1999
Legend

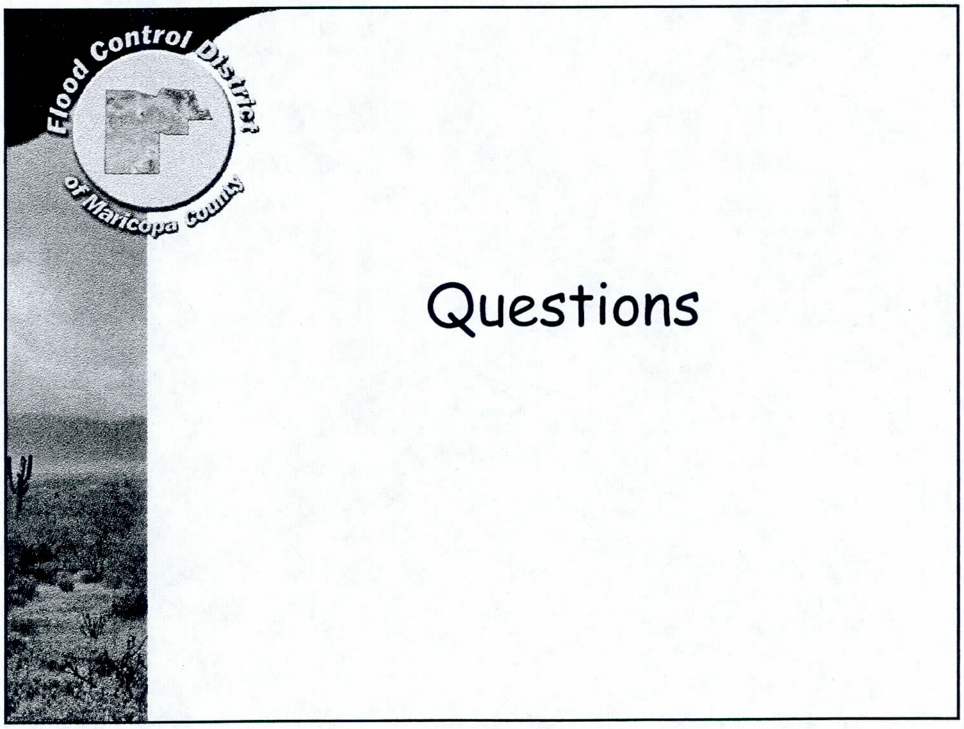

1999
Legend
Assessors Parcels
Buildings & Walls
Geomorphic Conveyance Corridors (JEF)


2004
Legend
Assessors Parcels
Buildings & Walls
Geomorphic Conveyance Corridors (JEF)



Drainage Guidelines

- Maintain existing natural washes
- Minimize disturbance of lots
- Retention needed, if disturb > 40%
- Discourage perimeter walls and fences
- Finished floor elevations – minimum 18 "


Flood Control District
of Maricopa County
Questions

Alluvial Fan Flood Hazard Management Symposium Case History: Non-Structural

Andy Seiger, PE
Pima County Flood Control District

Tortolita Alluvial Fan

1. Setting
    - A. Location
    - B. Characteristics of Fan Area
    - C. Infrastructure
    - D. Development Pressure
    - E. Type of Development

Tortolita Alluvial Fan

1. Setting
   A. Location
      - South, West Facing Canyons of Tortolitas & Adjacent Fan Area
      - Area
      - Accessibility
      - Jurisdiction

Alluvial Fan Flood Hazard
Management Symposium

Tortolita Alluvial Fan

1. Setting
   B. Characteristics of Fan Area
      - Climate
      - Vegetation and Wildlife Habitat
      - Topographic Relief
      - Drainage Stability
        - ✓ Apices
        - ✓ Age of Surface Soils
        - ✓ Debris Flows
        - ✓ Distributary vs Tributary Network
        - ✓ Channel Avulsions

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Tortolita Alluvial Fan

1. Settings
   C. Infrastructure
      - Interstate I-10
      - Southern Pacific Railroad Embankment
      - CAP Canal

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Tortolita Alluvial Fan

1. Settings
   D. Development Pressure
      - Land Availability in Pima County
      - Desirability of Fan Area
        - ✓ Aesthetics
        - ✓ Accessibility
      - Speed of Development

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Tortolita Alluvial Fan

1. Settings
   E. Type of Development
      - Undeveloped
      - SFR
      - Subdivisions
      - Urban, Suburban

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Tortolita Alluvial Fan

2. Non-Structural Approach to Hazard Avoidance
   A. Zone for Large Lot Residential
   B. Guide Development outside Spine Wash Floodplain
      - Maintain Spine Wash for Flood Conveyance
      - Engineering Required to Develop within Spine Wash Floodplain
      - Ordinance Allows County to Move Development within Lot
   C. Elevate per FEMA Zone, Plus 1 Foot State Requirement
   D. Require Engineered Erosion Protection, if Appropriate
      - If within EHSB of Minor Wash
      - If within Young Surface Soils

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Tortolita Alluvial Fan

3. Successes
   - A. County Has Been Able to Exclude Development from Conveyance Paths
   - B. Permitted Structures are above RFE and Protected Against Erosion

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Management Symposium

Tortolita Alluvial Fan

4. Failures
   - A. Approach Does Not Consider Cumulative Effect of Development
   - B. Approach Has No Provision for Controlling Alignment of Roads
   - C. Approach May Require Hydrologic Analysis
     - Outline Basin Boundaries
     - Evaluate Flow Splits

Alluvial Fan Flood Hazard
Management Symposium

Structural Approaches for Alluvial Fan Management: Hazard Modification

Alluvial Fan Flood Hazard Management Symposium

April 21, 2005

Types of Structural Measures

- Type 1: Flood Storage Structures
  - Water & Sediment
  - Debris Basins
  - Detention Basins
  - Advantages
    - Controls water & sediment
    - Removes uncertainty
  - Challenges
    - Ownership of Apex
    - 404 Permitting

Types of Structural Measures

- Type 2: Conveyance Structures
  - Channels: Diversions and/or Collector
  - Levees, Dikes, & Flood Walls
  - Advantages
    - 404 Permitting
    - Limited Land Ownership
  - Challenges
    - Sediment storage & conveyance
    - Flow concentration
    - Channel capacity
    - Outfall impacts

Types of Structural Measures

- Type 3: Combination Measures
  - Conveyance
  - Storage

Flood Control Issues

- Public Maintenance & Inspection Required
- Whole Fan Solution Preferred
- Piedmont Flooding Sources (below apex)
- Adjacent Property Impacts
- FEMA CLOMR Criteria
- Construction Phasing
- Cost/Funding

Case Histories

- Phil Shaller/ Exponent
  - Desert Dunes, Coachella Valley, CA
- Bruce Phillips/ PACE
  - Reserve Development, Palm Desert, CA
- Kevin Eubanks & Steve Roberts/CCRFCD
  - Las Vegas Piedmont

Alluvial Fan Flood Hazard Management Symposium

Investigating Flood Hazards on Alluvial Floodplains

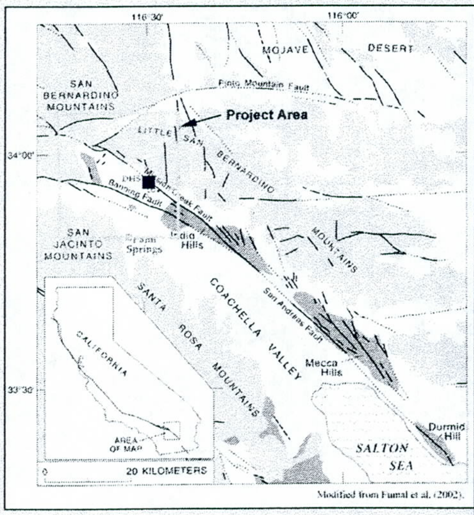
by

Douglas Hamilton, Philip Shaller, Parmeshwar Shrestha, Jene Lyle, and Macan Doroudian

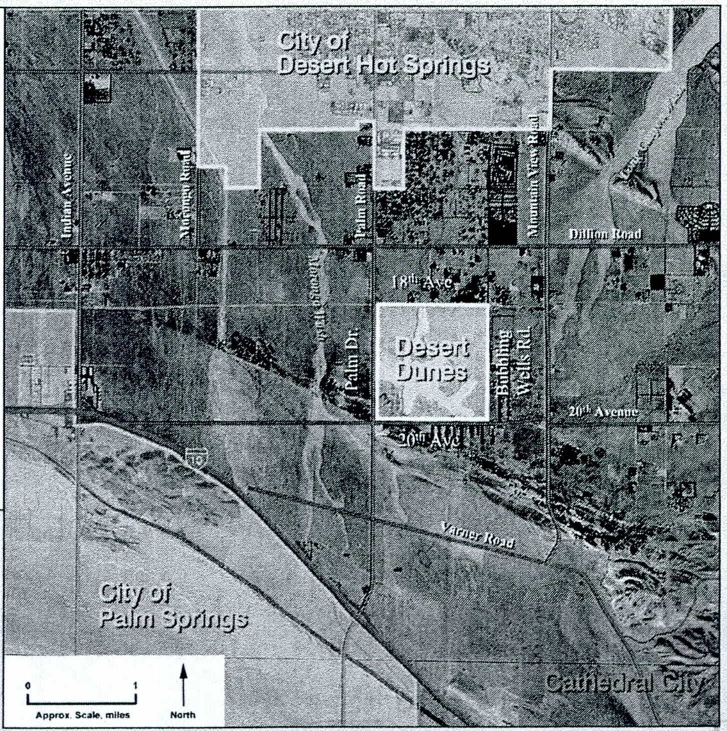
April 20-22, 2005
Mesa, Arizona

Exponent

Desert Dunes Project Area



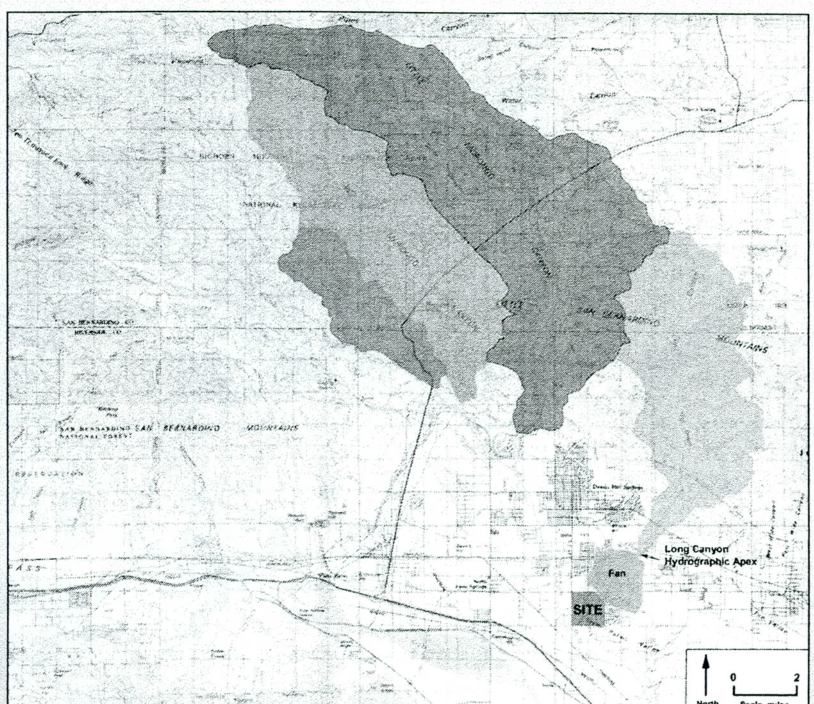
Modified from Fumal et al. (2002).



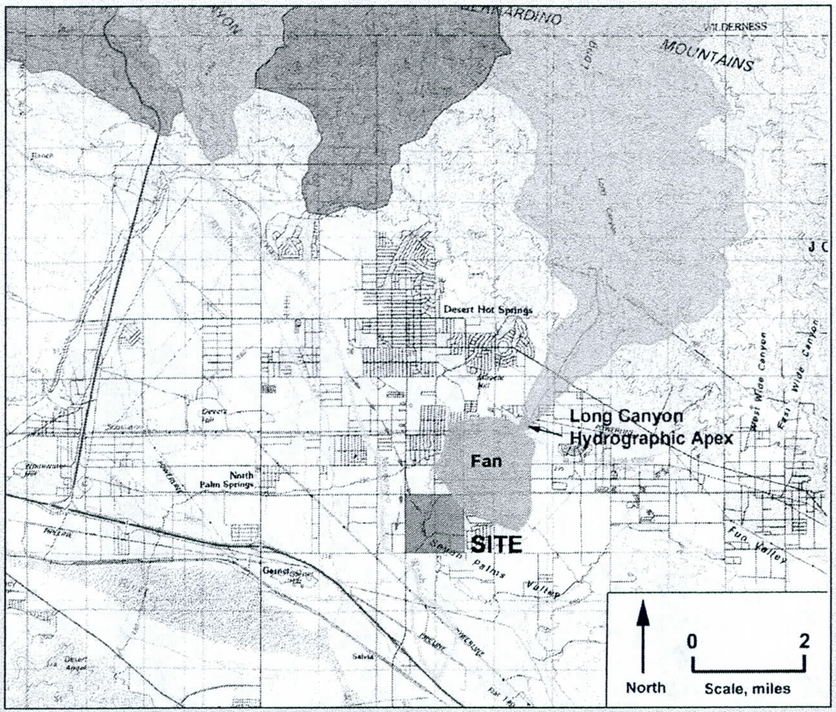
Objective – Flood Hazard Analysis

- Development of a flood routing model
  - Hydrologic features
  - Historical flooding
  - Topographic features
    - *USGS DEM*
    - *Aerial photography*
    - *LiDAR survey*
  - Domain discretization
  - Hydrologic inputs
  - Peak Discharges into Project Area

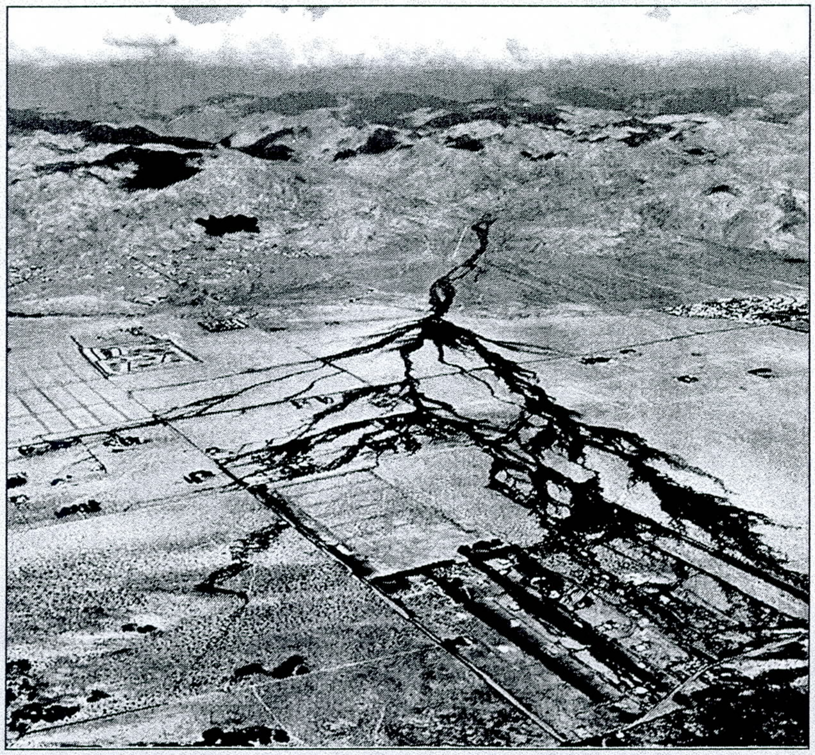
Major Hydrologic Features



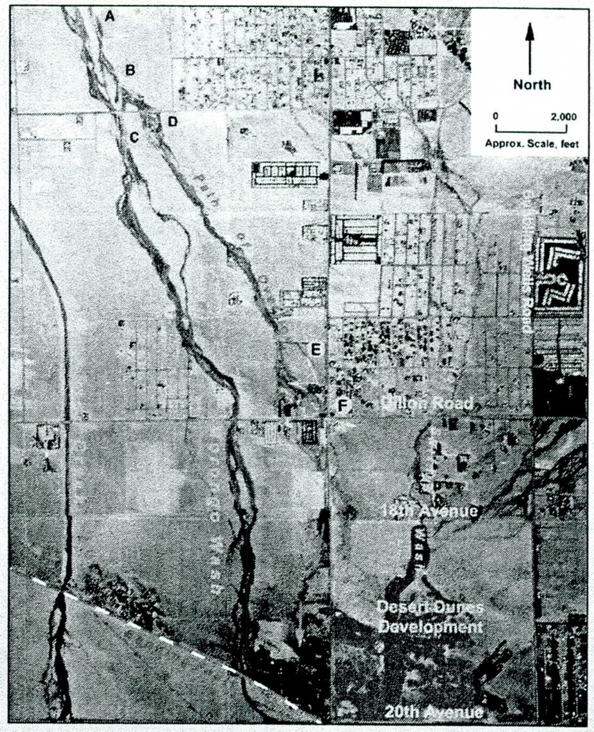
Hydrologic Features in Project Vicinity



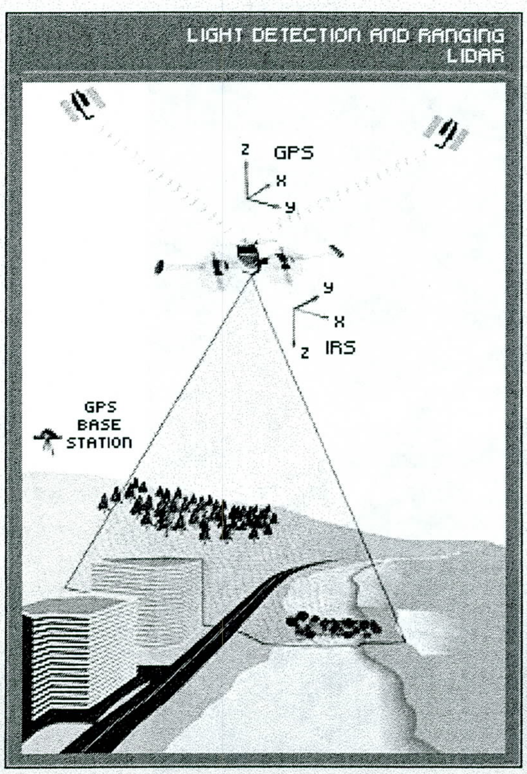
Historical Flood - Long Canyon Fan 1974



Historical Flood – Morongo Wash, 1991



LiDAR Technology

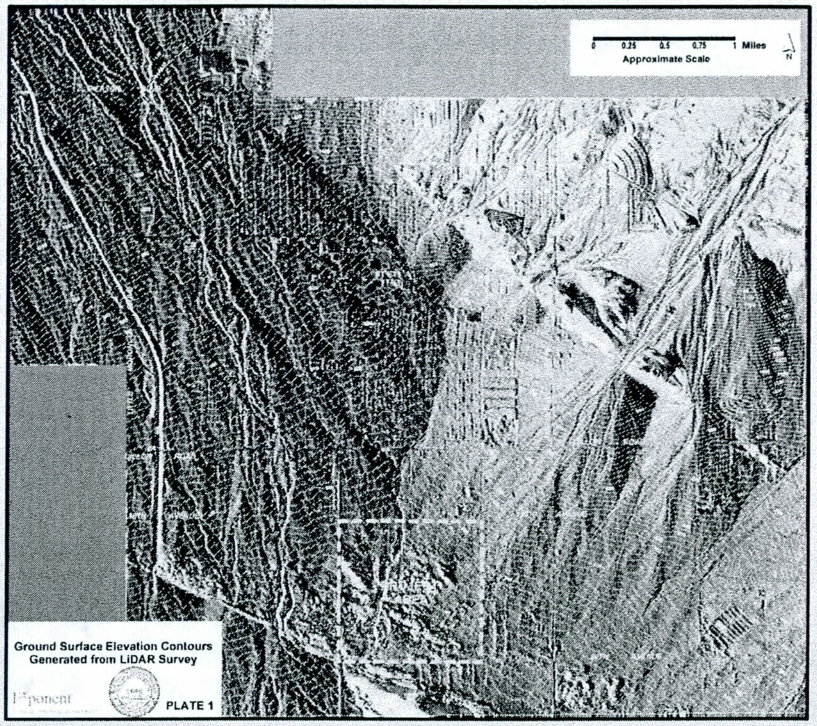


Horizontal Resolution ~ 0.5 m

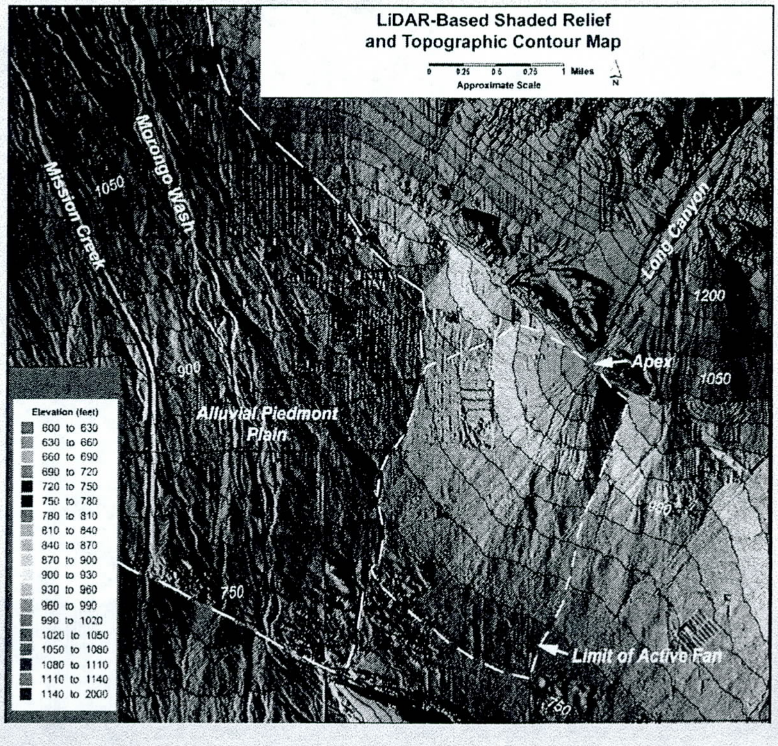
Vertical Accuracy ~ ± 15 cm

Horizontal Accuracy ~ 1/3000th flight height

Elevations from LiDAR Survey



LiDAR-based Topographic Contours



FLO-2D Model (O-Brien, 2004)

- Two-dimensional, finite-difference, flood routing model
- Domain discretization – uniform, square grids
- Governing equations

Continuity equation

$$\frac{\partial h}{\partial t}+\frac{\partial hV_x}{\partial x}+\frac{\partial hV_y}{\partial y}=i$$

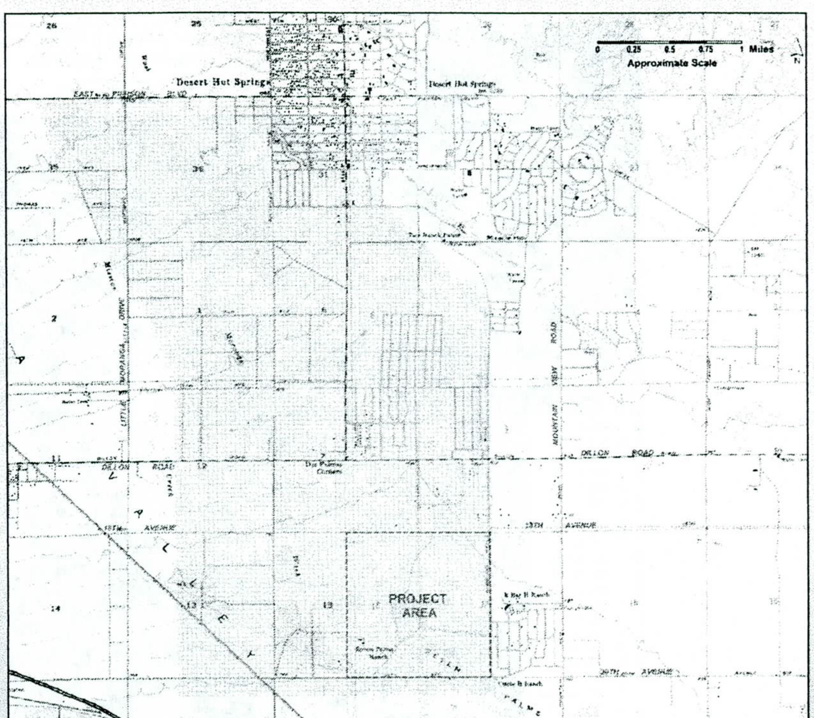
Momentum equations

$$\begin{cases} S_{fx}=S_{ox}-\dfrac{\partial h}{\partial x}-\dfrac{V_x}{g}\dfrac{\partial V_x}{\partial x}-\dfrac{V_y}{g}\dfrac{\partial V_x}{\partial y}-\dfrac{1}{g}\dfrac{\partial V_x}{\partial t} \\ S_{fy}=S_{oy}-\dfrac{\partial h}{\partial y}-\dfrac{V_y}{g}\dfrac{\partial V_y}{\partial y}-\dfrac{V_x}{g}\dfrac{\partial V_y}{\partial x}-\dfrac{1}{g}\dfrac{\partial V_y}{\partial t} \end{cases}$$

FLO-2D Model – Domain Discretization

No. of Grids = 9,146

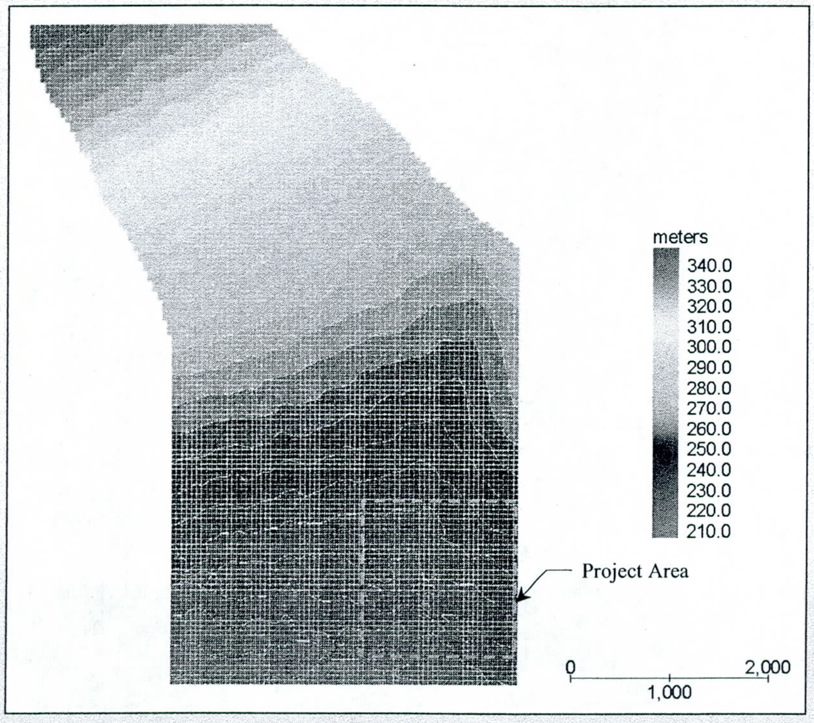
Grid size = 50 x 50 m



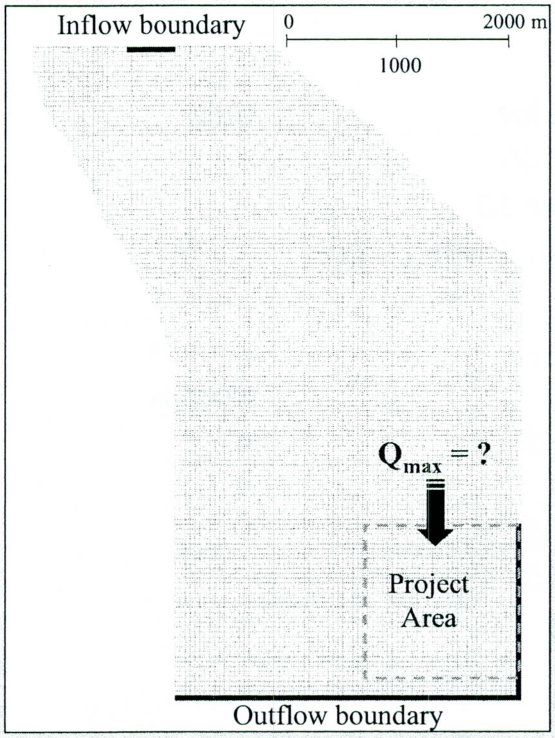
FLO-2D Model Parameters

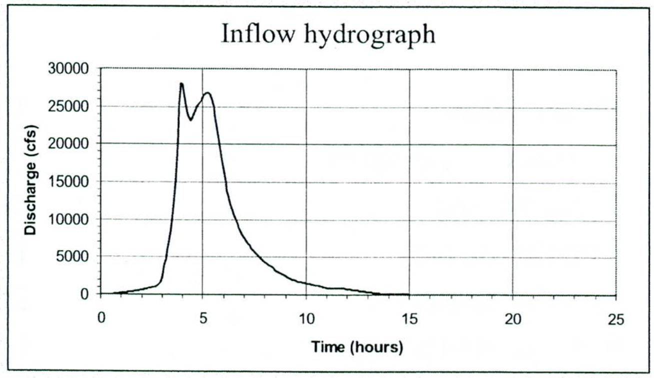
Description	Value	Units
Number of elements	9,146	-
Element size	50 x 50	m
Simulation type	Full dynamic wave	-
Simulation period	25	hours
Minimum time step	0.05	seconds
Maximum time step	45	seconds
Flood plain storage (surface detention)	0.03	m
Change in floodplain depth	30	%
Manning's n	0.05	-
Manning's n for shallow water flow	0.15	-
Area Reduction	10	%

Topographic Elevations

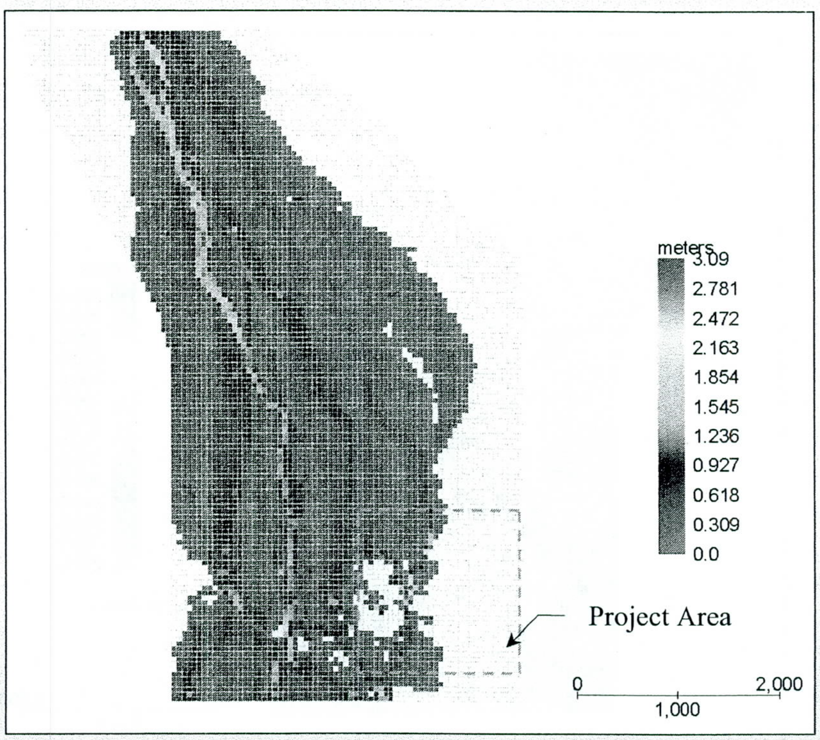


Inflow and Outflow Boundaries

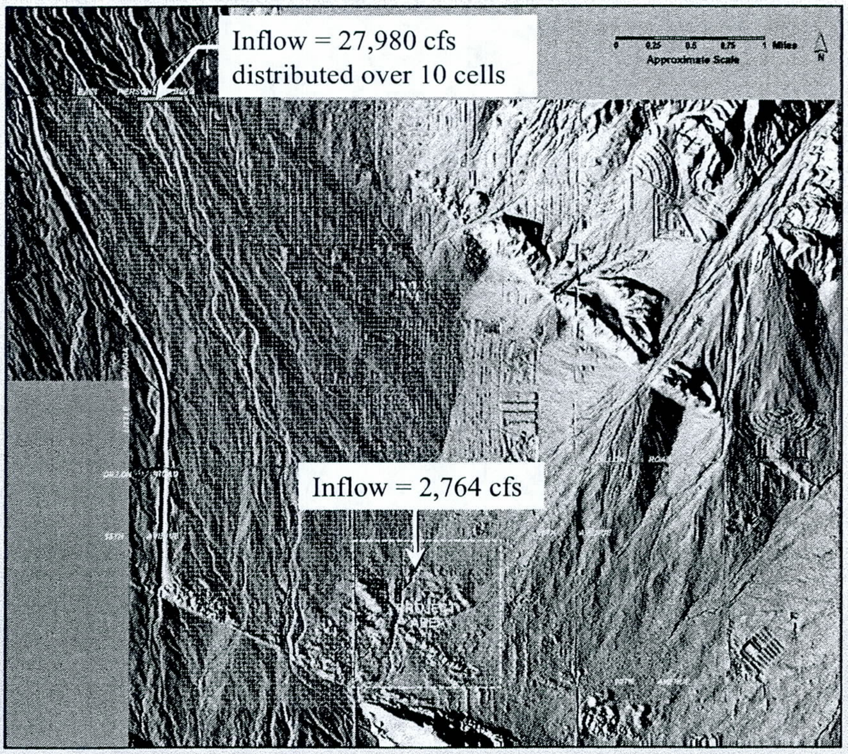




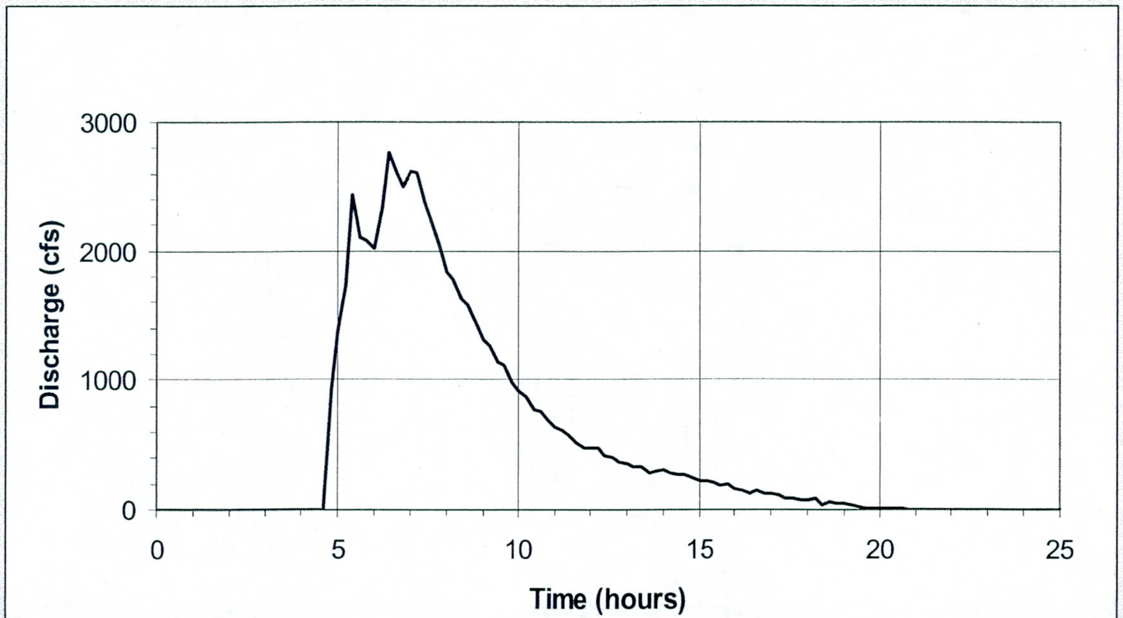
Maximum Flow Depths



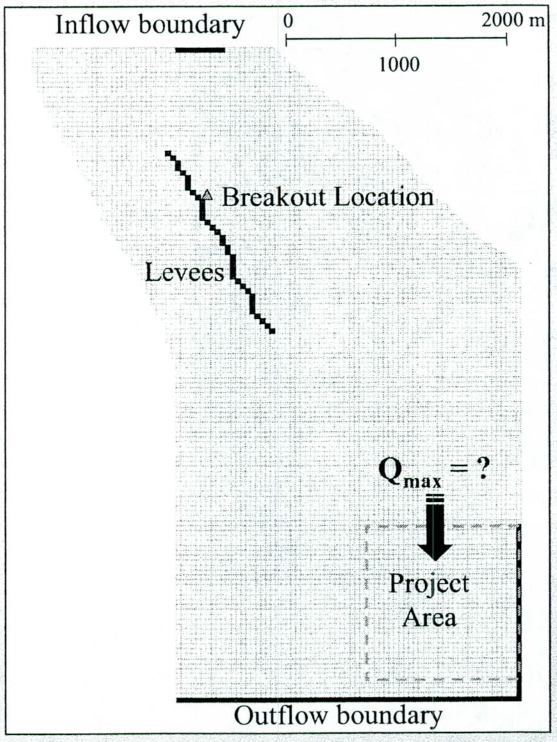
Peak Discharge into Project Area

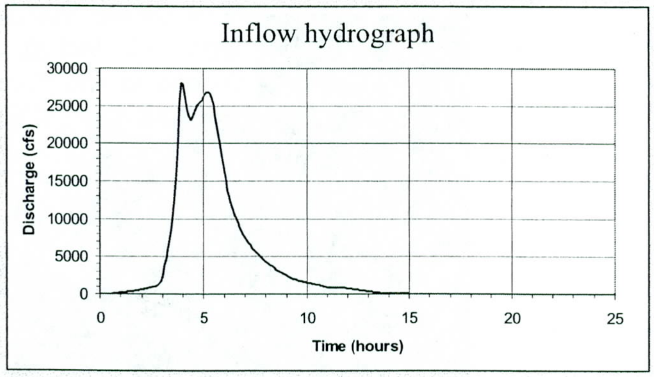


Inflow Hydrograph into Project Area

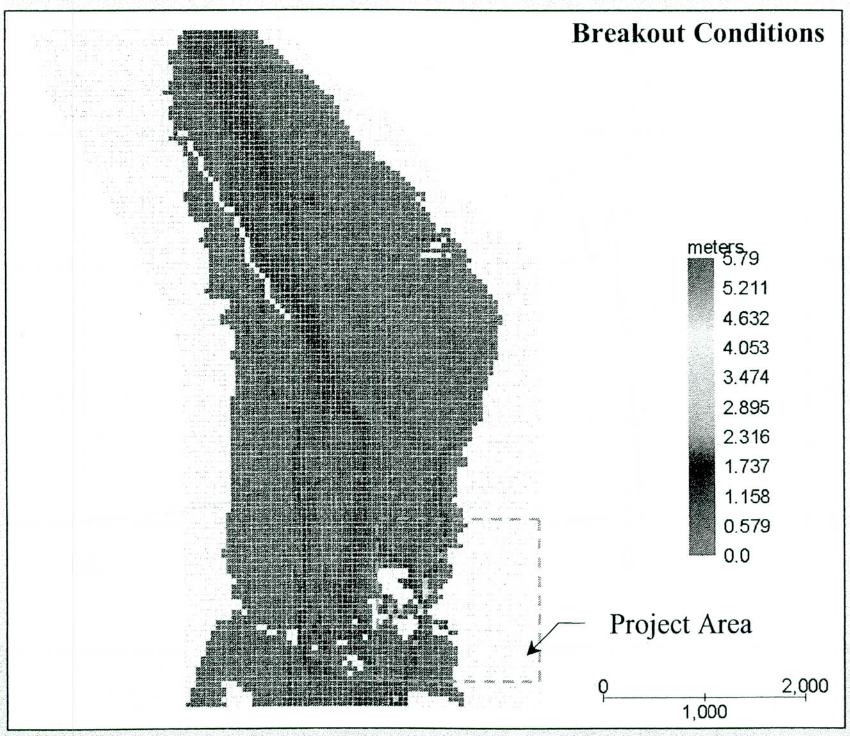


Simulation of Breakout Conditions

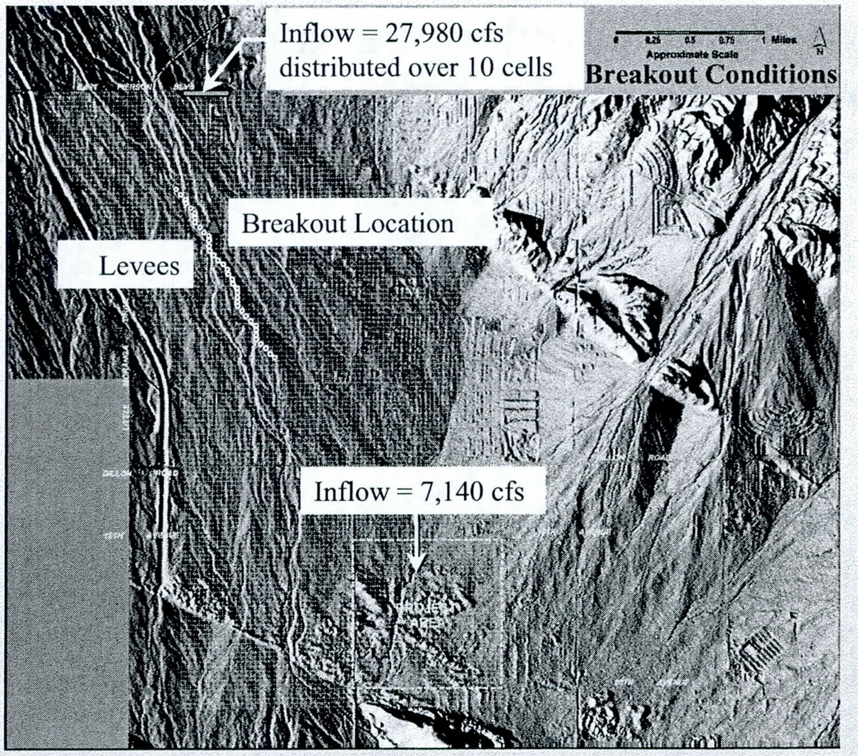




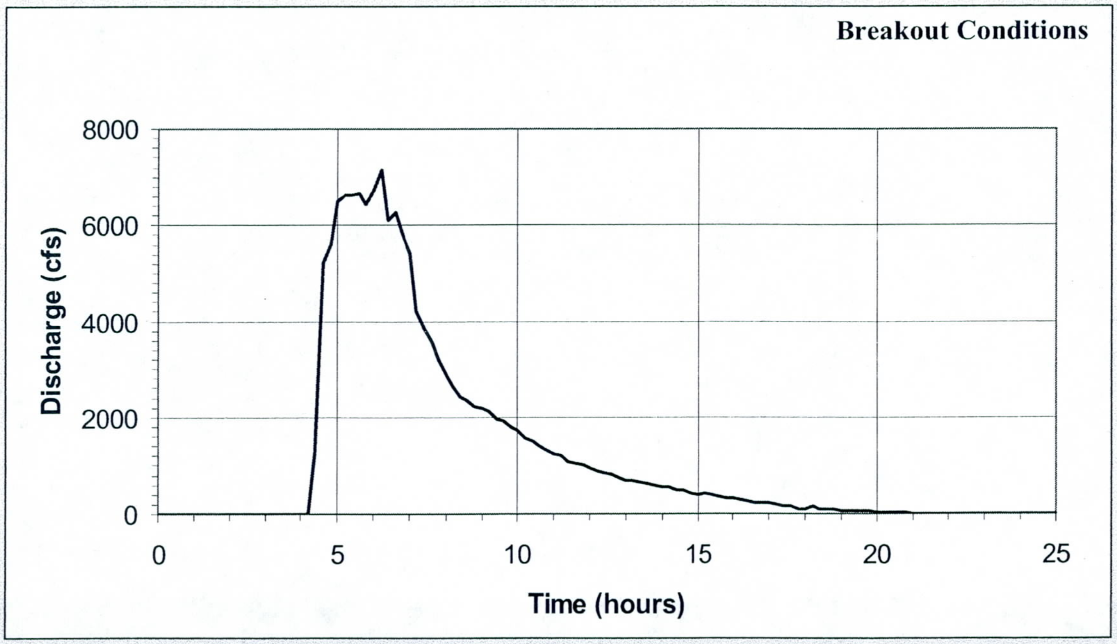
Maximum Flow Depths



Peak Discharge into Project Area



Inflow Hydrograph into Project Area



Conclusions

- Two-dimensional model used to route flood flows in a proposed development
  - Flood inundation patterns
  - Maximum flow depths
  - Determination of peak discharges
- Primary considerations for flood hazard analysis include:
  - Hydrologic Features
  - Historical flooding
  - Topographic features

THE END

Implementing Floodplain Management Measures for Alluvial Fans

Case Study

Presented by:

Bruce M. Phillips

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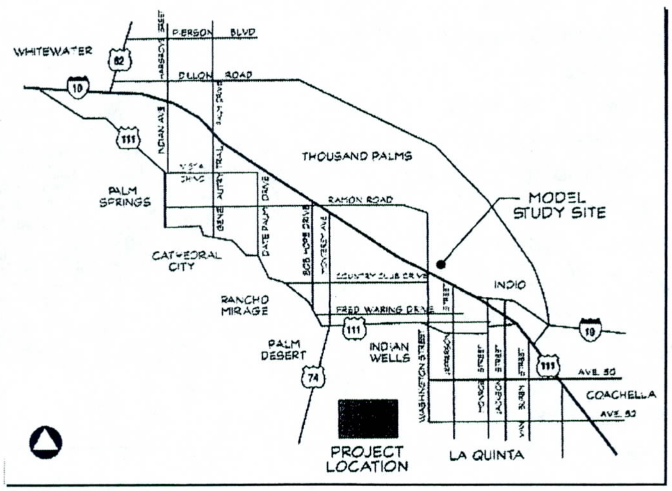
Project Vicinity Map



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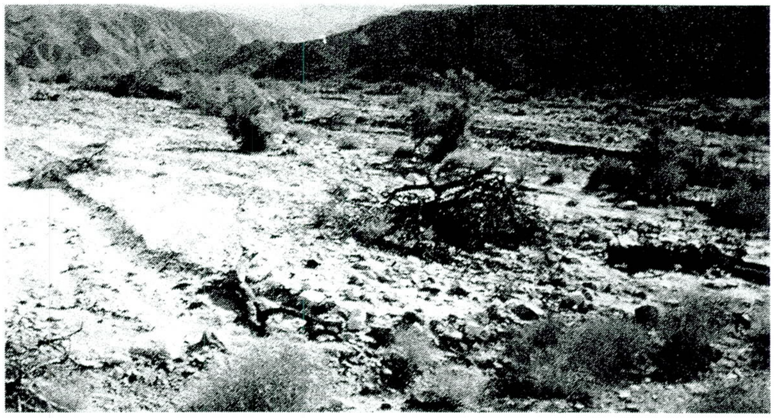
Alluvial Fan

Existing Alluvial Fan – Desert Hydrology



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The Reserve Development Project Location and Description

- Location in both cities of Palm Desert and Indian Wells, CA
- High-End luxury residential golf course development
- 500 acres of land adjacent to Ironwood Country Club
- Situated entirely on the active deep canyon alluvial fan
- Proposed 18-hole championship golf course
- 250 residential sites
- Encompass portion of living desert regional debris basin

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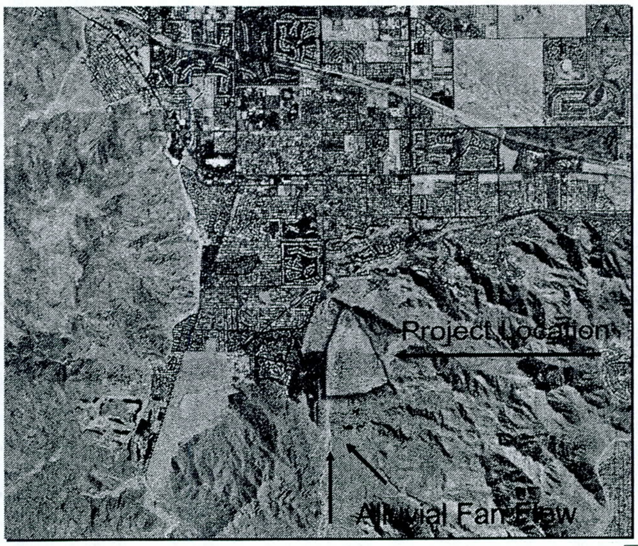
Aerial View - Pre Construction 1996



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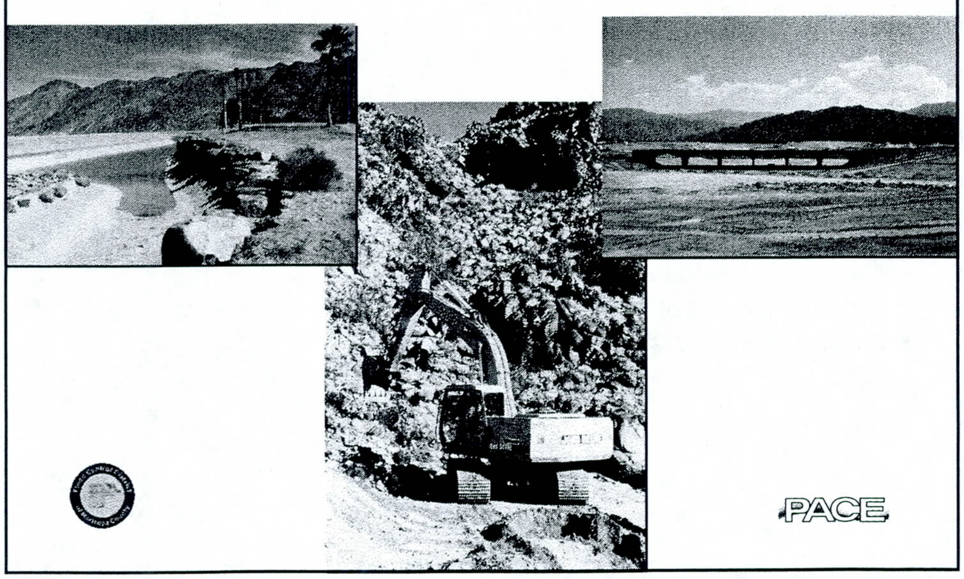
Project Pre-Construction



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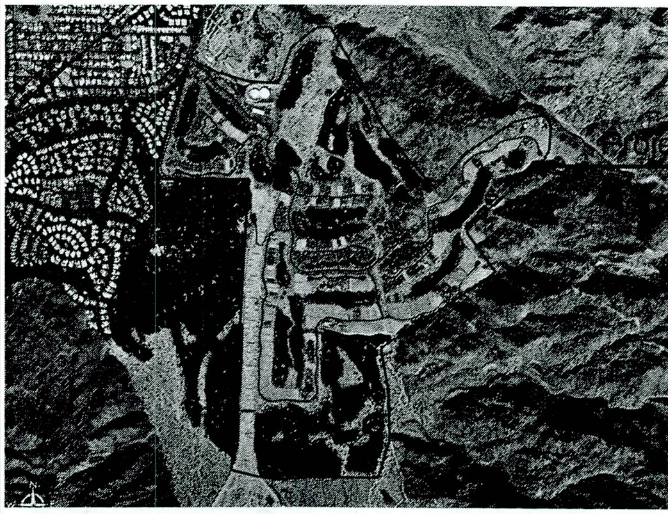
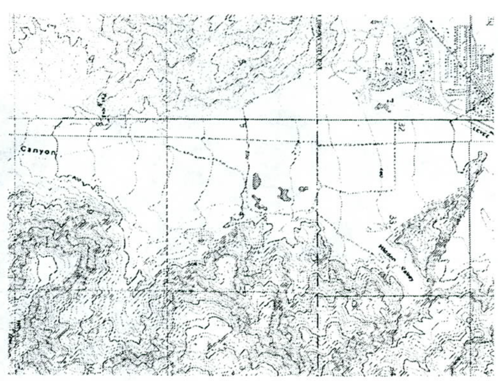
Aerial View - Post Construction 2005



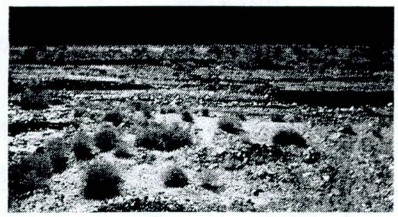
Flood Control Design Constraints

- Existing Flood Hazards
- Alluvial Fan hydraulics
- Debris Flow Quantities
- Environmental Regulatory Agencies
- Jurisdictional Agencies (CVWD and Cities)
- University of California Ecological Reserve
- CVWD Regional Debris Basin
- Existing Ironwood Golf Course
- FEMA



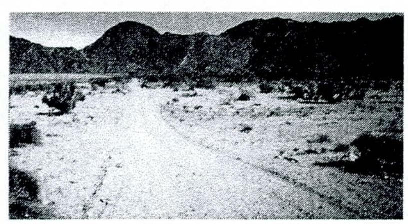
Technical Engineering Design Program

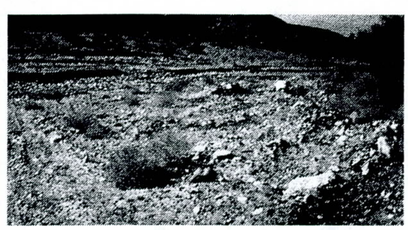
- Watershed and Hydrology Analysis
- Agency "Pre-design" Concept Approval
- Preliminary Engineering Design Report
  - Alluvial Fan Hydraulics
  - Sediment Transport Analysis
  - Sediment Yield and Delivery
  - Channel Hydraulics
  - Water Surface Profile
  - Grade Control Structure Hydraulics
  - Scour Analysis
  - Channel and Levee Design Requirements
  - Sediment Routing Model (HEC-6)
- Final Engineering Design
- Improvement Plans
- CLOMR
- Physical Model Study

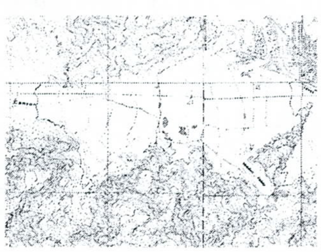


Existing Floodplain Description

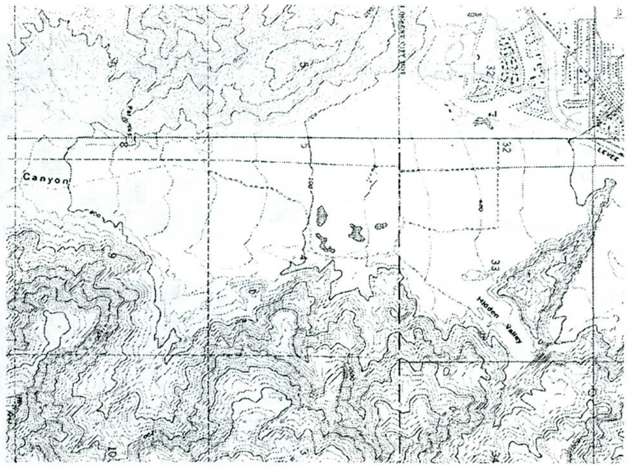
- FEMA designated Flood Hazard Zone "A"
- Hydraulically Steep - Average Slope of the Fan is $S_O = 0.030$
- Project boundary is located 12,000 Feet downstream from fan Apex
- Alluvial Fan is Primary Physiographic Landform
- Two Primary Historical Entrenchments Traversing Project
- Floodplain Dominated by Alluvial Fan Hydraulics



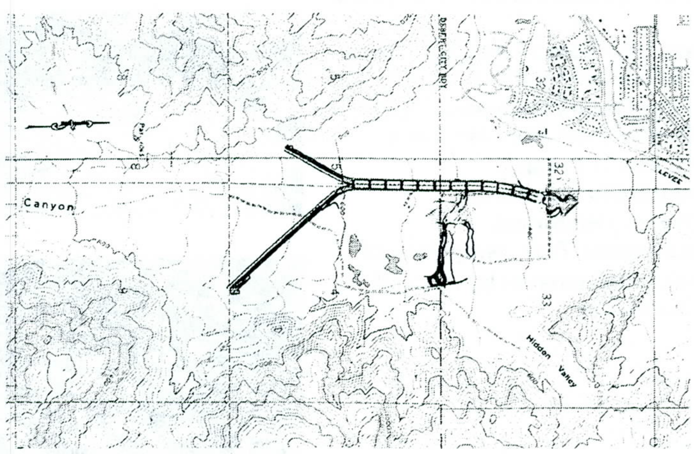




Project Location Map



Proposed Flood Protection



Existing Flood Control Improvements

Living Desert Regional Debris Basin

- Constructed in 1980
- Operated by Coachella Valley Water District
- Discharged to Vintage Country Club Downstream
- Element of the Regional Flood Protection System
- 93 acre basin area
- 321,600 cubic yards deposition from 1980 to 1995
- Maximum design debris storage volume 600,000 cubic yards
- Excavated into Alluvial Fan 5:1 slopes
- Design as entrenched pit with a wedge geometry
- Uncontrolled flow intercepted by mountain range and constructed levee
- Uncontrolled 200-foot wide spillway in solid rock

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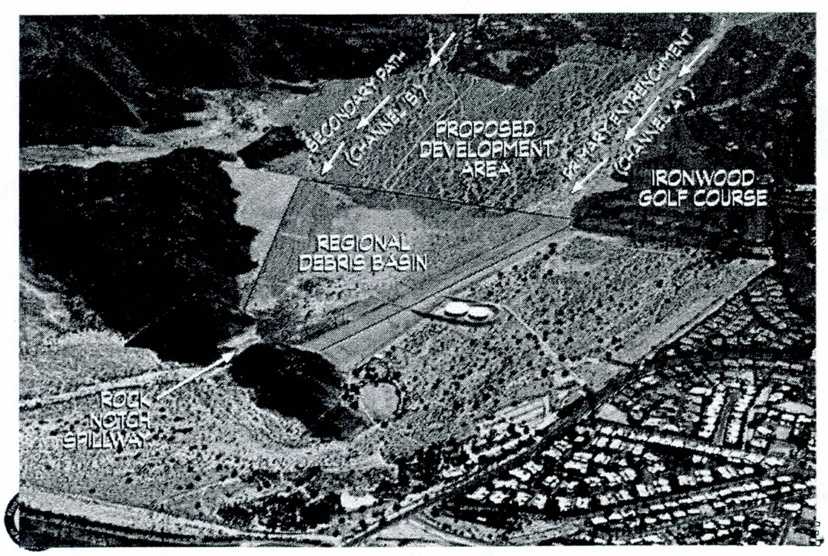
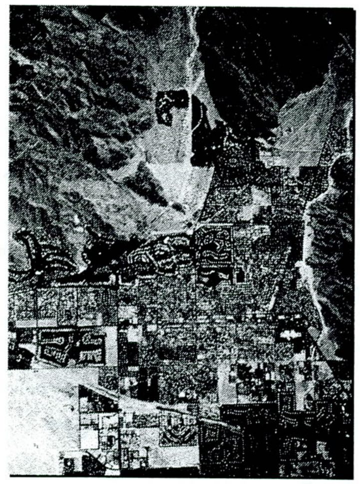
Aerial Schematic of Development Area



Existing Flood Control Improvements

Ironwood Golf Course Levee

- Constructed in 1983 approximately 1,800 feet in length
- Training dike to protect the ironwood golf course
- Concrete Slope Lined Earthen Embankment 11-feet high
- Average total lining height 21-feet



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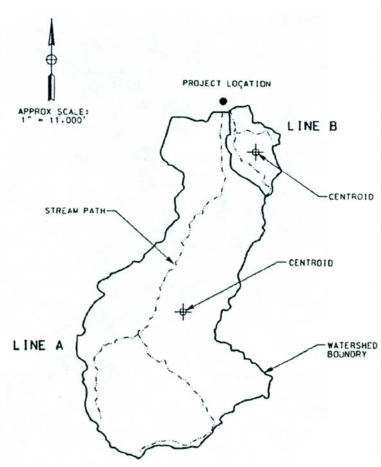
Watershed Description

- 46.4 square mile deep Canyon Watershed Tributary to living desert debris basin
- Deep canyon is tributary to Whitewater River
- Two independent drainage basins tributary to project boundary (A & B)
- Extremely rugged mountains and steep rocky canyons of Santa Rosa mountains
- Elevation variation extremes from 8,716 feet to 460 feet at project
- 17.7 miles watershed length
- Average slope 9%



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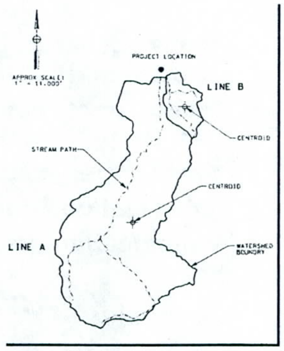
Watershed Hydrology Investigation

- Ungaged watershed
- Design storm – standard project flood (SPF)
- 6-hour 1939 Indio storm (6.45 inches)
- HEC – 1 synthetic hydrographs
- Bulking factor of 1.2 applied to clear water flows
- Bulking factors based on adjacent dead Indian wash debris basin ACOE study



FREQUENCY	CHANNEL "A" (42.7 sq. mi.)	CHANNEL "B" (3.7 sq. mi.)	COMBINED (46.4 sq. mi.)
SPF	35,570 cfs	5,360 cfs	36,950 cfs
100-year	14,700 cfs	2,930 cfs	16,400 cfs

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Description of Alluvial Fan Flood Protection Program

Overview

- Application of "Whole Fan" control measures
- Address both "Hydraulic" and "Sediment Transport" issues
  - Interception
  - Conveyance
  - Dispersion or Outlet

Facilities

- 3,890 feet Transverse levee - Earthen embankment 18-feet high with concrete slope lining
- 2,100 feet ironwood levee rehabilitation
  - Extend cutoff lining and top of levee
- 5,200 feet main conveyance channel
  - Incised trapezoidal section
  - 220 feet wide
  - 12-feet depth
  - Concrete slope lining (1.5:1) with 9 foot cutoffs
  - Landscaping earthen fill

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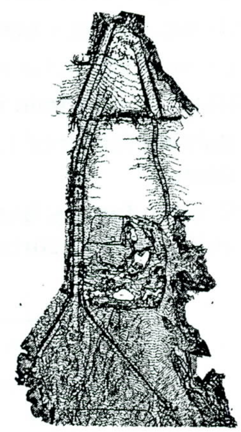
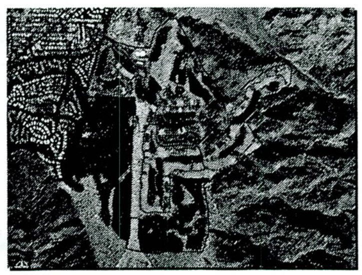
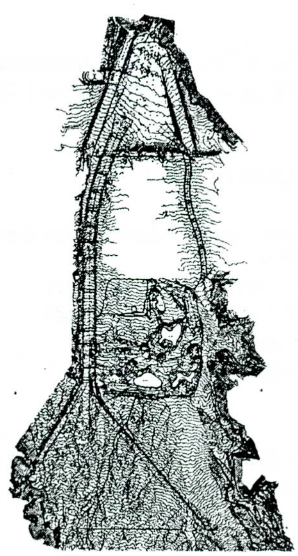
Description of Channelization Facilities

- Twelve concrete grade control structures (Net Drop 6.5 feet)
- Plunge-pool channel outlet structure (Net Drop 18 feet)
- Small entrenched sediment basin
- 1,400 feet golf course channel
- Water feature grade control



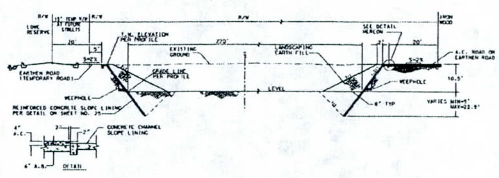


Proposed Reserve Development With Flood Control Improvements



Channel Design Criteria Requirements

- Channel depth
  - Satisfy FEMA and CVWD flood protection requirements
  - Maximum and minimum manning coefficient
  - Hydraulic capacity analysis “bank-full”
  - SPF depth + 1/2 dune height + freeboard + superelevation
  - Or 100-year critical depth applied to above relationship
- Channel toe protection depth
  - Bedform + low-flow incisement + contraction scour + general scour + bend scour



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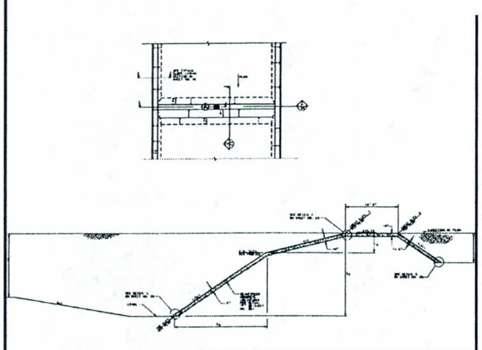
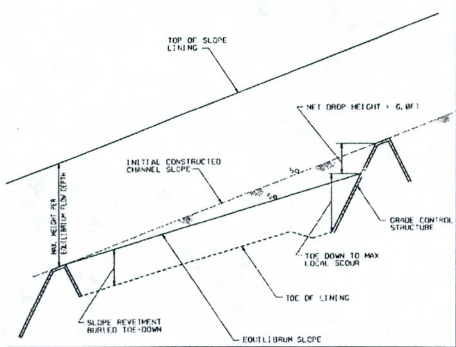
Typical Channel Section





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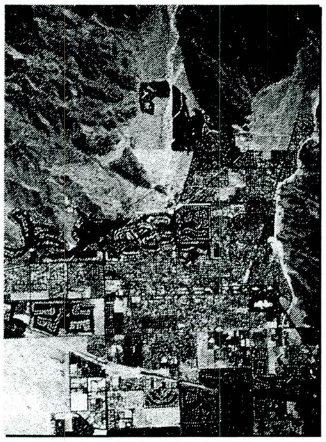
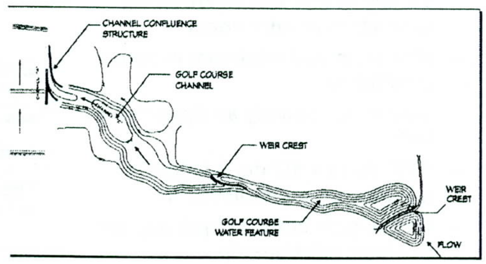
Golf Course Diversion Channel Concept and Debris Basin





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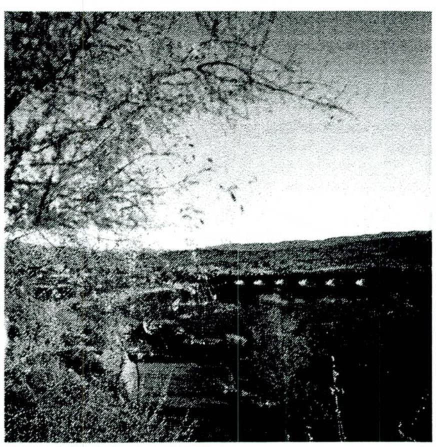
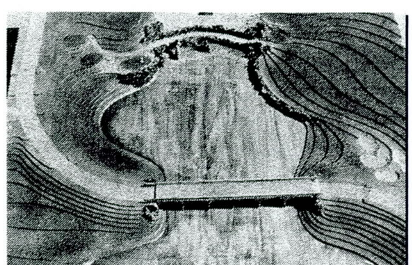
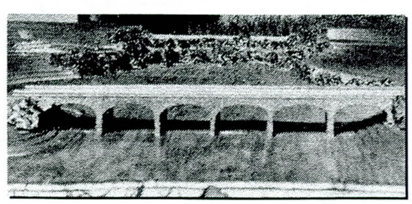
Plunge Pool Channel Outlet With Aesthetic Treatment







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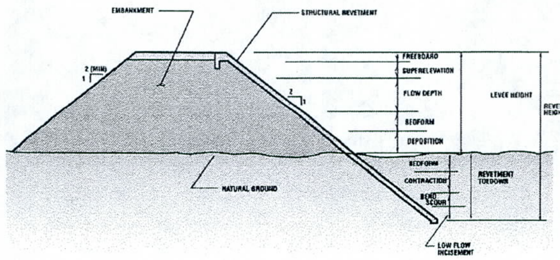
Alluvial Fan Design Requirements

- Revetment height
  - SPF depth + deposition + superelevation + 0.5 dune height
  - Or 100-year critical depth applied to above relation
- Revetment cutoff depth
- Deposition from direct impingement of flow path on levee



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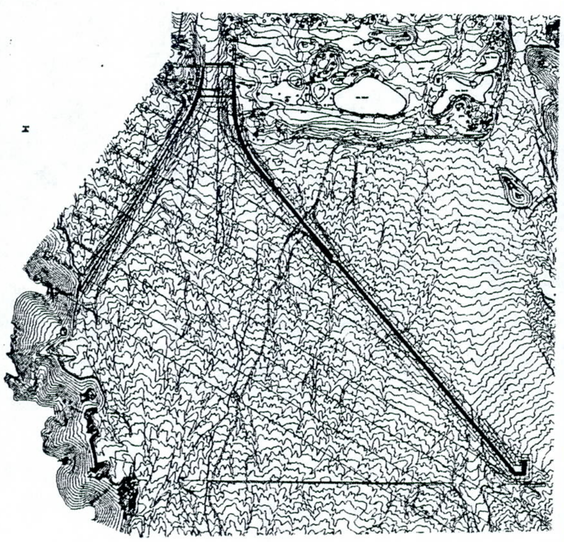
Alluvial Fan Traverse Levee System



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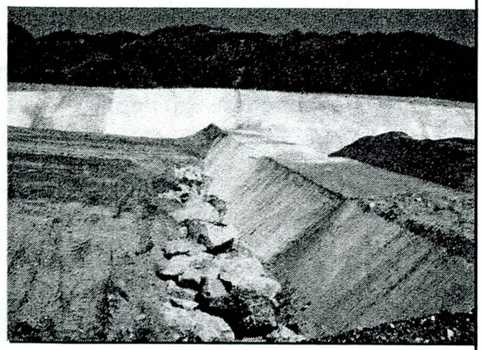

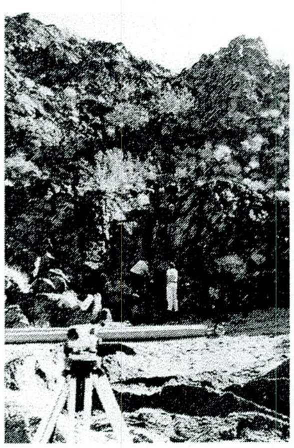

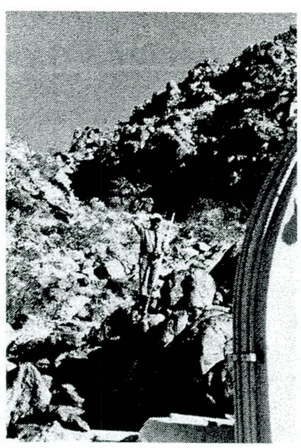

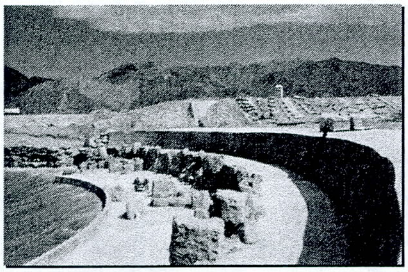
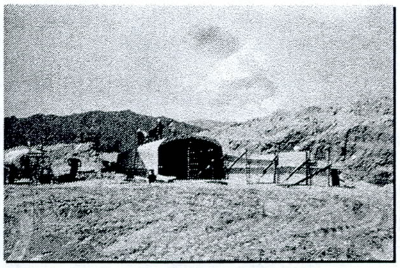
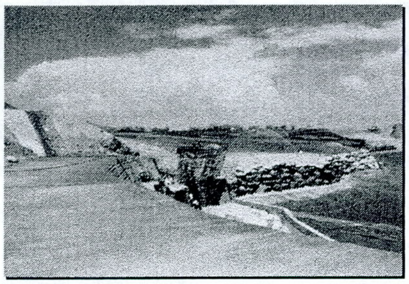
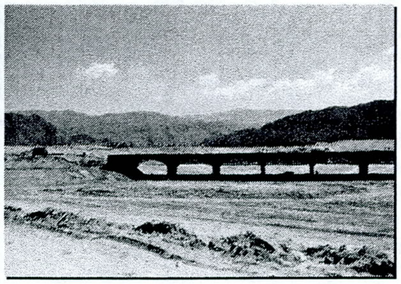
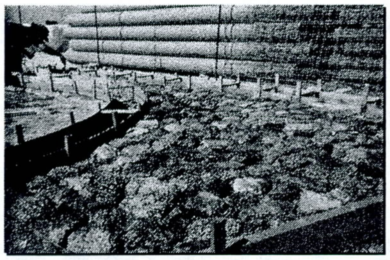

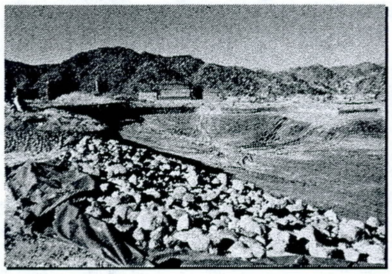
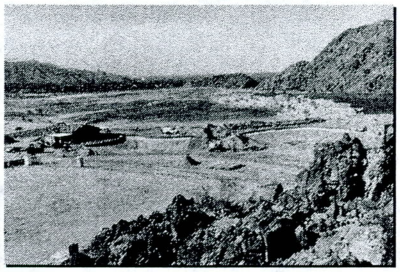

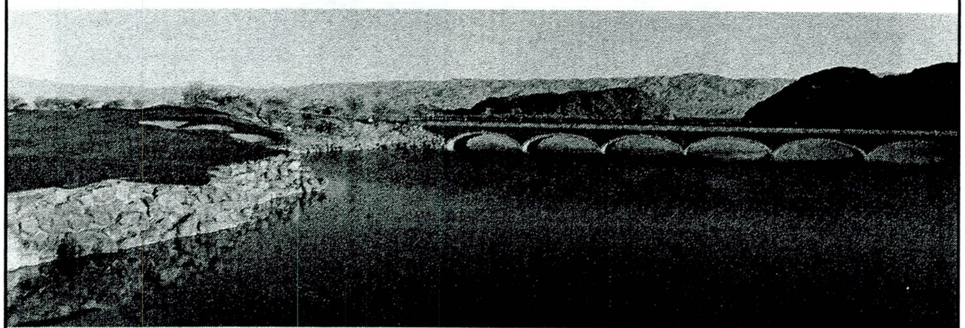

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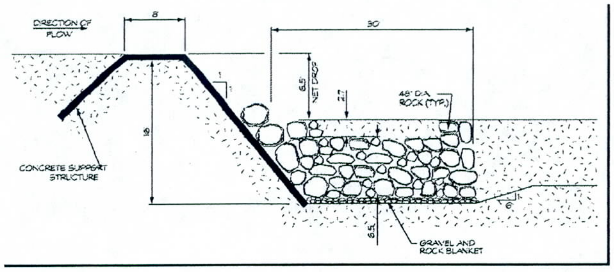
Physical Model Study Objective

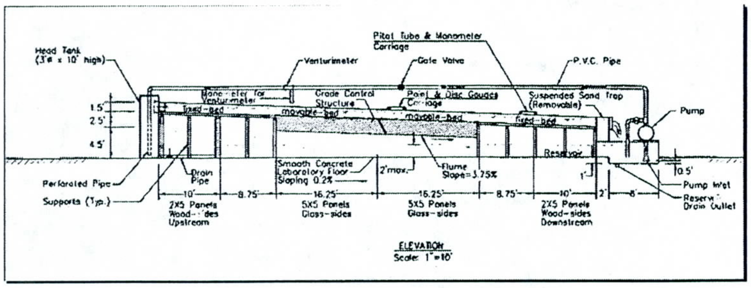
- Evaluate the modification to the Erosion patterns with alternative design of grade control structures
- Investigate the hydraulics of different grade control geometric configurations
- Determine the effect to the local scour from an artificial horizontal armor blanket



PACE

Model Description

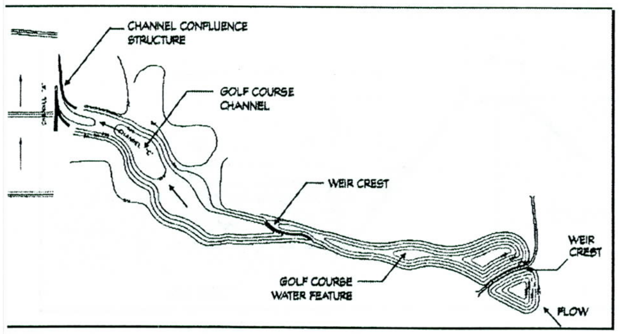
- Model construction and operated by PACE
- Experimental setup located outdoors under protected covered carport in Palm Desert
- 80-foot long and 24" wide flume



PACE

Model Description

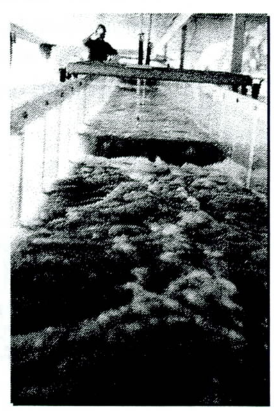
- Flume height 42"
- 40-foot segment with plexiglass side
- Constructed ring-embankment storage reservoir
- 2-10 horsepower pumps (1,800 gpm at 16-ft head)
- Sand bed material 60% medium to coarse sand, 20% pea gravel. 20% medium gravel

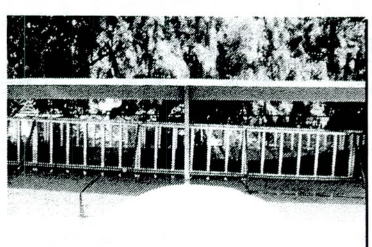


PACE

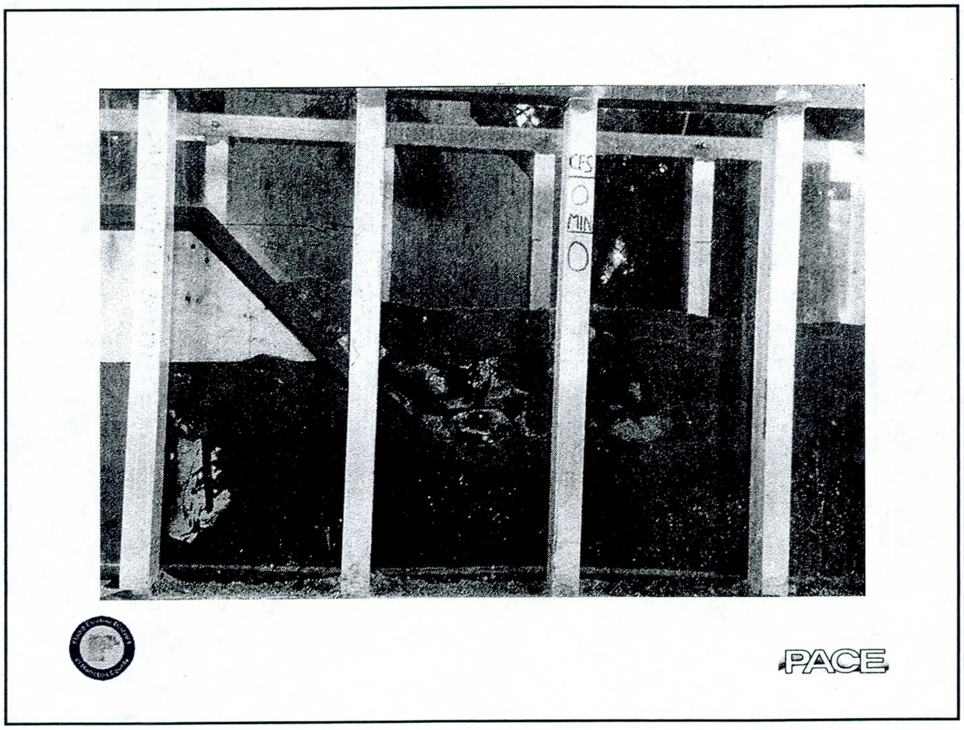
Model Scale to Prototype

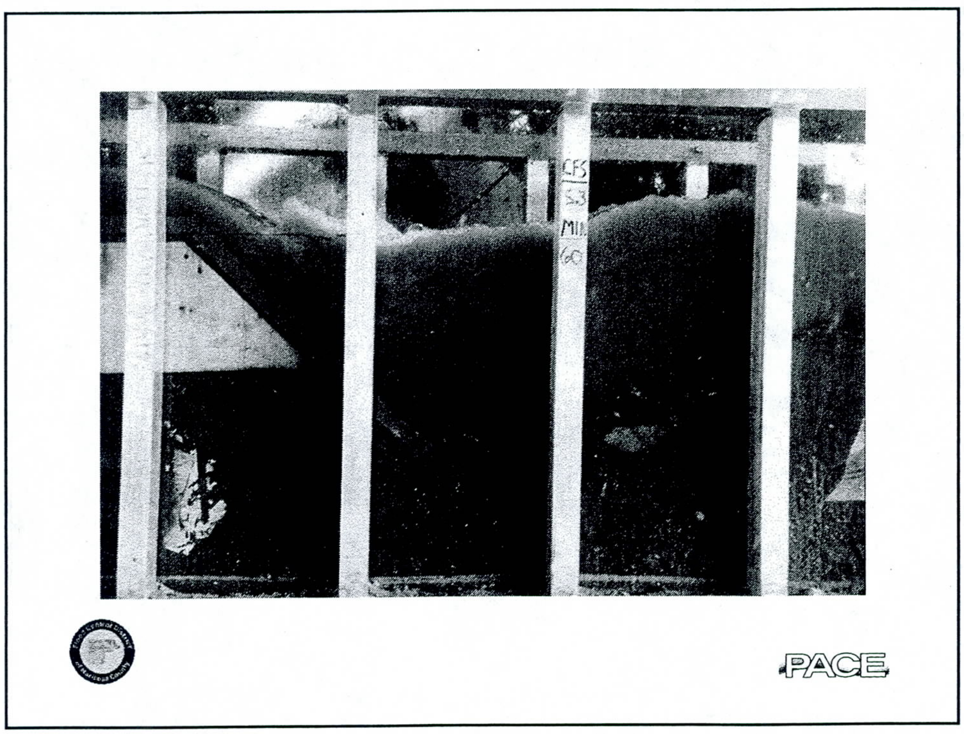
- Scales selected to provide the minimum dimensions which erosion features could be adequately observed and measured
- Linear scale of Lr = 1:16
- Discharge sable Qr = 1:1,024
- Time scale Tr = 1:16
- Velocity scale Vr = 1:16
- Selection of model sand-bed material





PACE


CFS
0
MIN
0
PACE

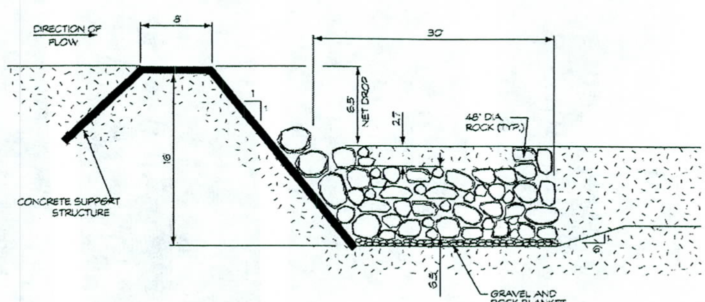

CFS
53
MIN
60
PACE

Prototype - Model Data

DESCRIPTION	PROTOTYPE	MODEL
Model Portion of Channel Width	32 feet	2.0 feet
SPF Discharge	5,380 cfs	5.25 cfs
Structure Net Invert Elevation Drop	6.5 feet	4.88 inches
Modeled portion of The Hydrograph	480 minutes	120 minutes

PACE

Model Study Configuration



PACE

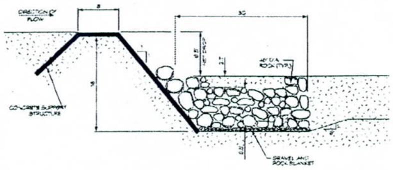
Testing Program Results

EXPERIMENT DATE	DISCHARGE (PROTOTYPE)[1]	MODEL BLANKET CONFIGURATION[2]	ACTUAL PROTOTYPE ROCK LENGTH	MODEL MAX. SCOUR DEPTH MEASURED
Nov. 21, 1996	100-year	37.5" length Rip-Rap	50 feet	9.0 inches [3]
Dec. 4, 1996	SPF	19.5" length Rip-Rap	26 feet	7.75 inches
Dec. 4, 1996	SPF	none	none	21 inches (flume bottom)
Dec. 11, 1996	SPF	13.5" length Rip-Rap	18 feet	Failed (flume bottom)
Jan. 3, 1997	SPF	23.5" length Rip-Rap	31.3 feet	5.75 inches
Jan. 8, 1997	SPF	19.5" length Rip-Rap	26 feet	Failed (flume bottom)

PACE

Recommendation and Conclusions From Model Study Investigation

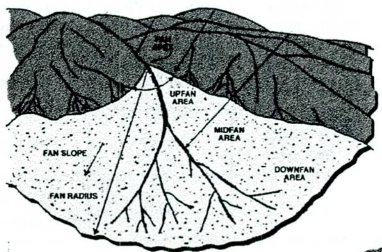
- Rip-rap armor blanket provided downstream from toe of grade control structure
- Length of armor blanket a minimum of 30-feet
- Blanket should be configured so it resembles shape of the scour hole
- Thickness of the armor blanket should be a minimum of 6.5-feet with 48" diameter rock
- Geometry of the rock blanket is important and should provide a 3-foot high thickened sill
- The minimum vertical height of the concrete lining for the chute is 16-feet compared to the original 24-feet from empirical equations

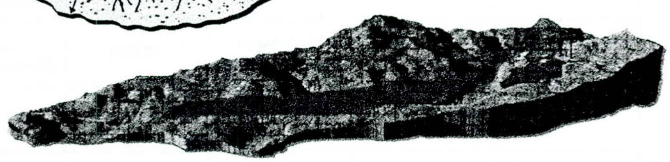


PACE

Implementing Floodplain Management Measures for Alluvial Fans

Case Study





Presented by:

Bruce M. Phillips

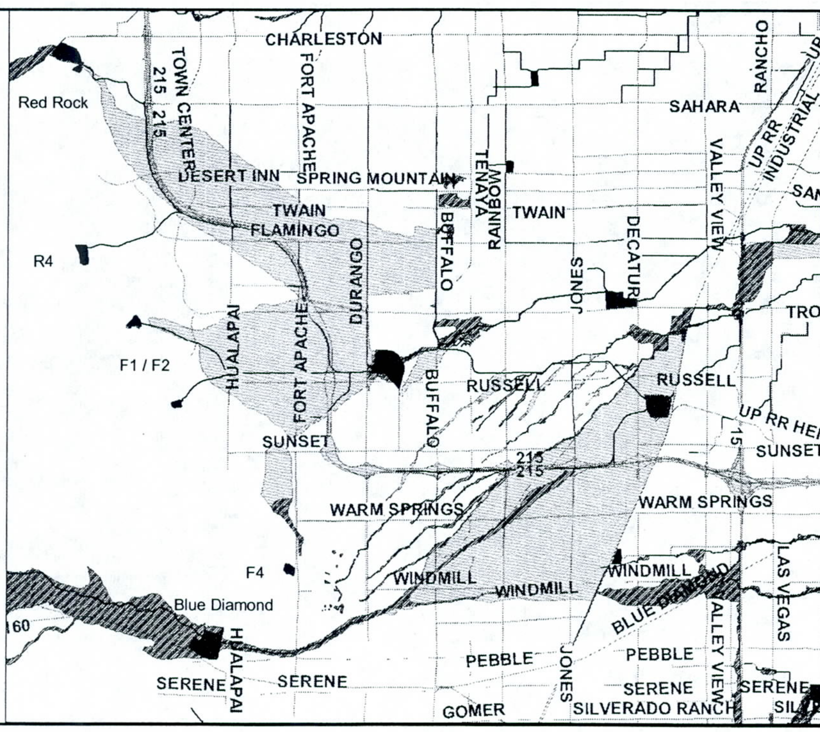
PACE

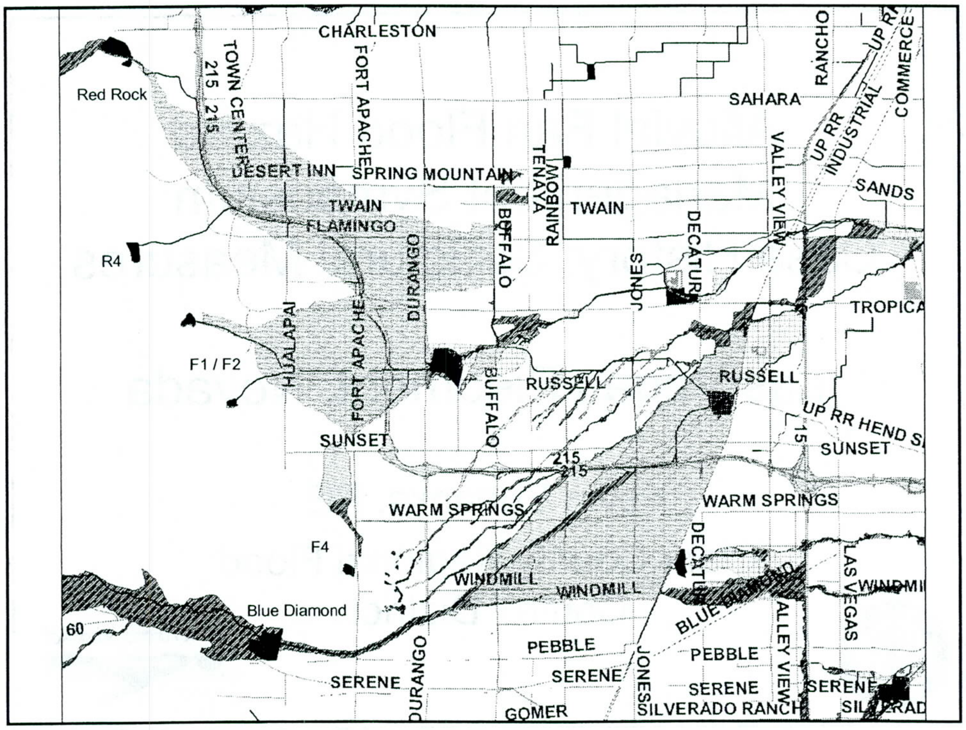
Alluvial Fan Flood Hazard Management Symposium
Case History: Structural Measures

Las Vegas Piedmont, Nevada

Kevin Eubanks, PE

Clark County Regional Flood Control District





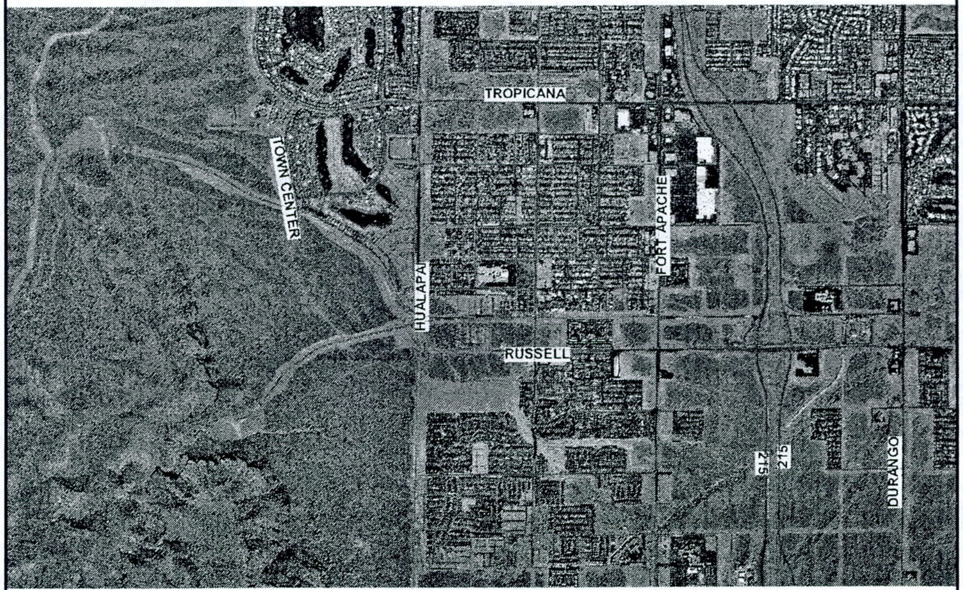
Red Rock Fan 1996

Red Rock Fan 1996

Red Rock Fan 2004

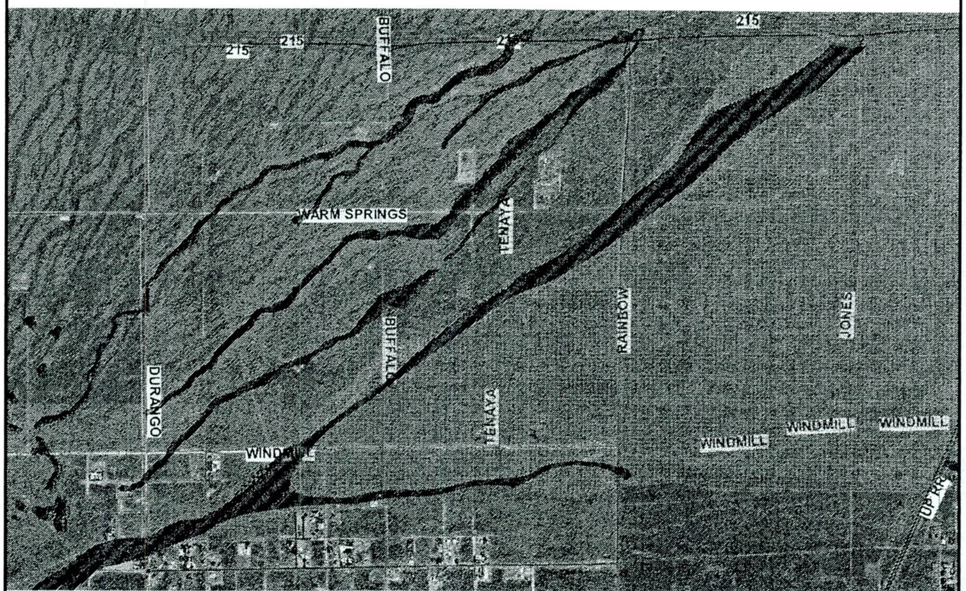
Flamingo Fan 1996

Flamingo Fan 1996

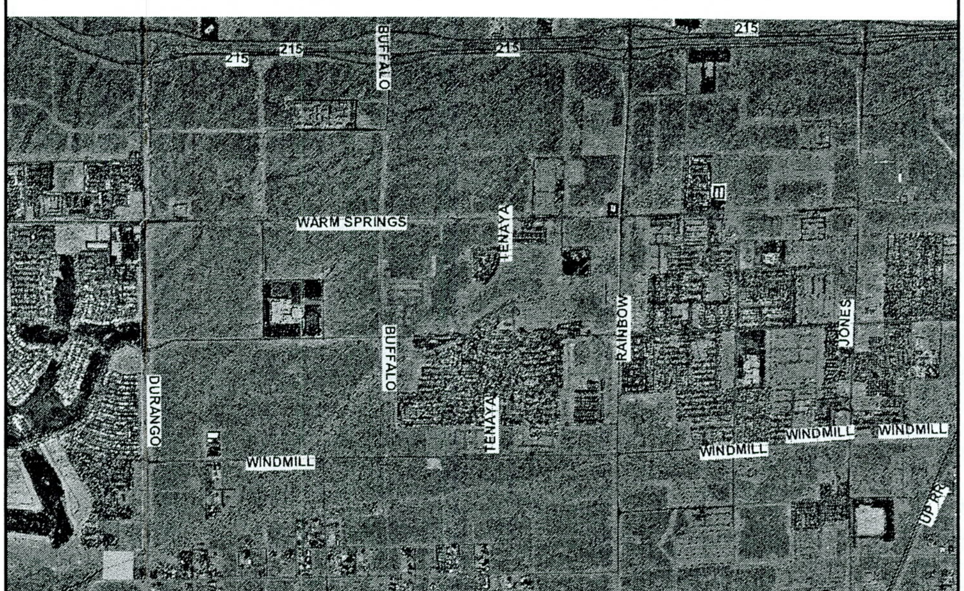


Flamingo Fan 2004

Blue Diamond Fan 1996



Blue Diamond Fan 1996



Blue Diamond Fan 2004

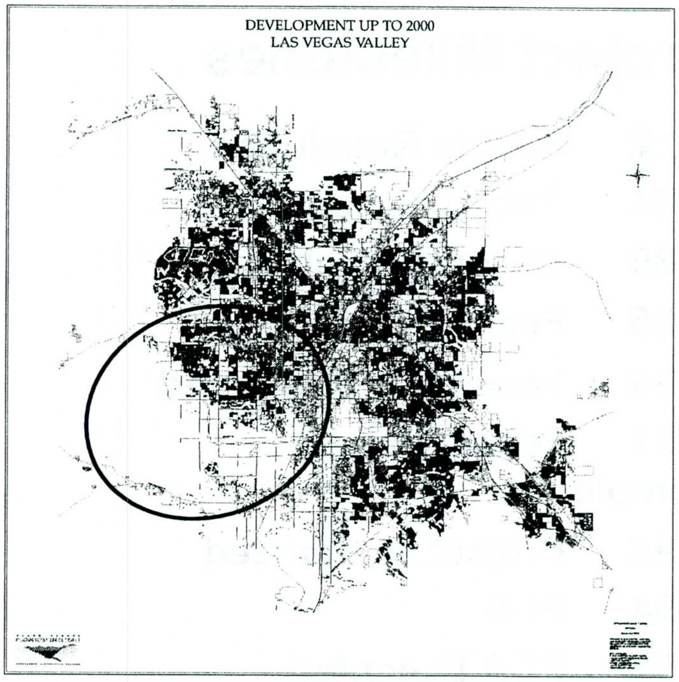
Project Milestones

- 1982 Senate Resolution
- 1984 Recon Funded
- 1985 Recon Completed
- 1985 Feasibility Started
- 1988 Feasibility Rescoped
- 1991 Feasibility Completed
- 1992 Project Authorized
- 1994 PED
- 1995 PCA Executed

TROPICANA/FLAMINGO

POPULATION GROWTH

- ***LAS VEGAS'S POPULATION GROWTH HAS BEEN EXPLOSIVE.***
  - *< 100,000 in 1960's to > 1,800,000 IN 2005*
  - *IN THE 1980'S, POPULATION FILLED EAST OF LAS VEGAS.*
  - *NOW EXPANDING TO THE WEST TO THE BLUE DIAMOND MOUNTAINS.*
- ***AREA BETWEEN THE MOUNTAINS & THE STRIP (I-15) IS AN ALLUVIAL FAN....IT'S KNOWN TO HAVE:***
  - *NO FIXED DRAINAGE PATTERN - EACH RAINFALL RUNOFF PATTERN IS DIFFERENT.*
  - *RUNOFF FLOWS HAPHAZARDLY ACROSS THE FLOOD PLAIN UNTIL IT ENCOUNTERS A CONVENIENT STREAMBED.*
  - *ONCE THE RUNOFF GETS TO A WELL DEFINED STREAMBEDS (LIKE TROPICANA & FLAMINGO WASHES) - IT OVERWHELMS THEM.*
- ***TWO BASIC CHALLENGES TO DESIGN & PROVIDE FLOOD PROTECTION:***
  - *LIMITATIONS TO ENLARGE EXT'G CHANNELS DUE TO URBAN GROWTH EAST OF THE STRIP.*
  - *A CHALLENGE TO COLLECT THE WATER ON THE ALLUVIAL FAN TO DETAIN IT.*



1950
Pop 47,000
1960
Pop 116,000
1970
Pop 262,000
1980
Pop 444,000
1990
Pop 708,000
2000
Pop 1,300,000

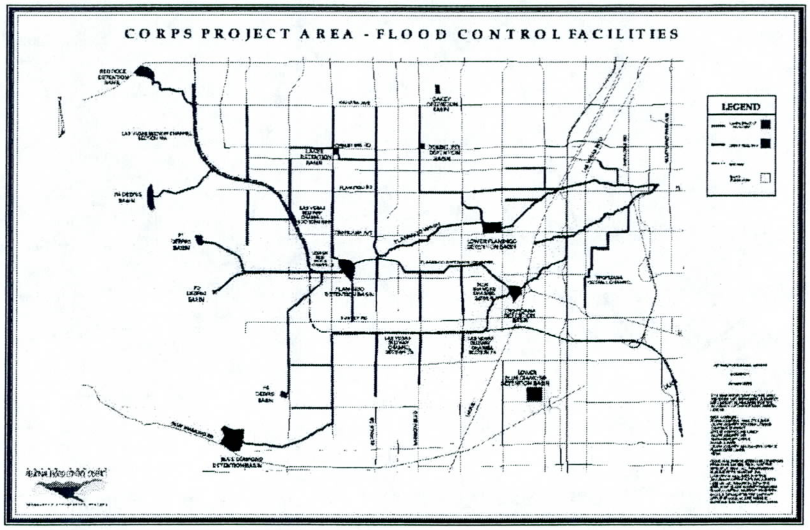
TROPICANA/FLAMINGO

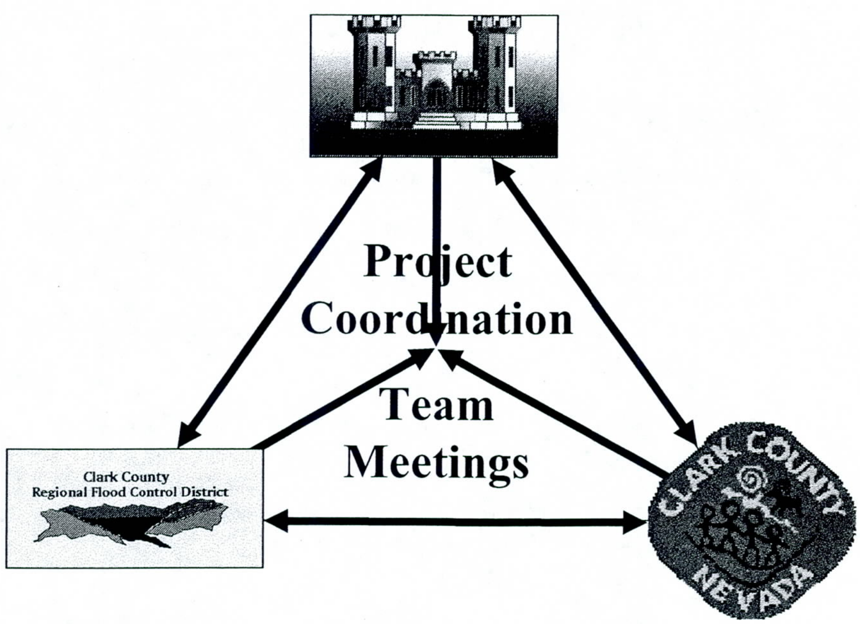
THE PROJECT:

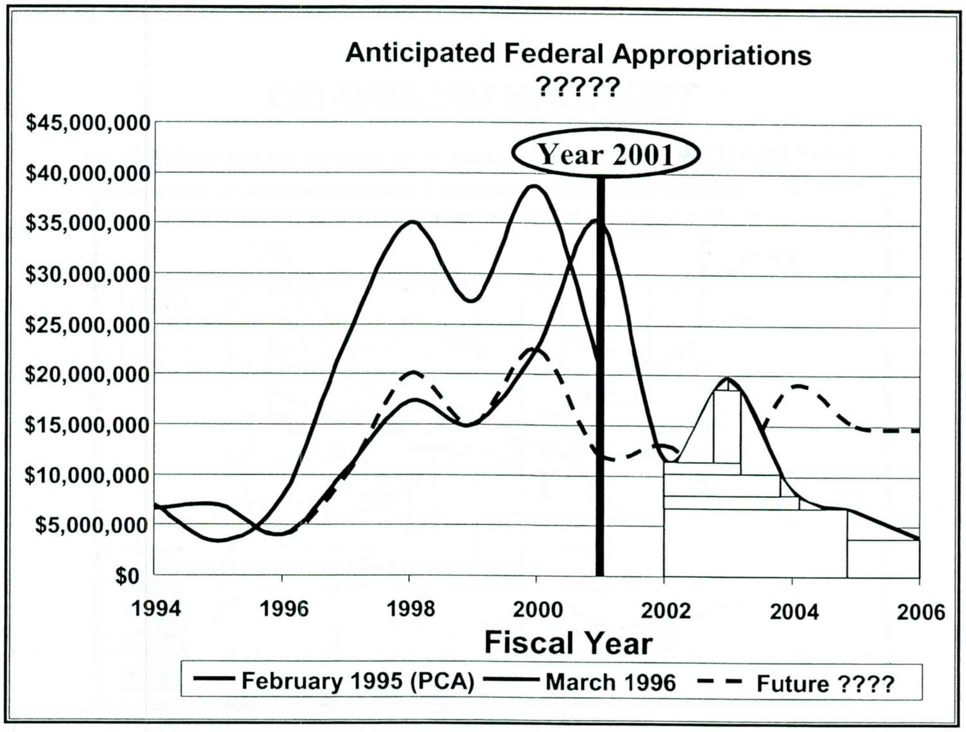
- ***THE PLAN FORMULATION PROCESS*** *~ A PLAN THAT WE DEVELOPED WITH THE SPONSOR'S MASTERPLAN FOR FLOOD CONTROL.*
- ***ESSENTIALLY DESIGNED A DETENTION SYSTEM*** *TO PROVIDE 100 YEAR LEVEL OF PROTECTION BY CAPTURING AND CONTROLLING ALLUVIAL FAN FLOWS ENTERING TROPICANA AND FLAMINGO WASHES ... AND RELEASING THEM THROUGH THE HIGHLY URBANIZED AREAS AT NON-DAMAGING RATES.*

TROPICANA/FLAMINGO

- *CLARK COUNTY'S MASTER FLOOD CONTROL PLAN ADDRESSES THIS ENTIRE BASIN.*







TROPICANA/FLAMINGO

➢ ***MAJOR FLOOD CONTROL FEATURES:***

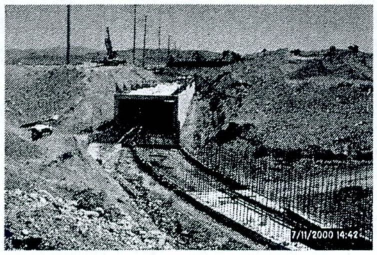
I. ***LATERAL COLLECTOR SYSTEM*** *~ 33 MILE LONG COLLECTION SYSTEM THAT WILL INTERCEPT THE RANDOM ALLUVIAL FAN FLOWS , COLLECT THEM AND DELIVER THEM TO OUR PRIMARY CHANNEL SYSTEM.*

- *THE LATERAL COLLECTORS WERE DESIGNED & CONSTRUCTED BY OUR SPONSOR TO MEET CORPS PERFORMANCE CRITERIA.*
- *THE LATERALS ARE AN "ASSOCIATED NON-FEDERAL COST" (100 % NON-FED); BUT ARE AN INTEGRAL PART OF OUR PROJECT .*
- *THE LATERALS DELIVER THE FLOWS TO THE SECOND MAJOR FEATURE.....*

TROPICANA/FLAMINGO

II. ***THE PRIMARY CHANNEL SYSTEM'S*** *TOTAL LENGTH IS ABOUT 28 MILES.*

- *THEY WILL BE ENTRENCHED, CONCRETE CHANNELS CARRYING BETWEEN 2,000 AND 6,000 CFS (AS WE MOVE DOWNSLOPE AND PICK UP MORE LATERAL FLOWS, THE PRIMARY CHANNEL FLOWS INCREASE).*
- *THE PRIMARIES ARE THE ARTERIES THAT LINK THE WHOLE SYSTEM TOGETHER.*



Red Rock Channel Construction

Beltway Channel Construction Section 211

TROPICANA/FLAMINGO

III. ***DETENTION BASINS ~*** *THEY WILL ACCEPT THE FLOWS FROM THE WATERSHED AND PRIMARY CHANNELS, COLLECT THEM, DETAIN THEM AND THEN RELEASE FLOWS INTO THE EXISTING TROPICANA WASH AT NON-DAMAGING RATES. THE 5 DETENTION BASINS ARE…*

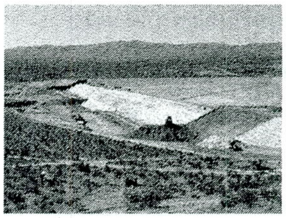
- *RED ROCK, FLAMINGO, BLUE DIAMOND, TROPICANA, R-4.*
- *RED ROCK & FLAMINGO = BUILT BY THE SPONSOR.*

IV. ***DEBRIS BASINS ~*** *THE 3 DEBRIS BASINS WILL TRAP LARGE BED LOADS & PREVENT EROSION DAMAGE TO THE PROJECT. THE DEBRIS BASINS ARE LOCATED ALONG THE BASE OF THE BLUE DIAMOND MOUNTAINS.*

- *F-1 DEBRIS BASIN*
- *F-2 DEBRIS BASIN*
- *F-4 DEBRIS BASIN*

Tropicana Flamingo Flood Control Facilities

TROPICANA FLAMINGO WASHES



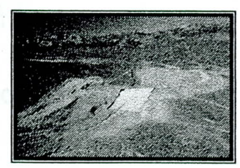
Blue Diamond Detention Basin

Red Rock Detention Basin

Flamingo Detention Basin Labyrinth Spillway

Tropicana Detention Basin

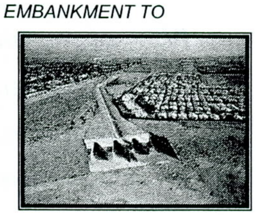
TROPICANA/FLAMINGO



RED ROCK DETENTION BASIN

- BUILT IN 1986 BY THE SPONSORS:

- *RED ROCK DAM WAS MODIFIED TO:*
  - *CONSTRICT THE OUTLET FROM EXISTING 1,420 CFS TO ABOUT 180 CFS.*
  - *THIS REQ'D ADDED STORAGE CAPACITY (ABOUT 300 ACRE-FEET ADDITIONAL). TOTAL STORAGE IS NOW ABOUT 2,200 ACRE-FEET.*
  - *CONSTRUCTED AN AUXILIARY SPILLWAY OVER THE EMBANKMENT TO ACCOMMODATE THE PMF FLOOD (110,000 CFS).*
  - *COMPLETED IN OCTOBER 1996:*



FLAMINGO DETENTION BASIN

- BUILT IN 1992 BY THE SPONSORS:

- *MODIFICATIONS SIMILAR TO RED ROCK:*
  - *CONSTRICT OUTLET FROM 1245 CFS TO 250 CFS.*
  - *EXCAVATE ADDED STORAGE (ABOUT 800 AC-FT) = TOTAL STORAGE ABOUT 1800 ACRE-FEET.*

TROPICANA/FLAMINGO

THE REMAINING 2 DETENTION BASINS ~ BUILT FROM THE GROUND UP:

- ***BLUE DIAMOND DETENTION BASIN:***
    - *AN "ON-LINE" COMPOSITE EARTHEN & RCC EMBANKMENT WITH AN OUTLET OF ABOUT 210 CFS.*

- ***TROPICANA DETENTION BASIN***
    - *THE MOST DOWNSTREAM BASIN OF OUR PROJECT.*
    - *WILL ACCEPT TOTAL SYSTEM FLOWS (ABOUT 4,500 CFS), DETAIN & RELEASE INTO THE EXT'G DOWNSTREAM CHANNEL @ 500 CFS.*
    - *WILL REQUIRE SOME DOWNSTREAM CHANNEL STABILIZERS TO PREVENT EROSION.*
    - *WE AWARDED THE CONSTRUCTION CONTRACT FOR TROPICANA DAM IN SEPT 1996 AND COMPLETED CONSTRUCTION IN NOV 1997 (14 MONTHS).*

TROPICANA/FLAMINGO

DESERT TORTOISE:

- *ANOTHER FEATURE OF OUR PROJECT IS ENVIRONMENTAL MITIGATION.*
- *INCLUDES PARTICIPATION IN THE HABITAT CONSERVATION PLAN FOR THE THREATENED DESERT TORTOISE.*
- *ALSO PROVIDES FOR RE-VEGETATION OF NATIVE PLANT SPECIES.*
- *ALSO PROVIDES FOR A MONITORING PROGRAM THROUGHOUT OUR EXPLORATION AND CONSTRUCTION PERIODS TO ASSURE COMPLIANCE WITH OUR EIS.*

TROPICANA/FLAMINGO

PROJECT COSTS:

- ***TOTAL COST = $284 MILLON**.*
  - ***FEDERAL COST = $210 MILLION.***
    - *INCLUDES 50% SHARE OF RECREATION COST.*
  - ***NON-FED COST = $67.5 MILLION***
    - *INCLUDES APPROX. $10 MILLION IN SECTION 104 CREDIT.*
    - *DOES NOT INCLUDE COST OF LATERAL COLLECTOR SYSTEM (ABOUT $19 MILLION).*
  - ***RECREATION COST = $6.5 MILLION** [POTENTIAL SPONSOR COST]*
  - *BASED ON M-CACES; INCLUDES INFLATION.*

TROPICANA/FLAMINGO

OVERALL SCHEDULE:

- *Began PED in January 1992.*
- *Began first construction contract (Red Rock Dam) In Sept. 95'.*
- *Will complete construction in Oct. 2005.*

CURRENT STATUS (as of Dec. 04')

- *The following projects are completed:*
  - *Red Rock Detention Basin, Lower Red Rock Channel Complex, Tropicana Detention Basin, Tropicana Outlet Channel, Lower Blue Diamond Channel, Blue Diamond Dam, Blue Diamond Beltway Channel; F1 & F2 debris Basins and Outfall Channels; and the Red Rock Beltway Channel.*
- *The Sponsors constructed Segments of the Beltway & Red Rock Channels as part of their Section 211 (WRDA 1996) work. Section 211 authorizes non-Federal sponsors to implement Corps flood control project. Section 211 work was physically completed in December 2000.*

TROPICANA/FLAMINGO

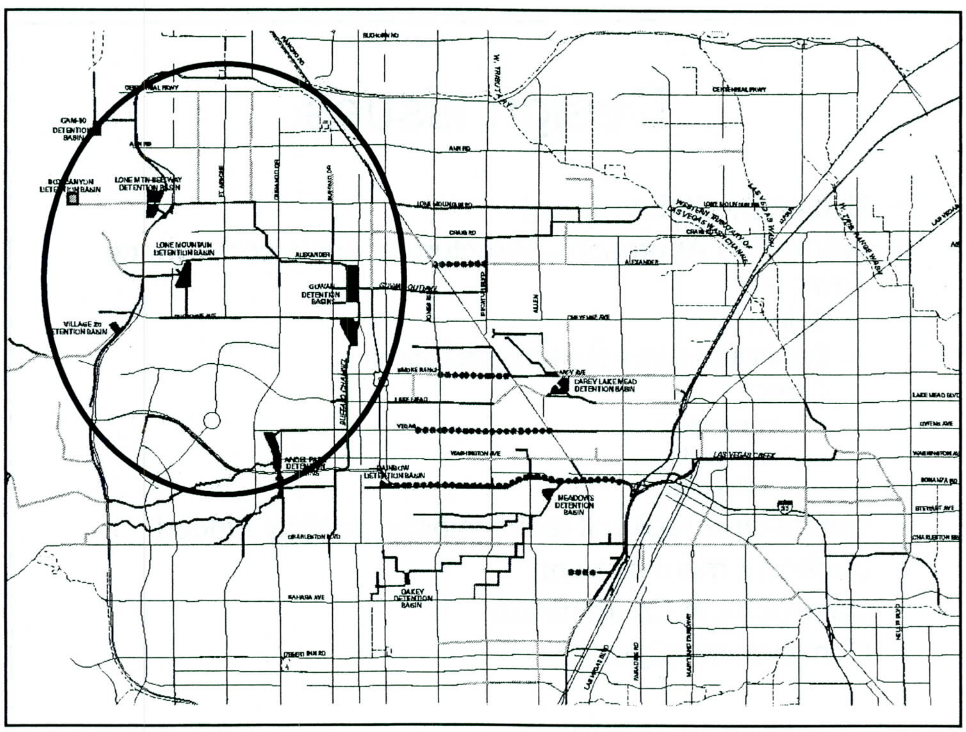
ACCOMPLISHMENTS:

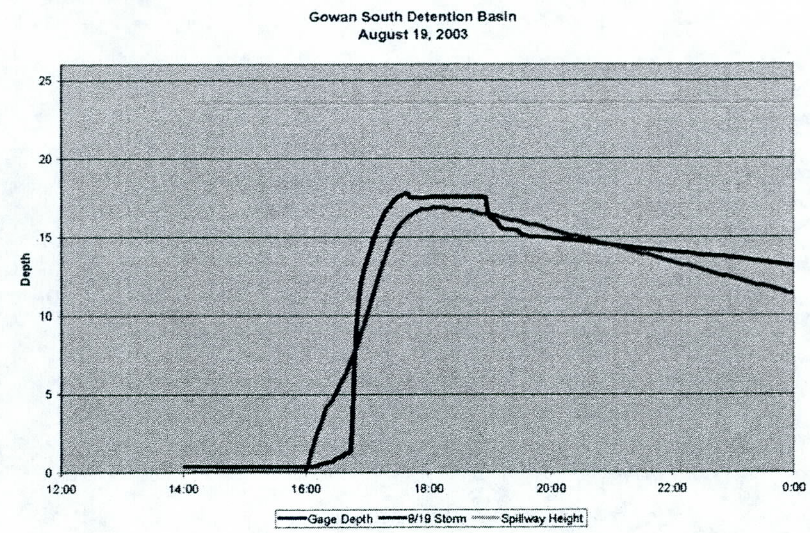
- *IN SUMMARY, THE TROPICANA & FLAMINGO WASHES FLOOD CONTROL PROJECT WILL BE COMPREHENSIVE AND WILL INTERFACE WITH THE SPONSOR'S MASTERPLAN.*
- *PROVIDE 100 YEAR LEVEL OF PROTECTION AND ACCOMMODATE THE DEVELOPMENT THAT IS OCCURRING.*
- *ALLOW THE EXISTING STEAMS IN THE URBANIZED AREA TO HANDLE THE DESIGN EVENT.*
- *PROVIDE COMPLETE MITIGATION FOR ALL ADVERSE ENVIRONMENTAL IMPACTS.*
- *MINIMIZE RELOCATIONS.*

Design Issues

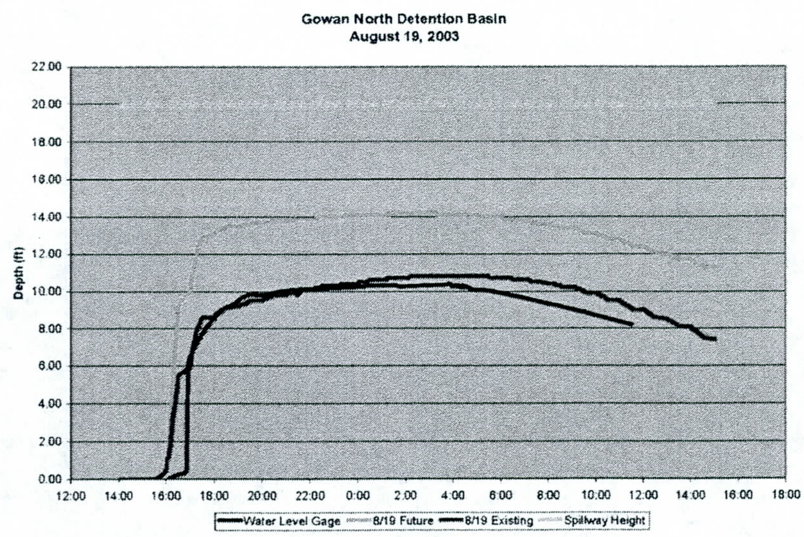
- Hydrology COE vs Local
- Whole Fan Approach – Structure at apex, conveyance down fan
  - Collect
  - Detain/attenuate –debris/no attenuation
  - Convey
    - supercritical
    - hard lined
    - confluences
- Detention is regional responsibility, publicly funded
- Sediment management
- Development Coordination
- Conveyance alignment


August 19, 2003
LAS VEGAS

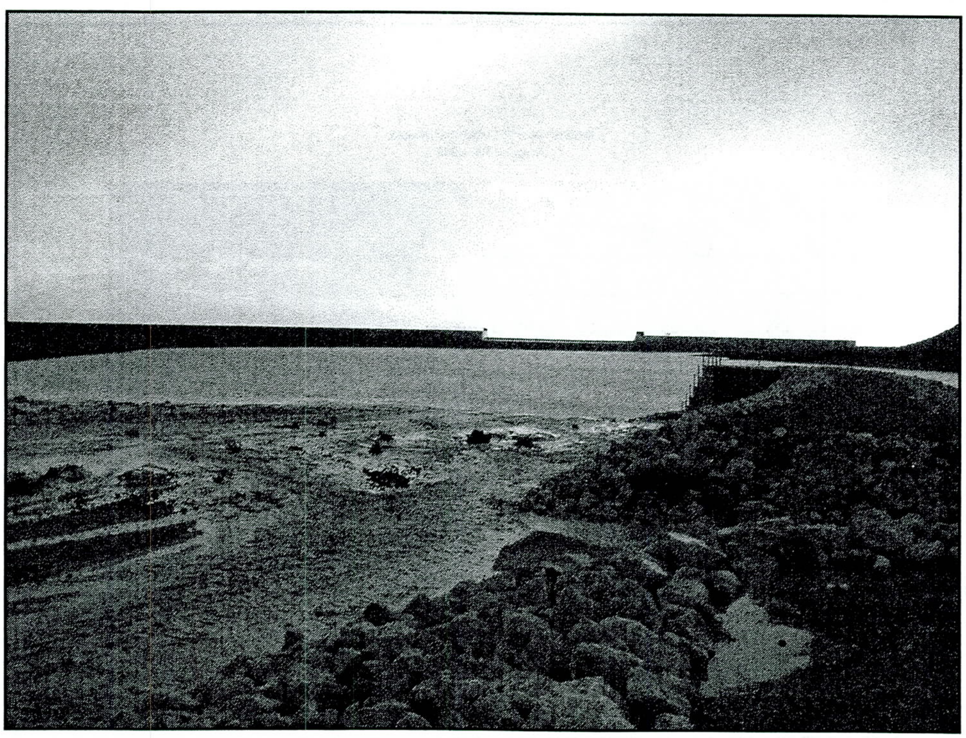

CENTENNIAL PKWY
ANN RD
LONE MOUNTAIN DETENTION BASIN
DETENTION BASIN
ALEXANDER
CRAIG RD
ALLEN
CHEYENNE AVE
DETENTION BASIN
CAREY LAKE MEAD DETENTION BASIN
LAKE MEAD BLVD
LAS VEGAS CREEK
WASHINGTON AVE
RAINBOW DETENTION BASIN
MEADOWS DETENTION BASIN
BONANZA RD
STEWART AVE
CHARLESTON BLVD
OAKEY DETENTION BASIN
SAHARA AVE

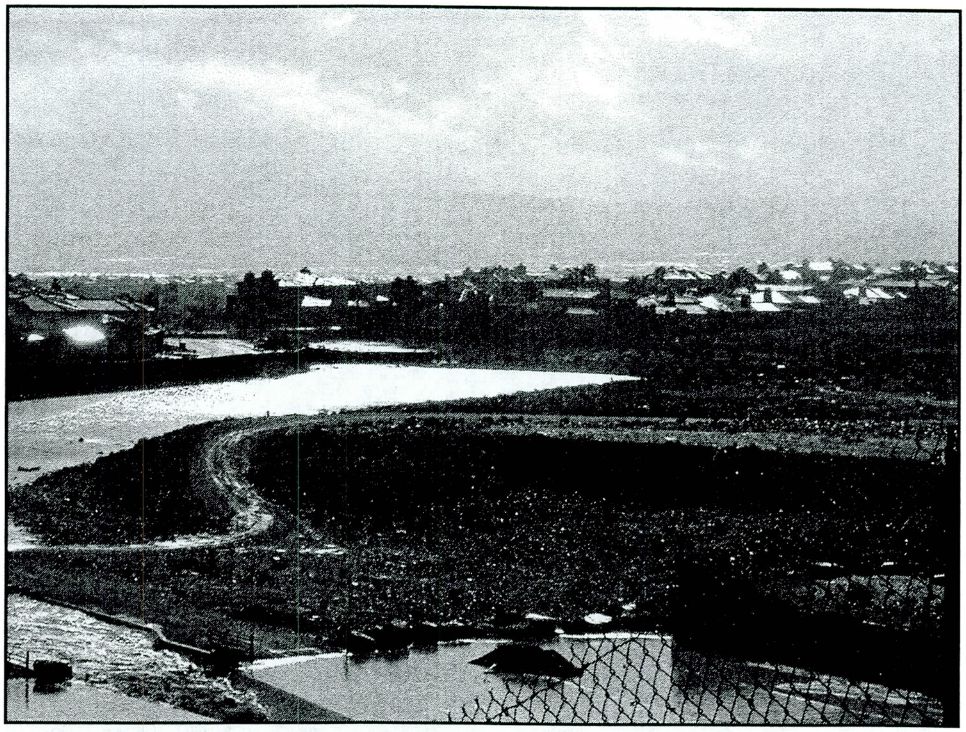


Gowan South Detention Basin
August 19, 2003
Depth
25
20
15
10
5
0
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Gage Depth
8/19 Storm
Spillway Height



Gowan North Detention Basin
August 19, 2003
Depth (ft)
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
Water Level Gage
8/19 Future
8/19 Existing
Spillway Height





Summary

- Principal Lessons Learned:

- Questions/Comments

Alluvial Fan Flood Hazard Management Symposium

Day 1 Summary & Wrap Up

Alluvial Fan Flood Hazard
Management Symposium

Day 1 Summary

- Notes

Alluvial Fan Flood Hazard
Management Symposium

Day 1 Summary

- Notes

Alluvial Fan Flood Hazard
Management Symposium

Day 1 Summary

- Notes

Alluvial Fan Flood Hazard
Management Symposium

Alluvial Fan Flood Hazard Management Symposium

Day 2 Introduction & Overview

Day 1 Overview

- Key Issues
  - Basic Concepts
  - Maricopa County Alluvial Fans
  - Hydrology
  - Hydraulics
  - Impacts Assessment
  - Non-Structural Measures
  - Structural Measures

Day 2 Overview

- Environmental Permitting
- Land Owner Perspective
- Panel Discussion #1: Planning Exercise
  - Skyline Wash Fan, White Tank Mtns
  - Application, Illustrate Issues
- Panel Discussion #2: Brainstorming
  - Maricopa County Fan Development Policy
  - Identify Needs & Solutions

US Army Corps of Engineers
Los Angeles District

Section 404 Clean Water Act

Sallie McGuire
Alluvial Fan Symposium
Phoenix, AZ
April 22, 2005

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Overview

Section 404 of the Clean Water Act regulates the discharge of dredged or fill material into waters of the United States

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Project Limits

- Single and Complete project
- Master planned community
- Regional flood control

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Jurisdiction

- Waters of the United States
- Entire alluvial fan?
- Recent active channels that exhibit an ordinary high water mark?

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Ordinary Highwater Mark

- Physical Evidence for an OHWM includes: a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, presence of litter and debris or other appropriate means.

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OHWM – Arid Southwest

- Braided Channels can make OHWM determinations much more complicated
- Due to high variability in peak storm flows, physical evidence from ordinary storm events (2-5 year event) can be completely eliminated by larger peak flows

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Avoid and Minimize

- 404 (b) 1 Guidelines require avoidance first
- Minimization of discharges of dredged/fill material
- Compensation for unavoidable discharges

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Permit options

- 43 Nationwide permits
- Activity specific
- ½ acre maximum of discharge of dredged/fill material
- NWP #39 Residential, Commercial and Institutional Developments
- NWP #43 Stormwater Management Facilities

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Permit Options

- Standard Individual Permits
  - Public notice on specific project
  - Opportunity for public hearing
  - Alternatives Analysis
  - 6-12 months review time

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Case Studies

- Scottsdale Desert Greenbelt
- Western slope of White Tank Mountains

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of Engineers
Los Angeles District

Conclusions

- Los Angeles District Website:
  www.spl.usace.army.mil/regulatory

Alluvial Fan Flood Hazard
Management Symposium

Alluvial Fan Flood Hazard Management Symposium

Land Owner Perspective

Bob Spiers, MBA
Stardust Development

Land Owner Perspective

- Major Infrastructure Planning Changes
  - Finance, Construction, & Maintenance
  - Historically
    - Municipalities & Agencies Installed & Maintained
    - Funded by Municipal Bonds
    - Developer Buy-In & Impact Fees
  - Recent Practice
    - Self-Funded Growth
    - Developers Finance & Install Infrastructure
    - Impact Fee Credits

Land Owner Perspective

- Major Infrastructure Planning Changes
  - Result of Modern Practice
    - Private Capital More Expensive Than Public Funds
    - Required Rates of Return Higher
    - Time is Critical
    - Demands on Capital Greater

Flood Control District of Maricopa County

Alluvial Fan Flood Hazard
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Land Owner Perspective

- Partnering v. Cooperative Effort
  - Partnering Implies Equal Investment & Risk
- Goal of Cooperative Planning
  - Foundation for 404 Permitting
  - Foundation for FEMA Submittals
  - Foundation for Drainage & Infrastructure
  - Sound Drainage Solutions

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Land Owner Perspective

- Land Owner Goals for Drainage Planning
  - Best Methodology for Flood Control
  - Identify the "Right" Answer for All Concerned
  - Identify Solutions in Cost-Effective Manner

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Land Owner Perspective

- Land Acquisition: Sun Valley Corridor
  - Large Contiguous Privately Held Parcels
  - Access to Interstate 10
  - White Tank Mountain Topographic Boundary
- Opportunities for Coordinated Planning
  - Large Master Planned Communities
  - Limited Number of Owners
  - Blank Canvas

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Land Owner Perspective

- Coordinated Planning Challenges
  - Multiple Ownership
  - Timing & Schedule
  - Physical Constraints
  - Infrastructure Constraints
  - Drainage Constraints

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Land Owner Perspective

- Coordinated Planning Opportunities
  - FCDMC & Stakeholder Planning Groups
  - Cooperative Stage III Floodplain Delineation
  - Coordination of Structural Measures
- Drainage Master Plan Process

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Land Owner Perspective

- 404 Permit, Platting & Construction
  - 404 Environmental Permits
    - Target Disturbance Percentages
    - Upland Buffer Requirements
    - Mitigation / Preservation
    - Governs Flood Control Design
    - Limited Flexibility Once Approved

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Land Owner Perspective

- Structural Flood Control Design
  - Structural Walls & Structural Weirs
    - Less Intrusive than Channelization
    - Surgical Construction Possible

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Land Owner Perspective

- Conclusions
  - Methods of Funding & Construction Changed
  - Developers Not in Business to Waste Money
    - Willing to commit funds to facilitate solutions
  - Private Funds: Less Patient, More Demanding
    - Results Driven
  - Sun Valley Planning Area
    - Unique Opportunities – Time Critical
  - 404 Permit Drives Process

Debris Transporting Channels
A Case Study

James D. Schall, Ph.D.
Ayres Associates Inc

Alluvial Fan Flood Hazard Management Symposium

April 20-22, 2005

Introduction

- Case Study based on debris transporting channels through the Wild Rose Residential Development
- Project located near Corona, CA
- Construction completed in 1992
- Provides an excellent case study

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Debris Loading

- Based on accepted standards for sizing debris basins in S. California
  - Tatum Method
  - Los Angeles County Method
- Checked against
  - Available field data
  - Sediment concentration based approach

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Results

Channel	Area (sq mi)	Unit Loading (cy/sq mi)	Debris Production (cy)	Debris Production (af)
Brown Canyon	1.75	85,000	149,000	92
McBride	1.33	69,000	92,000	57
Section 32	0.85	100,000	85,000	53

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Conceptual Design

- Four primary alternatives considered
  - Debris basins
  - Mapping and zoning
  - Debris transporting channels
  - Combinations
- In consultation with RCFCD, debris transporting channels recommended

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Design Considerations

- Bulking factors
- Inlet design
- Additional concrete in invert
- Horizontal and vertical alignment
- Superelevation and freeboard
- Outlet design

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Bulking Factors

Channel	100-yr Q (cfs)	Bulking Factor	Design Q (cfs)
Brown Canyon	3,640	1.75	6,370
McBride	1,125	1.58	1,776
Section 32	710	1.83	1,299

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Inlet Design

- Channels extended to apex of fan
- Mass grading included elevated building pads at inlet
- Concrete wing walls and dikes extending to valley side

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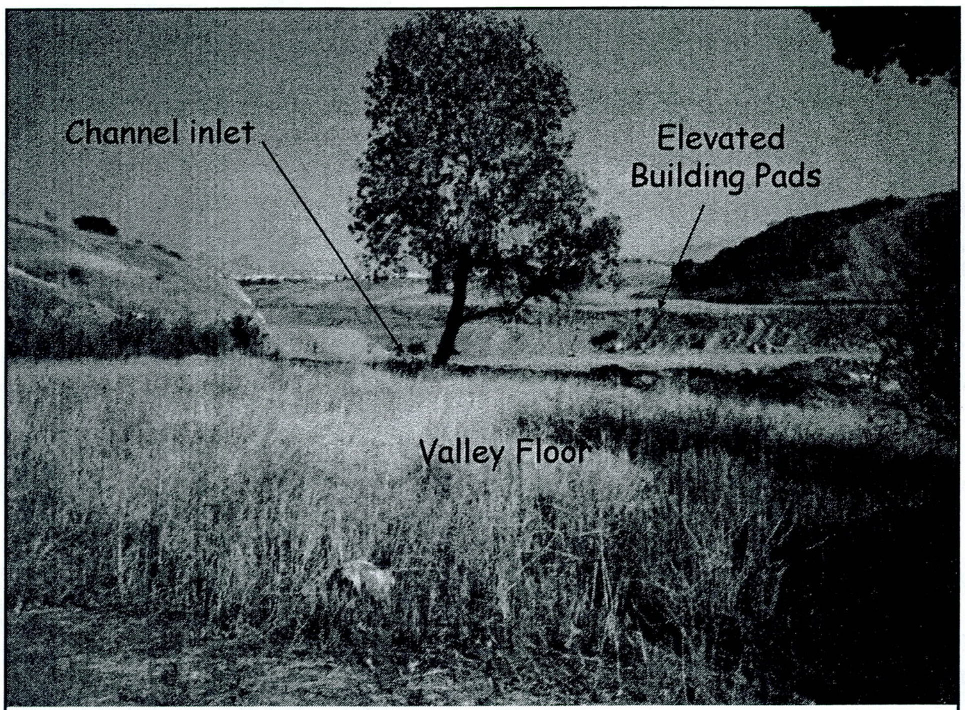
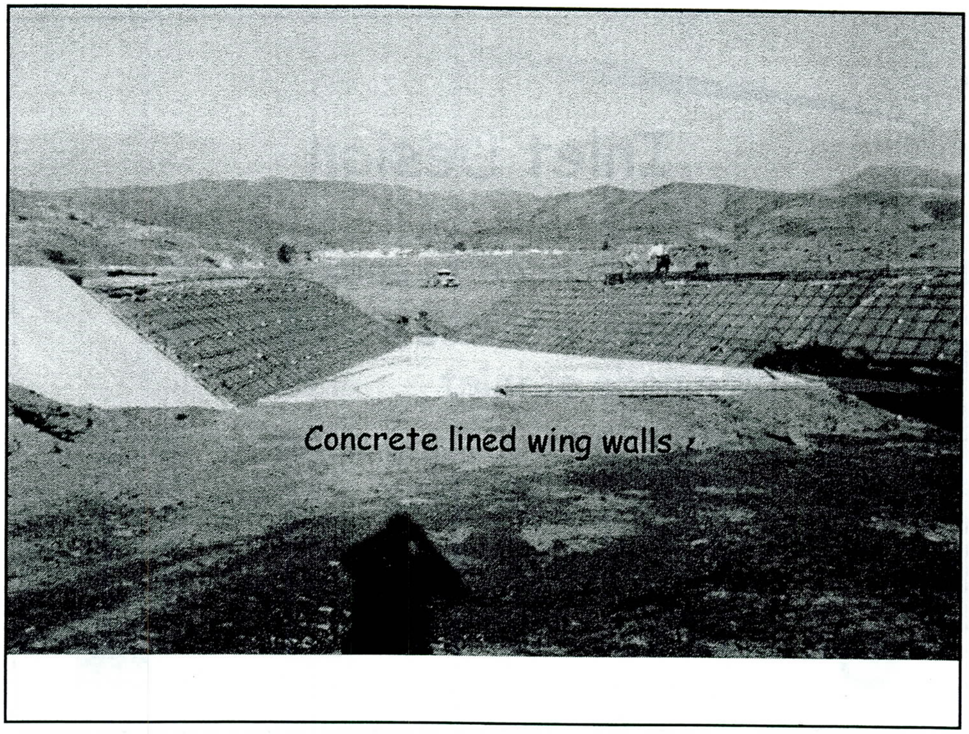
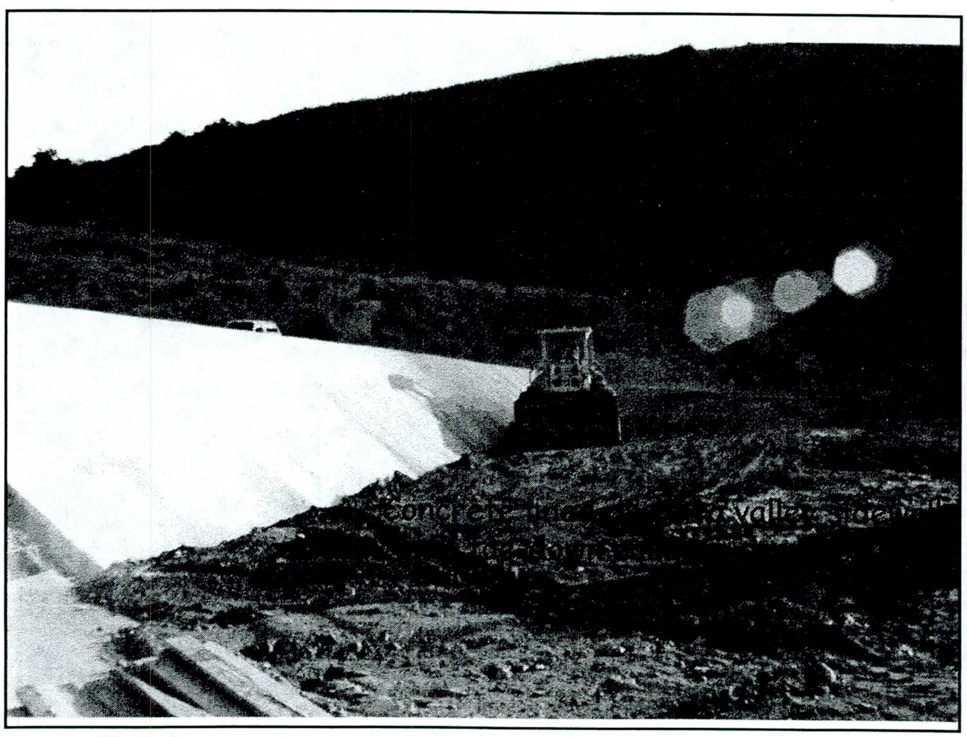



Concrete lined wing walls



Additional Concrete in Invert

- Standard plan was mild v-bottom trap channel with 6-in concrete invert
- Additional 3-in used as wear layer

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Horizontal and Vertical Alignment

- Minimize grade breaks to reduce potential sediment deposition
- Maximize radius of curvature
- Mild confluence angles with long transitions

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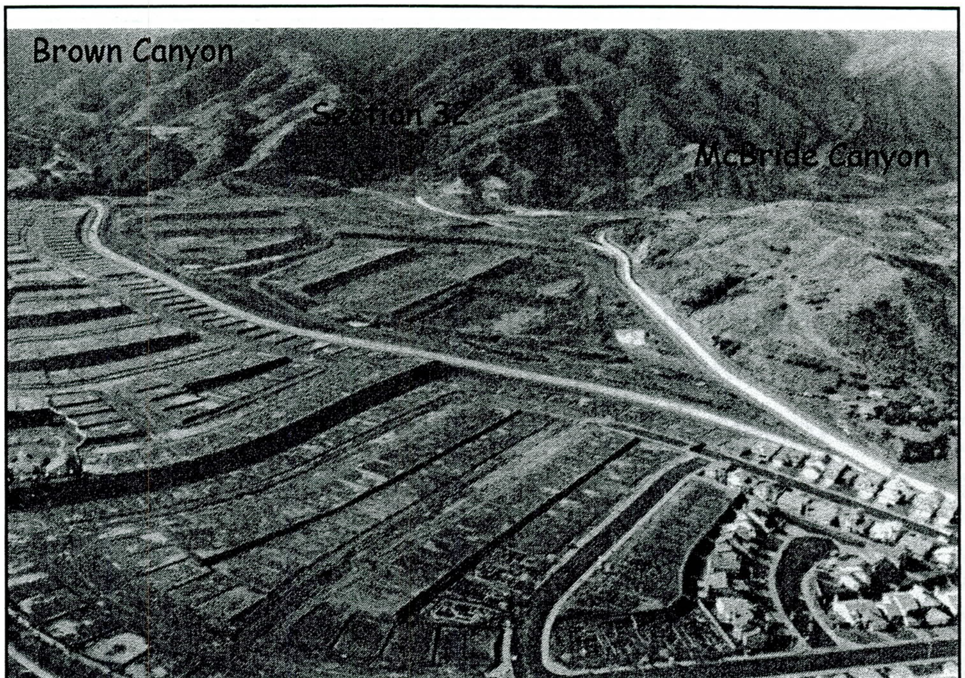
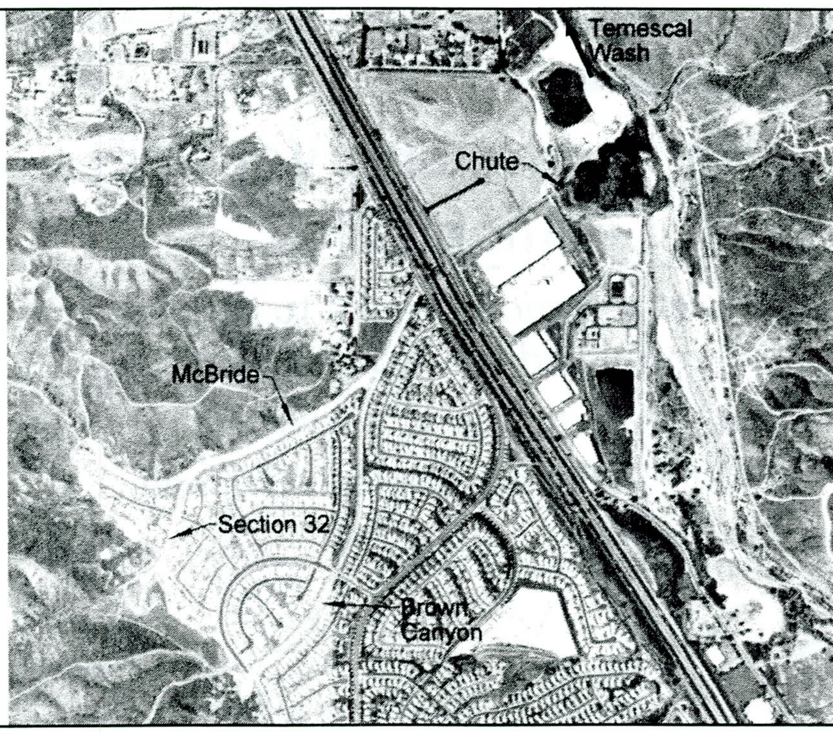

Brown Canyon
Section 32
McBride Canyon


Temescal Wash
Chute
McBride
Section 32
Brown Canyon

Superelevation and Freeboard

- Superelevation was calculated and added to entire channel depth
- Freeboard (1 ft) added to superelevation depth

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Outlet Design

- Base level lowering in Temescal Wash due to sediment imbalance:
  - Sand and gravel mining
  - Existing debris basins throughout watershed
- Created 45 ft drop in 150 ft for the Brown Canyon channel
- USBR Chute designed for outlet

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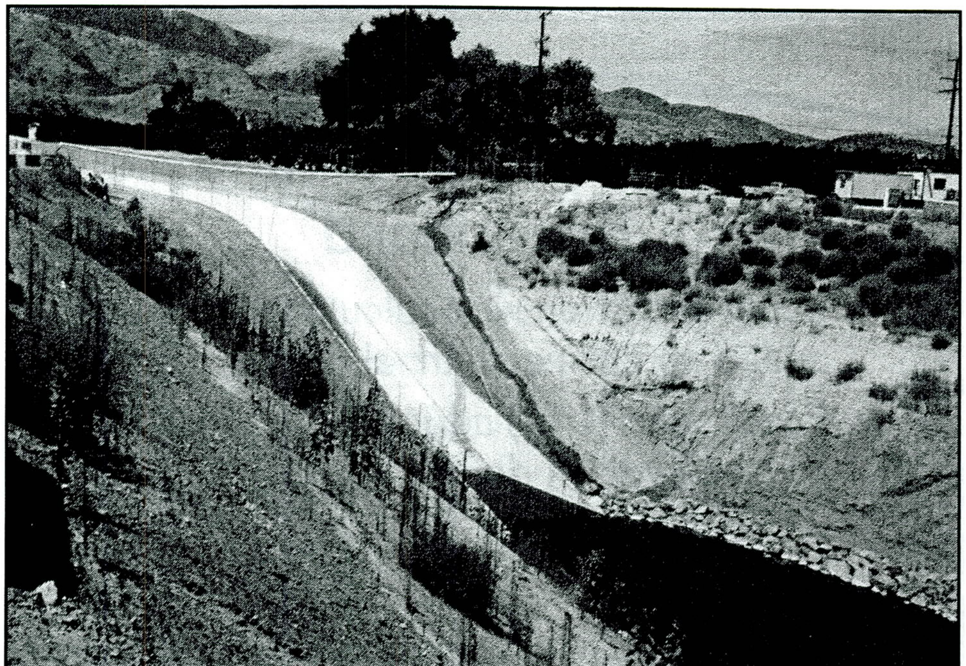

Lessons Learned

- Don't start construction immediately before rainy season…

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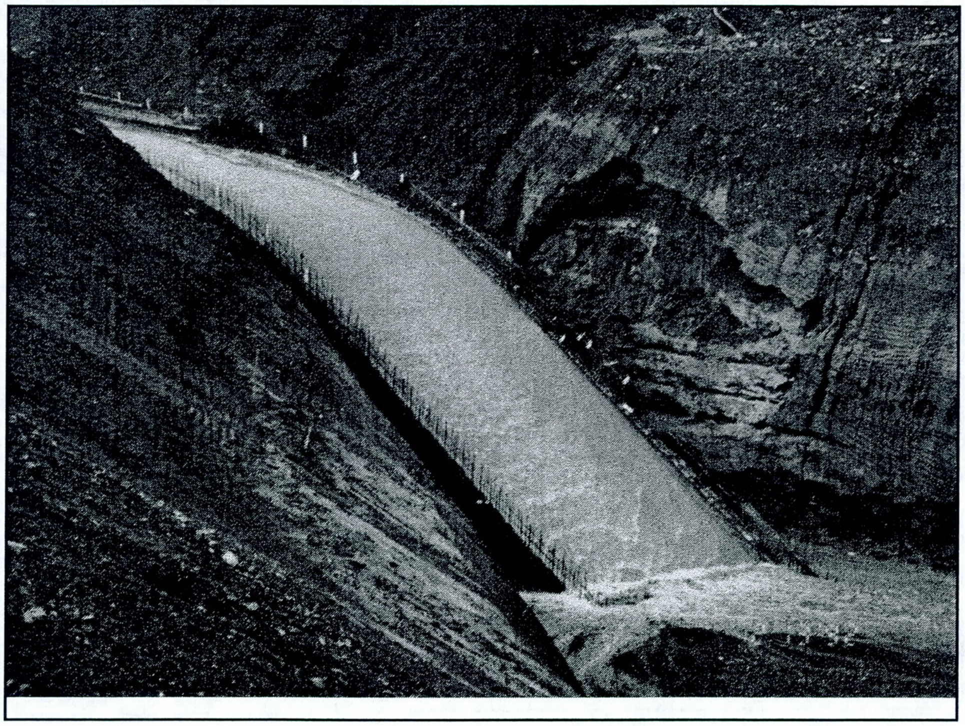

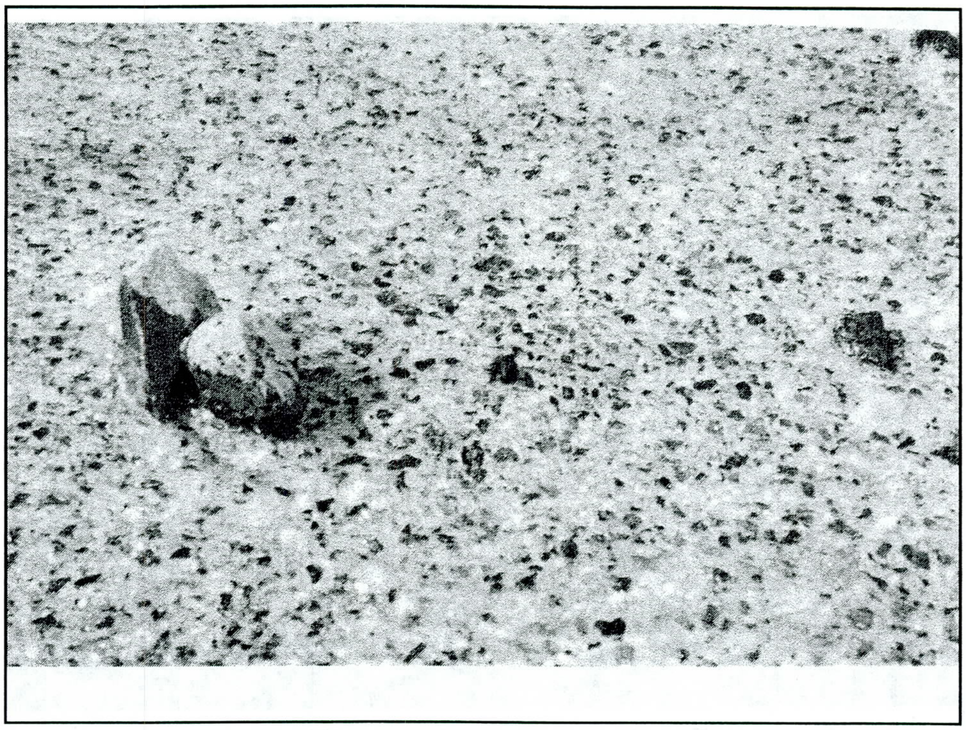

Lessons Learned

- Don't start construction immediately before rainy season...
- Consider high strength concrete and lots of it...

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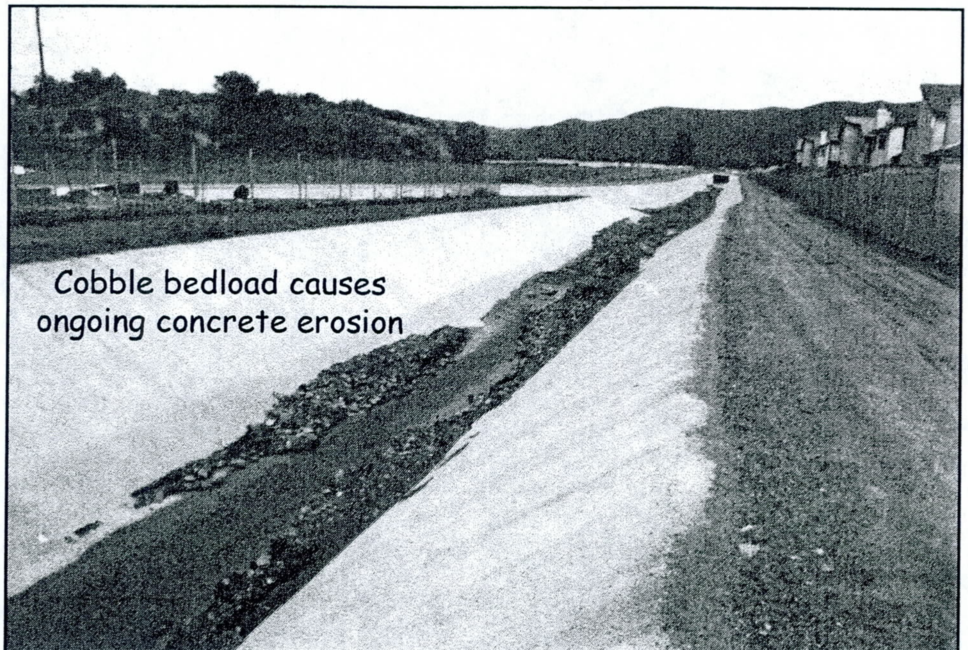
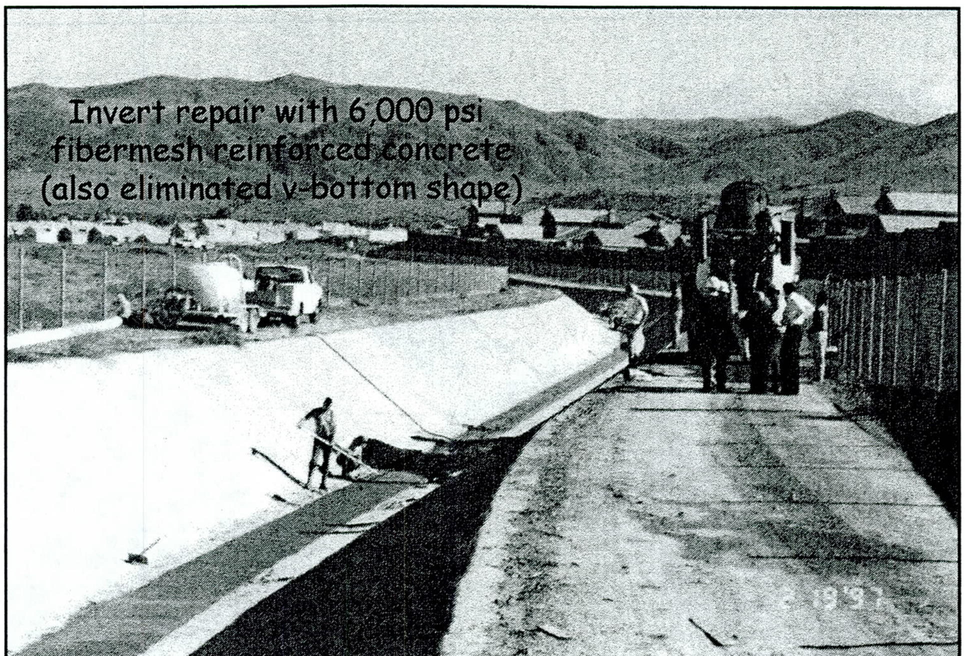


Standard Plan v-bottom design concentrated flow and erosion at centerline



Lessons Learned

- Don't start construction immediately before rainy season...
- Consider high strength concrete and lots of it...
- Don't compromise on alignment issues, especially with trapezoidal channels

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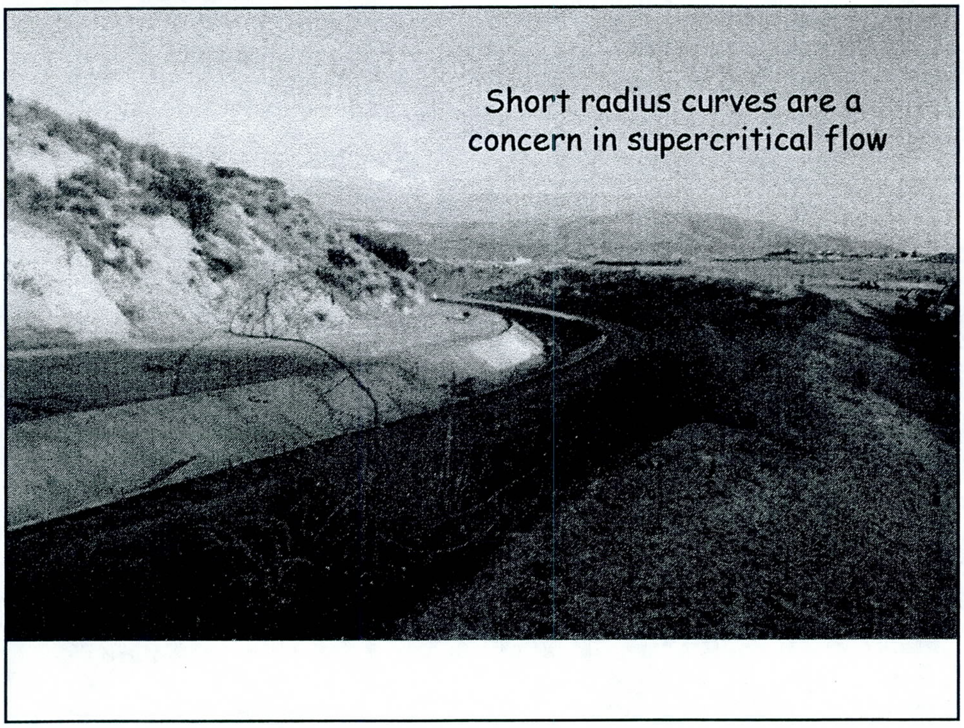
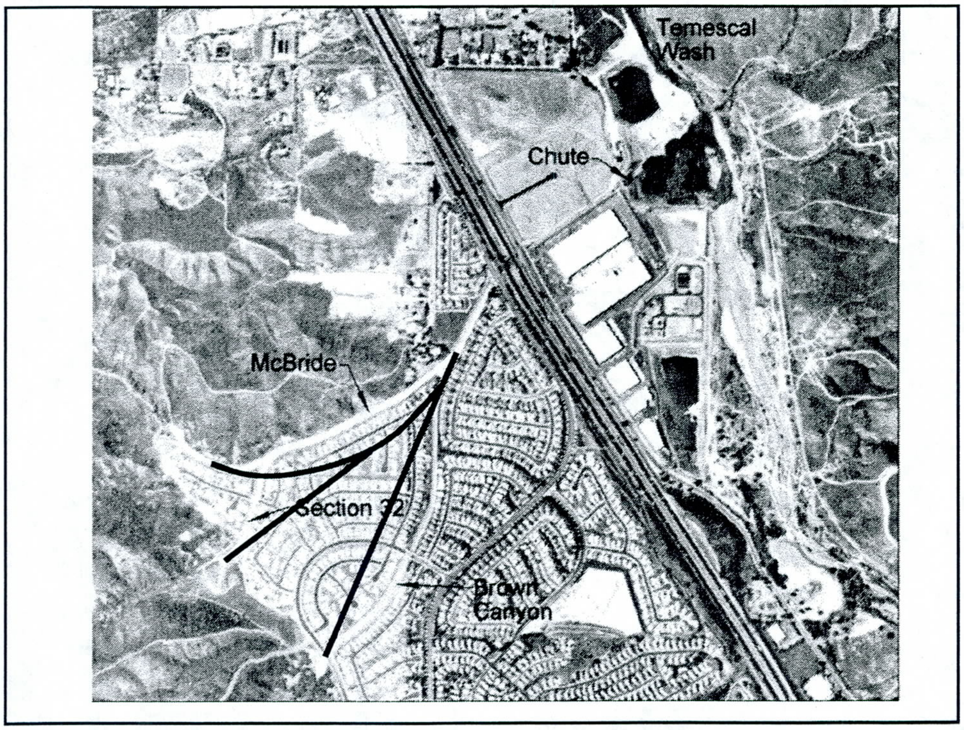

Short radius curves are a
concern in supercritical flow


Temescal
Wash
Chute
McBride
Section 32
Brown
Canyon

Conclusions

- What did we do well?
  - *overall concept maintained downstream sediment supply to Temescal Wash*
  - *bulking factor analysis/upsizing design Q*
  - *channel extended to apex with good inlet design assures flow capture*
  - *outlet design has performed well*

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Conclusions (cont)

- What would I do differently today?
  - *re-visit horizontal alignment*
  - *increase channel depth even more*
  - *increase concrete even more*
  - *flat bottom, rectangular section??*

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Conclusions (cont)

- Both the *owner* and the *designer* need to understand the risks involved
- Debris transporting channels will be bigger, and cost a lot more than standard flood control channels...
- Overriding lesson-BE CONSERVATIVE

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CASE STUDY – WHITNEY WASH, HENDERSON, NV

Richard H. French, Ph.D., P.E., D.WRE
Professor
Department of Civil & Environmental Engineering
University of Texas at San Antonio
San Antonio, TX
&
Research Professor Emeritus
Desert Research Institute
Las Vegas & Reno, NV

Alluvial Fan Flood Hazard Management Symposium

PRESENTATION TOPICS

- THE PROBLEM
- WATERSHED CHARACTERISTICS
- TASK
- RESULTS
- SOLUTION
- LESSONS LEARNED

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THE PROBLEM

Even minor precipitation events result in downstream flooding

Major precipitation events result in severe downstream property damage and in one case resulted in a fatality

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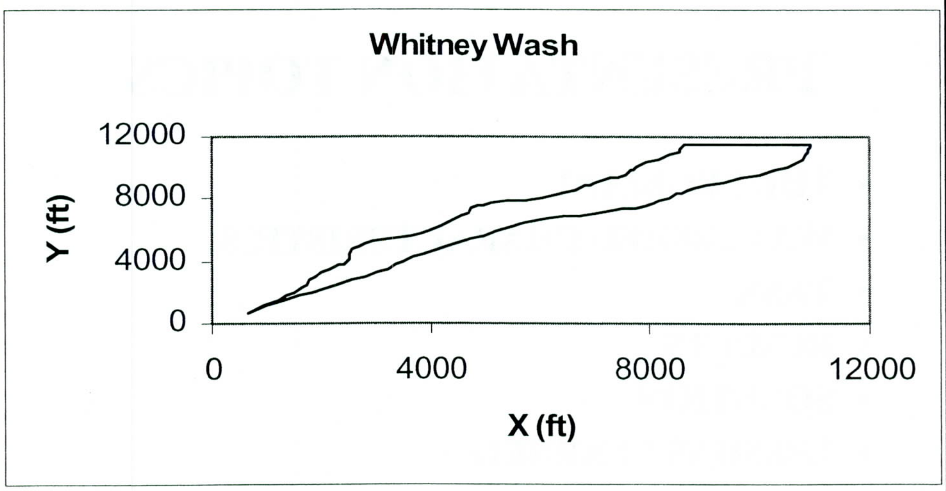

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WATERSHED CHARACTERISTICS

Area = 0.62 square miles

Landuse

- Upstream – suburban development and undeveloped land
- Downstream – golf course
- Outlet – suburban development

Watershed orientation southwest to northeast

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WATERSHED CHARACTERISTICS

Based on slope watershed can be divided into three sub-basins

- Upstream (0.075 sq mi)
  - S = 0.0095 ft/ft
  - CN = 77
- Middle (0.33 sq mi) – 0.0135 ft/ft
  - S = 0.0135 ft/ft
  - CN = 80
- Downstream (0.22 sq mi)
  - S = 0.0179 ft/ft
  - CN = 85

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WATERSHED CHARACTERISTICS

Length = 14,000 ft

Average Width = 1,200 ft

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TASK

Why is there persistent downstream flooding?

- Are there drainage design flaws in the developments?
- Were the applicable design procedures followed?
- How do we fix the obvious problem?

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RESULTS

- Design standards changed over the period of development. However, even under the most modern standards flooding should not occur!

- There are no drainage design flaws in the watershed.

RESULTS

- The orientation, shape and slope of the watershed is the likely problem.

  The watershed extends from the southwest to the northeast. Many summer convective storms track from the southwest to the northeast.

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RESULTS

- If a storm is moved over the watershed from the southwest to the northeast taking into account the sub-basin times of concentration and routing times, historical results can be "replicated."

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SOLUTION

- Detention on the golf course

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LESSONS LEARNED

- Nature will outsmart us every time
- Continuing to do the same old thing often does not work

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Panel Discussion #1:
Planning Exercise – Skyline Wash Fan

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Panel Discussion #1: Notes

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Panel Discussion #1: Notes

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Panel Discussion #2:

Maricopa County Fan Development Policy

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Panel Discussion #2: Notes

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Panel Discussion #2: Notes

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Panel Discussion #2: Notes

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