Skunk Creek

tercourse Master Plan

TECHNICAL SUMMARY

Flood Control District of Maricopa County

AUGUST 2001

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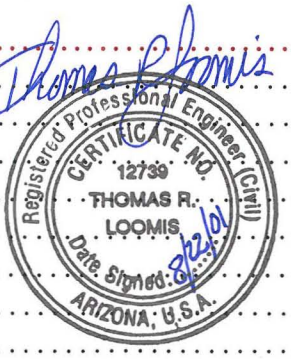

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List of Acronyms and Abbreviations

ADMP	Area Drainage Master Plan
ADMS	Area Drainage Master Study
ADWR	Arizona Department of Water Resources
AGFD	Arizona Game & Fish Department
ALERT	Automated Local Evaluation in Real Time
API	Arizona Preserve Initiative
ARS	Arizona Revised Statute
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
CAP Canal	Central Arizona Project Canal
COE	US Army Corps of Engineers
COP	City of Phoenix
District	Flood Control District of Maricopa County
EAS	Emergency Alert System
F.A.R.	Floor Area Ratio
FEMA	Federal Emergency Management Agency
FLO-2D	FLO-2D computer program for two-dimensional hydraulic modeling
FRP	Flood Response Plan
FWS	Flood Warning System
GIS	Geographic Information System
GLO	General Land Office
HEC	Hydrologic Engineering Center
MSL	Mean Sea Level
MSP	Flood Control District of Maricopa County Meteorological Services Program
NBCC	North Black Canyon Corridor Plan
NWR	NOAA Weather Radio
NWS	National Weather Service
PO	Precipitation Forecast
QPF	Quantitative Precipitation Forecast
RTIMP	Percent impervious area of a watershed
Study Team	Flood Control District of Maricopa County, City of Phoenix, Tetra Tech, Inc., Stantec Consulting Inc., JE Fuller/Hydrology & Geomorphology, Inc., Logan Simpson Design Inc.
T & E Species	Threatened and Endangered Species
WCMP	Skunk Creek Watercourse Master Plan

Acknowledgements

The individuals with Maricopa County, the City of Phoenix, the Arizona State Land Department, and the consultant team listed below have worked together to prepare this watercourse master plan. These are the people who formed the steering committee for the study. They have contributed not only their professional expertise, but their shared belief that planning for the safety and welfare of future generations is an important aspect of performing our professional roles today. Finally, this long-range planning tool would not be a reality without the support of the Maricopa County Board of Supervisors. Thanks to all of you for your contributions to the creation of this plan.

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Preface

Providing a safe floodplain environment for residents is the primary goal and responsibility of the Flood Control District of Maricopa County (District). To that end, the District, along with the City of Phoenix, has developed a floodplain management plan for Skunk Creek and Sonoran Wash. Implementation of this plan will protect existing and future residents, and permit appropriate uses of floodplain areas, while allowing both watercourses to function naturally.

This study has determined that the floodplains of these watercourses are highly prone to the dangers of flooding, bank erosion, and sedimentation. The primary purpose of the plan is to provide public safety, and the District recognizes that there are many methods through which this purpose can be achieved. It is the intent, in preparing the Watercourse Master Plan, to not only protect residents from the hazards of a 100-year flood, but also to investigate the feasibility of preserving physical, cultural, and biological resources and the ability of the watercourses to function naturally.

If land is to be protected in its natural state, it must first be determined that the land has qualities worth preserving. The riparian habitat along Skunk Creek and Sonoran Wash offer Maricopa County's native plants and animals opportunities for survival that are limited and diminishing in other regions of the Valley. Mesquite bosques, palo verde trees, and saguaros flourish within the watercourse area as well as Harris hawks, foxes, and Sonoran Desert tortoise. The area provides a travel corridor for many wildlife species as well. The desert watercourses with their dense ribbons of desert hackberry, palo verde, and mesquite trees along the banks create a distinct visual character. Land of this character has value that warrants consideration for preservation. The study findings show that preservation also results in an increased level of public safety, and a reduction in public expenditures.

Flood control is a challenge in the Skunk Creek and Sonoran Wash area. However, beyond the hazards of flooding, the study area is subject to significant erosion hazards and sedimentation problems. This means that not only could homes built within these watercourses be filled with water in the event of a 100-year flood, but homes adjacent to the banks could become victims of erosion as the soil they sit on crumbles and moves downstream during floods. Soil deposits and channel movement could change the floodway putting existing and future homes in jeopardy and requiring extensive public investments to protect them. Historically, floodplain management throughout the county has not studied the shifts in watercourses due to these factors. Changes in Arizona law have established regulations for developing watercourse master plans to address these issues.

Research findings illustrate that in the last 50 years Skunk Creek and Sonoran Wash have been subject to bank erosion and lateral movement. Large floods have moved the main channel of Skunk Creek by more than 400 feet in some areas, while during an average year, the creek will move less than a foot. To address these hazards, the District developed four watercourse management alternatives:

- a full-structural solution which maximizes developable area within the floodplain but necessitates extensive construction of levees and bank protection;
- a stakeholders solution which maximizes developable area, in accordance with proposed development plans for the areas downstream of the Carefree Highway, but necessitates extensive construction of levees, channelization and bank protection;
- a low-impact structural solution that allows limited developable land within the floodplain but reserves the minimum area necessary for the natural function of the watercourse; and
- a nonstructural solution which reserves the maximum area needed for the natural function of the watercourse.

Based on pubic safety, economic impacts, and social and environmental criteria, the recommended management plan for the watercourse is the Low-Impact Structural Alternative, as described on pages 36-46 of this document. This alternative is the most successful for meeting the goals of the study.

For more information on this study, please contact Marilyn DeRosa or Doug Williams of the Flood Control District of Maricopa County at (602) 506-1501.

1 Introduction

The Flood Control District of Maricopa County (District) teamed with the City of Phoenix (COP) to develop the Skunk Creek Watercourse Master Plan (WCMP) for Skunk Creek, and its tributary Sonoran Wash. A watercourse master plan is a comprehensive flood management plan based on hydrologic and hydraulic analyses, lateral migration potential, future land use development, and environmental considerations. Historically, floodplain management within the COP and Maricopa County has not considered bank erosion, the potential long-term lateral movement of a watercourse over time, or future growth patterns within a watershed. The State of Arizona recently established Arizona Revised Statute (ARS) 48-3609.01 that enables local flood control agencies to identify sensitive watercourses for inclusive floodplain management through a process of watercourse master planning. The authority for preparation of this study and management of the Skunk Creek and Sonoran Wash watercourses is established in ARS 48-3609.1 and the Floodplain Regulations for Maricopa County (Flood Control District of Maricopa County, 2000).

The District contracted with Tetra Tech, Inc. who assembled a highly qualified team of subconsultants to assist in preparation of the WCMP in conjunction with District and COP staff (Study Team). Tetra Tech, Inc. managed the project, performed the hydrologic modeling, assisted with hydraulic and erosion analyses, identified and analyzed the management alternatives, and prepared the WCMP report. Tetra Tech, Inc. contracted with the firm of Stantec Consulting Inc. to perform the majority of the hydraulic and sediment transport modeling, JE Fuller Hydrology & Geomorphology, Inc. to perform the lateral stability analyses, and Logan Simpson Design Inc. to perform biological reconnaissance, delineate waters of the United States, manage the public involvement process, and prepare final graphics.

The study area, shown on Figures 1 and 2, includes Skunk Creek from the Central Arizona Project Canal (CAP Canal) to about 2,200 feet north of the Skunk Creek crossing of New River Road. The study covers a length of about 13.2 stream miles of Skunk Creek, starting at the CAP Canal and extending upstream. The study area also includes Sonoran Wash, a tributary watercourse that joins Skunk Creek approximately 0.5 miles downstream of the CAP Canal, and has a study length of about 3.3 stream miles. The study area is generally defined as a 500-foot perimeter beyond the known 100-year floodplain of these watercourses, as determined by the Federal Emergency Management Agency (FEMA). Both Skunk Creek and Sonoran Wash have significant desert riparian vegetation. The potential exists for bank erosion and lateral migration of their channel banks to occur over time, particularly if vegetation along the banks is removed or disturbed by natural or human activities.

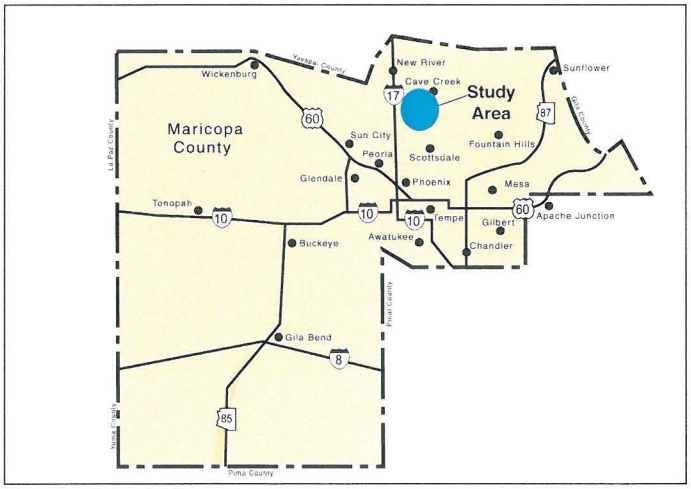


Figure 1. Study Area Vicinity

The study was divided into two phases to accommodate a request by the COP to fast track the area south of the Carefree Highway. Phase 1 consists of the study area between the CAP Canal and the Carefree Highway including Sonoran Wash, and Phase 2 covers the study area north of the Carefree Highway. Phase 1 lies within the area covered by the COP North Black Canyon Corridor Plan, adopted by the Phoenix City Council in July 1999. During the adoption of the North Black Canyon Corridor Plan, the Phoenix City Council directed COP staff to closely examine alternative approaches to flood control

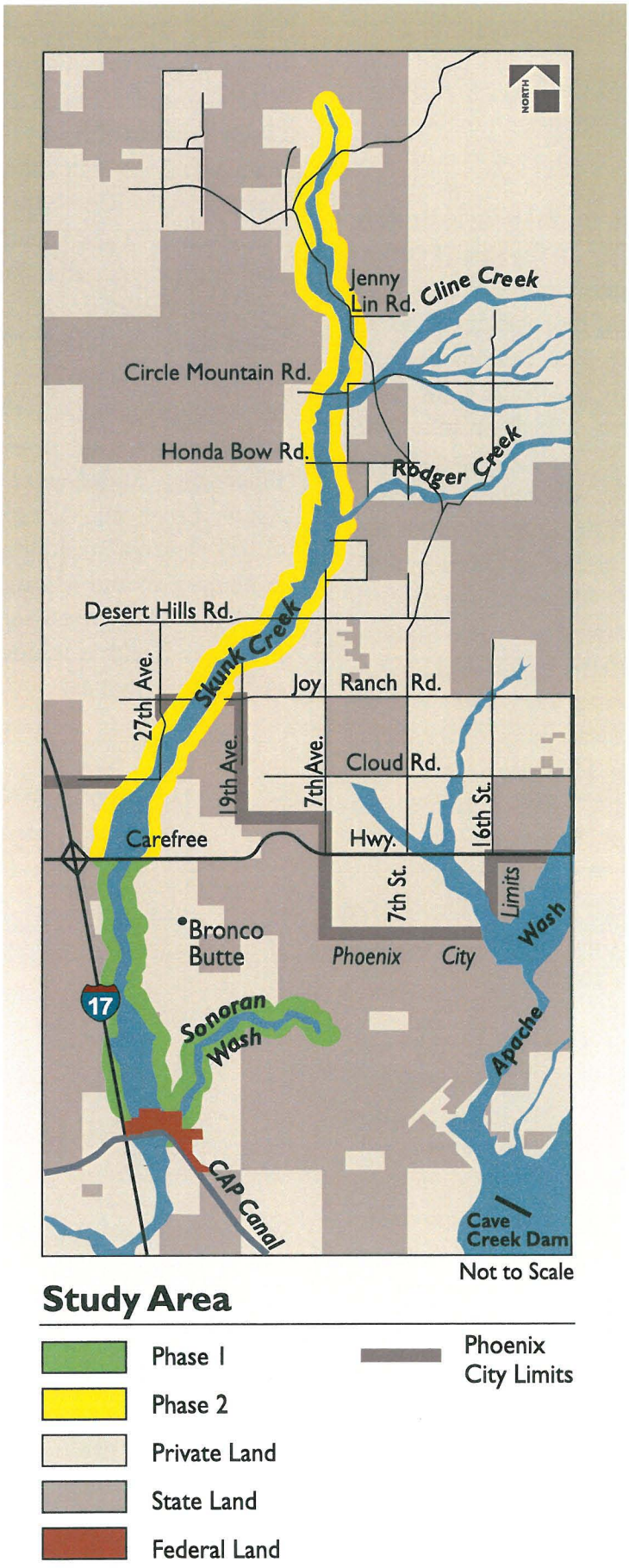


Figure 2. Study Area

management in the corridor within a period of 12 to 18 months through a cooperative study with the District. Therefore, the Phase 1 study area was undertaken first, with completion scheduled for August 2000. The Study Team completed the Phase 1 technical and alternative analyses in May 2000, and the COP planning department staff published the Skunk Creek Water Course Master Plan Alternative Analysis report for Phase 2 on May 16, 2000. That report is included in Attachment 11 as Appendix F. The WCMP includes the results for Phase 1 as well as the results for Phase 2.

This report describes the master plan purpose and goals, the watercourse characteristics, and the watercourse management plan alternatives and recommendations. Many terms used in this report have definitions specific to the purpose of this study. There are also technical terms used that require definition. These terms are italicized, and defined in the glossary. The titles of documents and reports referenced herein are underlined. A complete list of references for the WCMP is contained in Attachment 1.

Skunk Creek

Sonoran Wash

2 Master Plan Purpose and Goals

Much of the relatively undeveloped lands located within the study area have not been identified for preservation, and therefore face development pressure in the near future. In recent years, there has been increasing controversy surrounding the future of desert *watercourses* such as Skunk Creek and Sonoran Wash. This controversy centers on the continuance of traditional development practices and trends versus increasing support for maintaining open space corridors. Traditionally, as development takes place, bank stabilization, levees, and basins have been constructed to control flooding. These structural alternatives are costly, destroy natural *watercourse* corridors, and create negative impacts upstream and downstream. Because public safety and welfare are affected, these negative impacts are usually addressed using public funds. Opportunities for implementation of a long-term floodplain management plan that minimize expenditures of public funds diminish as development increases.

Skunk Creek

The purpose of the WCMP is to examine the benefits, opportunities, and weaknesses of various flood control solutions, including structural, nonstructural, and a combination of structural and nonstructural measures, and to recommend a management plan. This includes examining the *watercourses* as components of the overall watershed system. The primary goals of the WCMP are:

- ★ Protect existing and future residents from the 100-year flood event and damages associated with *channel erosion* and lateral migration of the *watercourse*.

Sonoran Wash

- ★ Consider structural, nonstructural and a combination of structural and nonstructural alternatives.
- ★ Minimize future expenditures of public funds for flood control and emergency management.
- ★ Consider multiple-use opportunities for flood plain areas.
- ★ Develop a *watercourse* management plan that generates widespread support and is implementable.

Residences in Phase 2 Area

3 Public Involvement Program

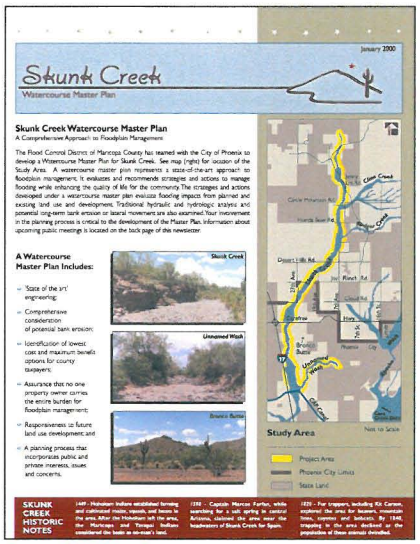
Public involvement was an integrated component in the development of the WCMP. A Public Involvement Plan was developed to outline the goals of the public involvement program, describe the types and formats of public meetings and presentations, and identify the various outreach techniques and methods. The goals of the Public Involvement Plan were to:

- ★ Inform the community of the study.
- ★ Enhance understanding of the alternatives through timely and effective distribution of information.
- ★ Obtain input from all potentially affected interests including citizens, agencies, developers, and special interest groups regarding issues and concerns.
- ★ Coordinate this study effort with Federal, State, and other county and local agencies.

In order to inform and provide the public with the opportunity to furnish input, there have been numerous outreach components to the study process. Such components included: public meetings, newsletters, information provided in the District's existing website, community meetings, a Stakeholders Task Force and individual meetings with local property owners. Notices for the public meetings were published in the Foothills Sentinel, Scottsdale Tribune, and the Arizona Republic newspapers.

A. Phase 1 Public Involvement

An initial newsletter was developed in January of 2000 and distributed to property owners within the study area as well as to any affected agencies. The newsletter introduced the study, identified the study area, established a study schedule, and announced the first public workshop. A mail-back card was included in the newsletter for people who wanted to receive information on the WCMP. The first public meeting was held on January 27, 2000 at the Desert Mountain Middle School in Phoenix. A brief presentation was made introducing the study and the Study Team members. Participants were asked to provide their input on issues and concerns about flooding problems.



January 2000 Newsletter

The second public meeting was held on May 16, 2000 at the Paradise Valley Community Center in Phoenix. The meeting was facilitated by the COP staff as part of their continuing North Black Canyon Corridor planning process. Five proposed floodplain management alternatives were presented at the open house as part of a joint presentation by COP and the Study Team staff. An example of one of the exhibits illustrating the alternatives is shown on Figure 3. Participants were asked to provide comments on the proposed alternatives.

Property owners in the Phase 1 area were invited to participate in a Stakeholders Task Force. The purpose of the Task Force was to provide input and to be informed of the Study Team's progress. Five Task Force meetings were held in addition to one-on-one meetings with individual property owners. This process culminated in a workshop conducted by the Study Team with the interested property owners and

February 15, 2001 Public Workshop

stakeholders on March 20, 2000. As a result of the workshop, a consensus was reached for the approach to be utilized for floodplain management of the Phase 1 study area. This approach was used to define the Stakeholders Alternative discussed in Section 7.

In addition to the public and stakeholders meetings, presentations and progress updates were made periodically to several entities, including the COP North Gateway Village Planning Committee, Planning Commission, City Council Natural Resources subcommittee, and Parks, Recreation, and Library Board. Periodic presentations were also made to the COP North Gateway Village Planning Committee in Phase 2 of the study.

B. Phase 2 Public Involvement

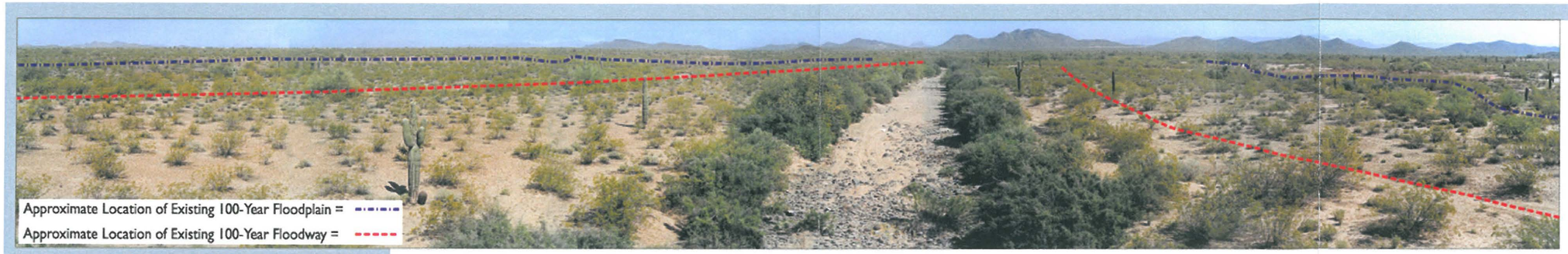
A special public workshop was held on December 14, 2000 at the Desert Valley Baptist Church in New River at the request of the property owners to discuss the WCMP and local drainage problems. Meeting announcement letters were sent to each property owner in the project area. At this meeting, there was a brief presentation by the District followed by a small group interaction session with Study Team members to assist the participants with their questions.

Another public meeting was held on February 15, 2001 at the Desert Mountain Middle School in Phoenix that focused on the Phase 2 study area. At this meeting, a handout was distributed to the public providing a summary of the three proposed floodplain management alternatives. The Study Team made a brief presentation that outlined the major components to each of the alternatives. The public gave their input regarding the initial alternatives, their preferences, and any recommendations they may have for other alternatives.

The final public meeting was held on June 28, 2001 at the Desert Mountain Middle School in Phoenix. Flyers were mailed to local homeowners and previous workshop attendees. At this meeting, a handout was distributed to the public that outlined the recommended floodplain management alternative. The June 2001 public meeting was held in an open house format and Study Team members were available to receive input from the public regarding the recommended alternative. Information was also provided on the flood warning system being proposed as part of the planning initiative.

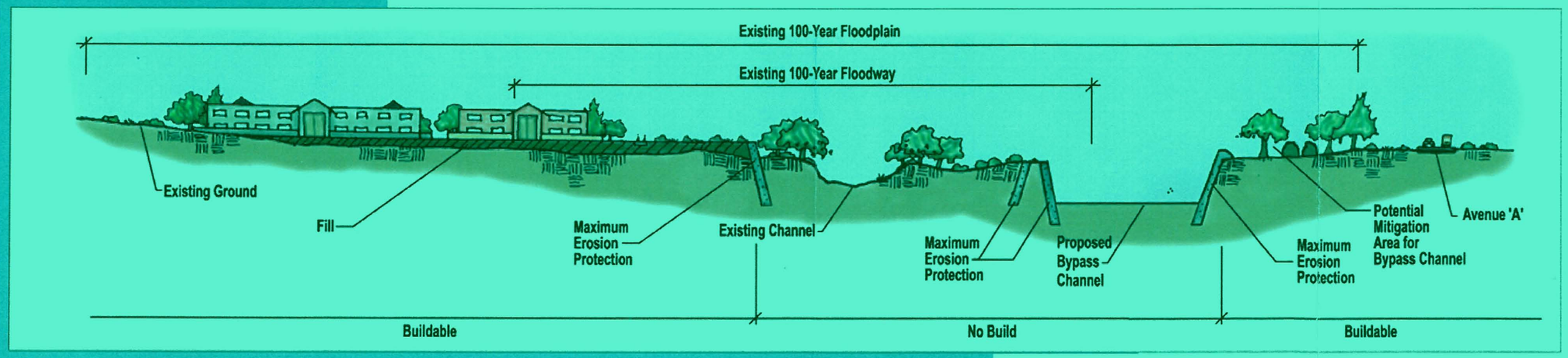
June 28, 2001 Open House

The results of the technical analyses show existing residences are located in the *FEMA 100-year floodway*. These residences were constructed prior to the adoption of the existing *FEMA 100-year floodway* in 1997. The location of these residences is an area very hazardous to public safety, both from a flood and *erosion* standpoint. The District sent letters to the owners of the identified properties requesting that each property owner contact the District to schedule a meeting regarding the floodplain status of their property. Six (6) property owners responded and individual meetings were held at the property in



North View

Perspective Sketch

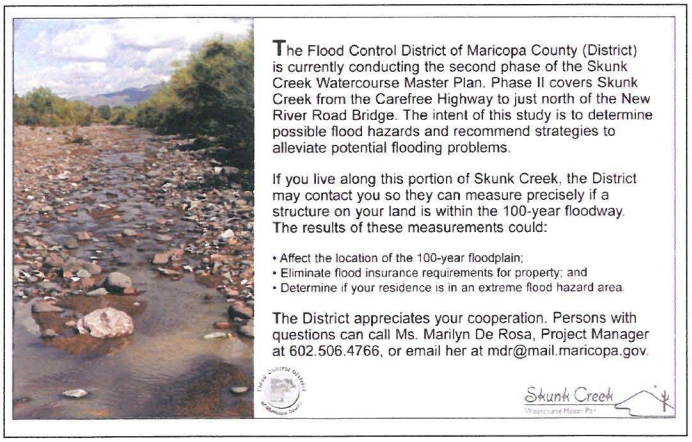


Section

Sonoran Wash Main Stem-Stakeholders Alternative

Figure 3. Exhibit Example from May 2000 Public Meeting

question. Materials specific to each property were handed out to the property owners, and included a plan view of the parcel showing the *FEMA 100-year floodplain* and *floodway*, the *erosion* hazard zones, an aerial photograph of the property and the property boundary. Also included was a cross section of Skunk Creek taken through the residence and significant outbuildings on which was shown the structure finished floor elevation and the estimated 100-year flood water surface elevation and floodway limits. A written summary of findings for the parcel, and a table of historical flood peak flow rates for Skunk Creek at the crossing of Interstate 17 (I-17) were handed out. The proposed *watercourse* management alternatives were described, and the possible effects of each alternative were presented to the property owners. Preliminary WCMP implementation strategies were explained; including a potential voluntary acquisition program for residences located within the *FEMA 100-year floodway*. Property owners expressed the desire to have the District establish a flood warning/notification system for the area as soon as possible, and most favored a voluntary acquisition program for existing residences located within the *FEMA 100-year floodway*. It was made clear to each property owner that a acquisition program would require approval by the Maricopa County Board of Supervisors, and could take several years for funding. Follow up meetings were held with several property owners at their request, and with some of their neighbors. Time was also spent with interested property owners at each public meeting. The District sent letters, including the handout materials, to the property owners that did not respond to prior notices.



The Flood Control District of Maricopa County (District) is currently conducting the second phase of the Skunk Creek Watercourse Master Plan. Phase II covers Skunk Creek from the Carefree Highway to just north of the New River Road Bridge. The intent of this study is to determine possible flood hazards and recommend strategies to alleviate potential flooding problems.

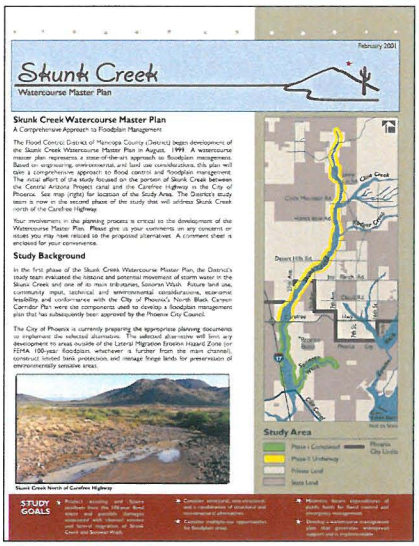
If you live along this portion of Skunk Creek, the District may contact you so they can measure precisely if a structure on your land is within the 100-year floodway. The results of these measurements could:

- Affect the location of the 100-year floodplain;
- Eliminate flood insurance requirements for property; and
- Determine if your residence is in an extreme flood hazard area.

The District appreciates your cooperation. Persons with questions can call Ms. Marilyn De Rosa, Project Manager at 602.506.4766, or email her at mdr@mail.maricopa.gov.

Skunk Creek

Study Advertisement Published in Foothills Sentinel.



February 2001 Newsletter

4 Watercourse General Characteristics

The study area is located within the COP and unincorporated areas of the northern portion of Maricopa County. The small rural community of New River is located at the north end of the study area, with the Anthem, Dynamite Mountain Ranch, and Tramonto residential communities lying to the west and south. Lands within the study area are primarily privately owned with some land owned by the Arizona State Land Department (ASLD) and the Bureau of Reclamation (BOR). Refer to Table 1 for the percentages of private versus State and Federal land ownership for the two phases of the study. Minor elevation differences within the study area provide panoramic views of mountainous and mesa landforms, undeveloped desert areas, and rural development. The desert *watercourses* within the study area are generally undisturbed, with the desert riparian vegetation adjacent to the *watercourse channel* intact. The regional and local planning strategies that affect the WCMP study area, and the physical characteristics of the study *watercourses*, are described in the following sections.

A. Regional and Local Planning Strategies

There are several planning documents that provide recommendations regarding land use and development characteristics for the build-out of the planning study area. These documents include Maricopa County's New River Area Plan, the COP's North Black Canyon Corridor Plan and Sonoran Desert Preserve Plan, and Maricopa Association of Governments' (MAG) Desert Spaces Plan. In addition, the County and COP adopted the Carefree Highway Scenic Corridor Study. A brief summary of the planning documents and their relevance to Skunk Creek are provided below.

1. Maricopa County's New River Area Plan

In 1985 the Maricopa County Planning and Development Department requested proposals from professional planning firms to create seven specific land use plans as part of the Maricopa County Comprehensive Land Use Plan. The New River planning area was included as one of these seven areas. For the planning areas, existing data was reviewed to formulate goals and policies to guide land development. The New River Land Use Plan was first adopted November 5, 1990 and updated in 1999. The adoption of the Eye to the Future 2020, Maricopa County Comprehensive Plan in October 1997 required the update of all area plans. The updated New River Area Plan was adopted April 7, 1999. The purpose of the plan is to promote high quality living and community development, while preserving a variety of lifestyles and the Sonoran Desert. Portions of the study area north of the COP corporate boundary are addressed in the New River Area Plan and are primarily designated as open space.

2. City of Phoenix's North Black Canyon Corridor Plan

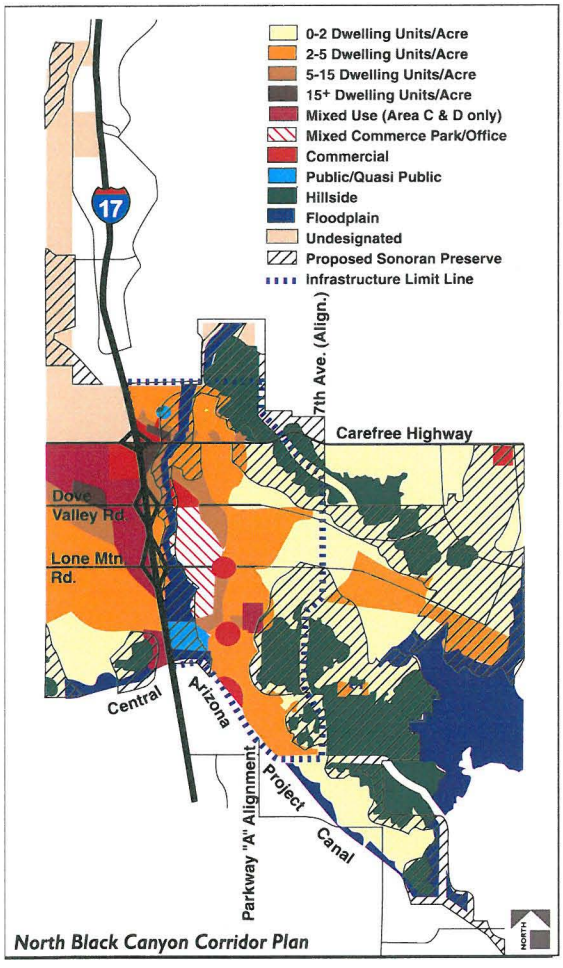
In 1987, the study area was part of the COP's adopted General Plan for Peripheral Areas C and D. The plan for Peripheral Areas C and D provided recommendations regarding land use and development characteristics

Table 1

Summary of Areas of Private Land vs State and Federal Owned Land

WCMP Phase (1)	Private Land		State Land		Federal Land		Total
	acres (2)	% (3)	acres (4)	% (5)	acres (6)	% (7)	acres (8)
Phase 1	359.4	37.8	494.6	52.0	97.9	10.3	951.9
Phase 2	1041.7	74.0	366.9	26.0	0.0	0.0	1408.6
Totals	**1401.1**	**59.4**	**861.5**	**36.5**	**97.9**	**4.1**	**2360.5**

for build-out of the planning area. In 1994 the COP began to guide growth under a new set of concepts entitled the Strategic View of Growth. These concepts suggested Phoenix was growing as a family of regional communities. Several of the planning efforts described in the Strategic View of Growth have been completed and implemented. One of these efforts was for the area known as the North Black Canyon Corridor. The North Black Canyon Corridor Plan was adopted in the fall of 1997 by the City Council. The concept plan proposed the development of a regional employment center and residential areas integrated with the surrounding desert environment. As a result of this concept plan a General Plan amendment (GPA-NG-1-97-1-2) regarding revised land use and General Plan text was proposed and approved. The entire portion of the study area addressed in Phase 1 of the WCMP is regulated by the COP and is covered by the North Black Canyon Corridor Plan.



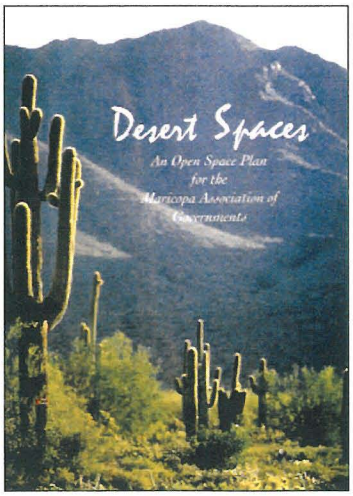
North Black Canyon Corridor Land Use Plan

3. Carefree Highway Scenic Corridor Study

The Carefree Highway Scenic Corridor Study was completed in March of 1997 and adopted by the Maricopa County Board of Supervisors on May 14, 1997. The plan was created by a Technical Advisory Committee, which included representatives from the State of Arizona, Maricopa County, and local municipalities. The plan provides recommended policies to balance the retention of scenic qualities with the provision of safe and efficient traffic flow and the reality of development. Skunk Creek and the associated WCMP study area intersect the Carefree Highway and nearby hillsides that are addressed in the Carefree Highway Scenic Corridor Study.

4. Desert Spaces

The MAG Regional Council adopted the Desert Spaces plan for the 9,200 square mile region of Maricopa County in 1995. The intent of this plan is to provide a non-regulatory framework directed toward establishing a regional open-space network by defining regionally significant mountains, rivers, *watercourses*, and upland desert. The Desert Spaces plan identified Skunk Creek as having outstanding open space values. The WCMP study area is within the areas defined in Desert Spaces as Environmentally Sensitive Development Areas (ESDA). Development in these areas should be limited to designs that retain the integrity of regionally and locally significant natural features, wildlife habitats, scenic resources, and cultural resources. Rivers



Desert Spaces Plan

and washes of regional significance within ESDA areas should be managed to retain their natural character and public access to them.

5. Sonoran Desert Preserve Plan

Utilizing the 1993 Desert Preserve Preliminary Plan and the 1995 Desert Spaces plan, the Sonoran Preserve Master Plan was approved by the Phoenix City Council in 1998. The residents of the COP approved by an 80% vote in May of 2000 to pursue acquisition of approximately 20,000 acres of lands held by the ASLD that were identified in the 1998 Sonoran Desert Preserve Plan. The purpose of this plan is to accommodate quality growth and preservation of the Sonoran Desert. The stated goals of the plan were not only to preserve significant portions of the Sonoran Desert, but also to preserve the natural hydrologic processes. These goals can be accomplished by preserving the floodway, the definable 100-year floodplain, and buffers wide enough to allow for the natural meandering of the *watercourse* over time. Several areas within and adjacent to the WCMP study area are recommended for preservation under the Sonoran Desert Preserve Plan.

The Sonoran Preserve Master Plan evolved through an extensive four-year public involvement process. This reflects the nationwide trend towards promoting nonstructural approaches and ecosystem preservation, as witnessed by the removal of flood control structures in many parts of the country. Federal agencies such as the U.S. Army Corps of Engineers and the BOR have, in recent years, significantly changed their focus from hard engineering solutions to include nonstructural alternatives, preservation of natural hydrologic functions, and ecosystem restoration.

B. Watercourse Characteristics

Skunk Creek is a moderately large *ephemeral watercourse* that originates in the New River Mountains, northeast of the unincorporated rural community of New River. Skunk Creek flows southward from the New River Mountains, across the Little Deer Valley and northern Phoenix, and into the Adobe Dam impoundment area. Prior to the construction of Adobe Dam in 1982, Skunk Creek flowed freely through the Little Deer Valley, around the edge of the Hedgpeth Hills (where the dam is now located), and then southwest across Deer Valley in northern Glendale toward its confluence with New River. Between the study area and Adobe Dam, Skunk Creek is now controlled through most of that *reach* by levees or channelization. The *reach* of Skunk Creek below I-17 is heavily developed with residential and commercial land uses and a major landfill. This downstream *reach* is also very susceptible to flooding breakouts where the structural drainage features have limited freeboard in excess of the design discharge. The potential for flooding breakouts is particularly true upstream of Pinnacle Peak Road at 35th Avenue where a small increase in discharge over the 100-year existing condition peak discharge can cause Skunk Creek to overtop its banks and flood adjacent neighborhoods. This issue is important because management methods for the WCMP affect public safety in these areas.

Skunk Creek Downstream of Adobe Dam

Sonoran Wash is a small *ephemeral watercourse* that originates in the Union Hills east of Skunk Creek. Sonoran Wash flows westerly out of the Union Hills and then south around the hills, across the CAP Canal, and joins Skunk Creek about 0.5 miles south of the CAP Canal. Sonoran Wash is a relatively intact natural *watercourse* that has heavily vegetated banks for most of the entire study area.

Sonoran Wash

The Skunk Creek watershed for the study area is about 50.3 square miles at the CAP Canal and encompasses portions of the COP, unincorporated Maricopa County, and the Tonto National Forest. Much of the watershed is comprised of undeveloped desert mountain terrain or desert upland foothills with low-density suburban ranch development. Higher density commercial, industrial, and residential development is planned or under construction in the southern portion of the study area, especially within the COP. Construction of the 1,100-acre Tramonto development between Cloud Road and the Carefree Highway is currently underway, with numerous other large developments in the planning phases in the Phase 1 portion of the study area. The Del Webb Anthem development extends into the study area between Desert Hills Drive and Rockaway Hills Road, although the portions along Skunk Creek have yet to be constructed. The Sonoran Wash watershed for the study area is about 13.4 square miles, and is also expected to experience rapid urbanization.

Elevations within the creek bed of Skunk Creek Phase 1 range from approximately 1,519 feet above mean sea level (MSL) at the CAP Canal to 1,671 feet above MSL at the Carefree Highway, over a length of 3.9 miles. The *watercourse* study area elevations within the creek bed of Sonoran Wash range from approximately 1,518 feet above MSL at the CAP Canal to 1,622 feet above MSL at the upstream study limit, over a length of 3.3 miles. Elevations within the creek bed of Skunk Creek Phase 2 range from approximately 1,671 feet above MSL at the Carefree Highway to 2,122 feet above MSL at the upstream study limit, over a length of 9.3 miles. The total length of the study area is 13.2 miles for Skunk Creek, and 16.5 miles when Sonoran Wash is included.

As part of the study process, Skunk Creek and Sonoran Wash were categorized into segments with similar characteristics, called *reaches*. These *reaches* were defined based on landscape character, including vegetation, landforms, land use, and special features, and the geomorphologic and hydraulic considerations of each *watercourse*. Figures 4 through 18 illustrate the unique characteristics of the *reaches* within the study area. The floodplain management alternatives developed for the WCMP were based on the analyses of these *reaches*. The characteristics of each *reach* are identified in Tables 2, 3 and 4.

Skunk Creek

Land Use/ Land Form

- Undeveloped land use with mining operation adjacent to watercourse

Special Features

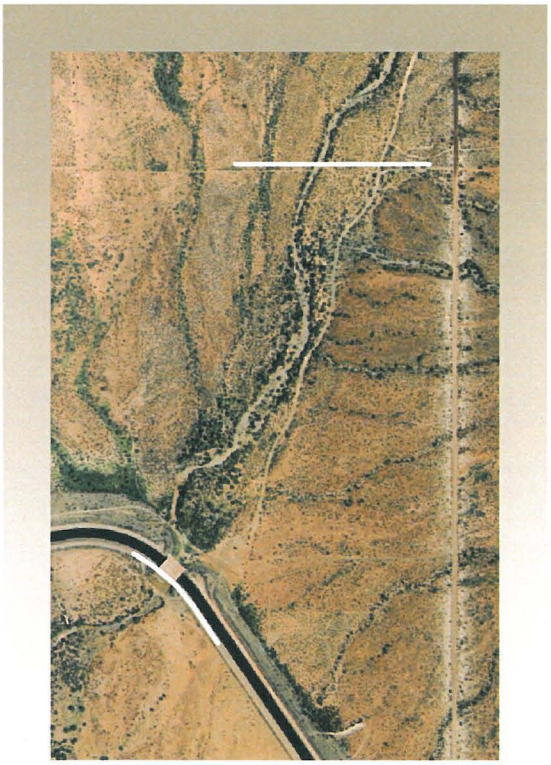
- CAP Canal and overchute
- Mesquite bosque

Channel

- Channel width varies
- Bottom cover predominately sandy
- Low bank height

Vegetation

- Relatively dense desertscrub upland and riparian vegetation



July 1999 Aerial Photograph

Phase I Key Map:

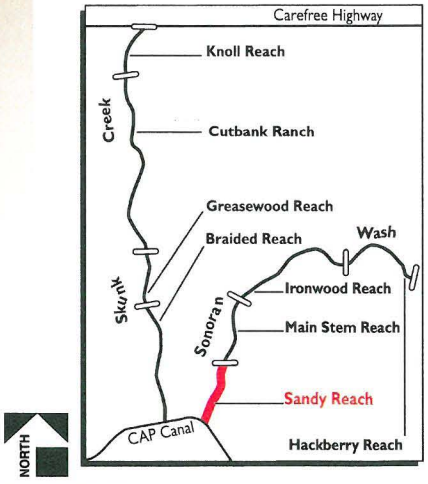


Figure 4. Sonoran Wash - Sandy Reach Landscape Character

Land Use/ Land Form

- Undeveloped land use with mining operations adjacent to watercourse

Special Features

- Mining operations
- Dense desert riparian vegetation

Channel

- Channel width relatively uniform
- Bottom cover predominately sandy/gravel surface
- Bank height varies

Vegetation

- Open desertscrub upland and desert riparian vegetation

July 1999 Aerial Photograph

Phase I Key Map:

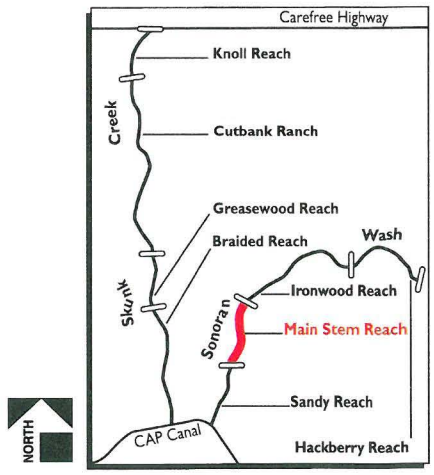
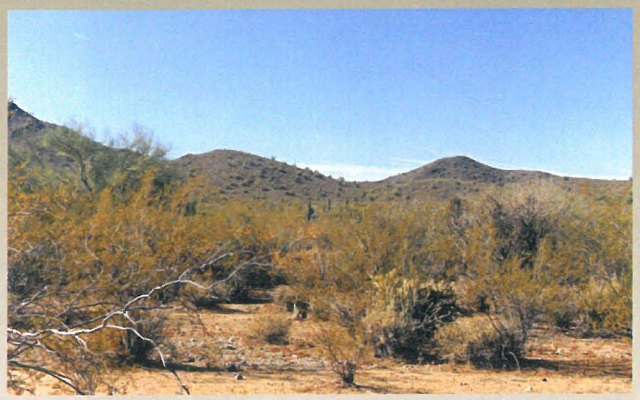


Figure 5. Sonoran Wash - Main Stem Reach Landscape Character

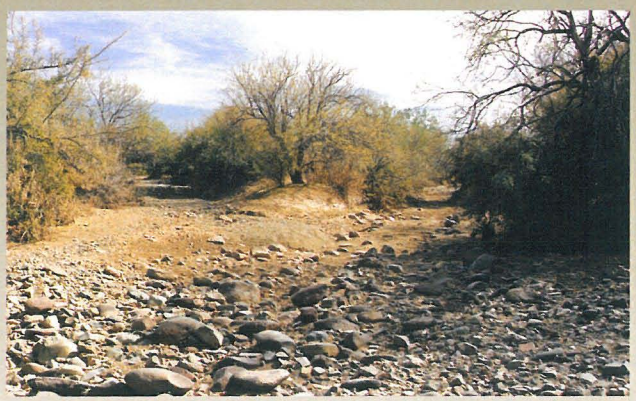


Land Use/ Land Form

- Undeveloped land use with mining operations adjacent to watercourse
- Relatively flat, uniform terrain transitioning to foothills of Union Hills

Special Features

- Gravel mining operation
- Desert riparian habitat
- Union Hills

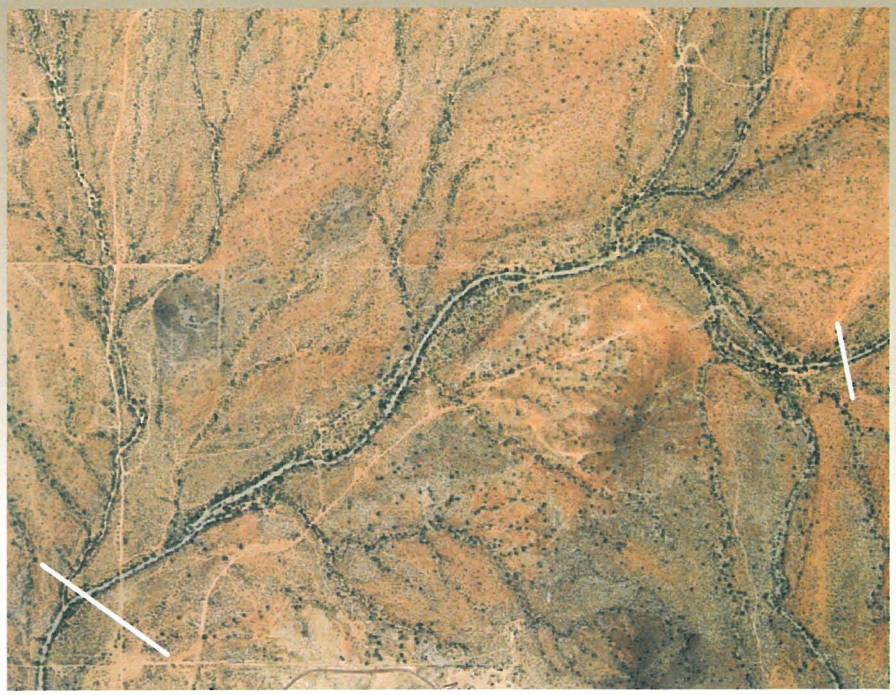


Channel

- Multiple channels
- Bottom cover includes sandy cobble surfaces
- Bank height varies

Vegetation

- Moderately desertscrub upland and riparian vegetation



July 1999 Aerial Photograph

Phase I Key Map:

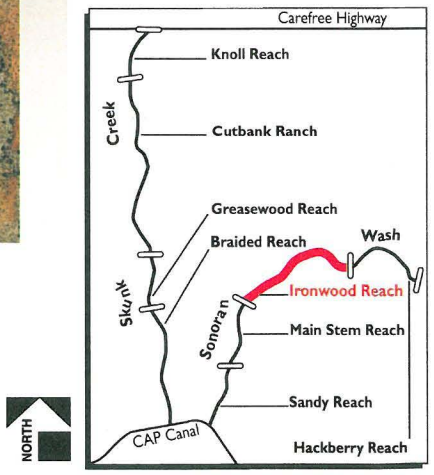
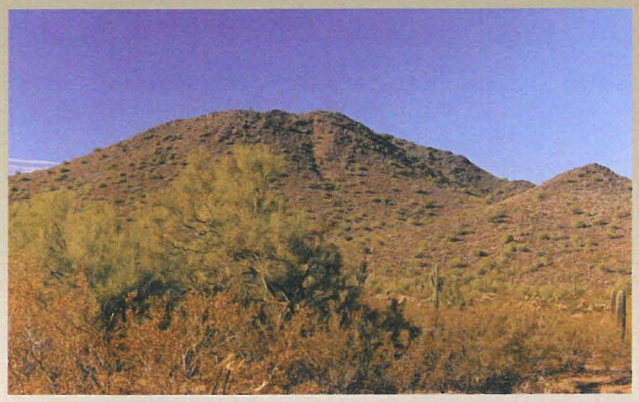


Figure 6. Sonoran Wash - Ironwood Reach Landscape Character



Land Use/ Land Form

- Undeveloped land use transitioning to foothills of Union Hills

Special Features

- Union Hills
- Desert riparian vegetation

Channel

- Channel bed generally sand and gravel
- Occasional cobble/boulder surface cover
- Low bank height

Vegetation

- Dense vegetation of mesquite and hackberry trees line watercourse banks

July 1999 Aerial Photograph

Phase I Key Map:

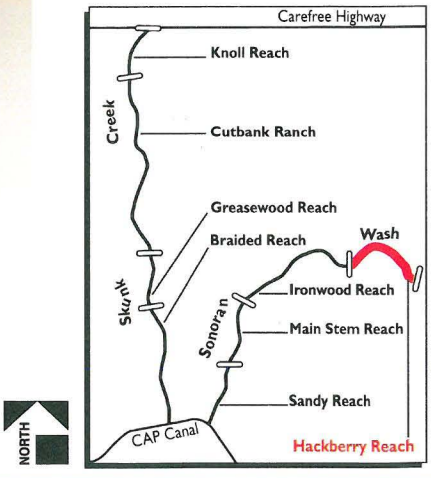


Figure 7. Sonoran Wash - Hackberry Reach Landscape Character

Land Use/ Land Form

- Undeveloped land use
- Braided or multiple channels create low, rolling landforms

Special Features

- CAP Canal and overchute
- Interstate 17

Channel

- Channel bottom varies from sandy to cobble
- Moderate to low bank height

Vegetation

- Relatively uniform vegetation cover between braided channels
- Predominately open creosotebush flats

July 1999 Aerial Photograph

Phase I Key Map:

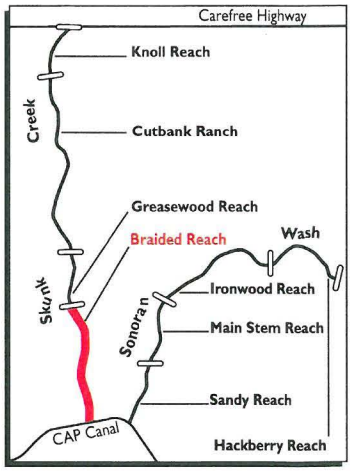


Figure 8. Skunk Creek - Braided Reach Landscape Character

Land Use/ Land Form

- Relatively flat, uniform terrain
- Undeveloped land use

Special Features

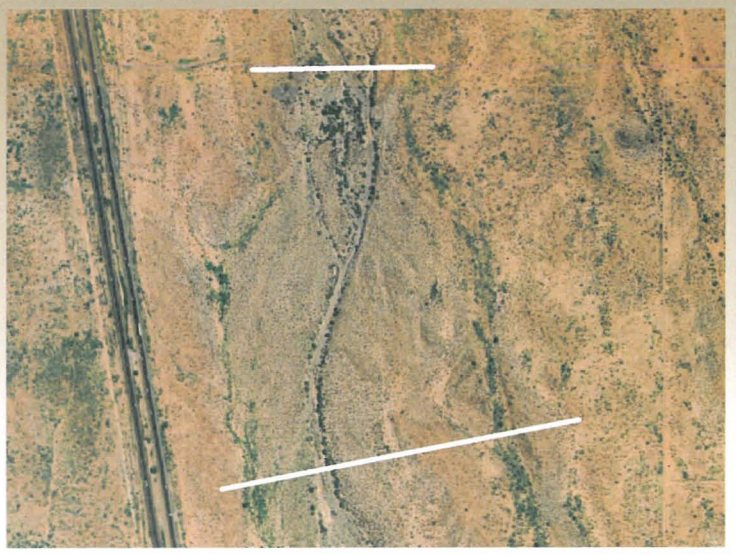
- Interstate 17
- Gravel mine operations

Channel

- Channel width uniform
- Bottom cover includes sandy cobble surfaces
- Moderate bank height

Vegetation

- Open, creosotebush flats and 'shrub' size riparian vegetation



July 1999 Aerial Photograph

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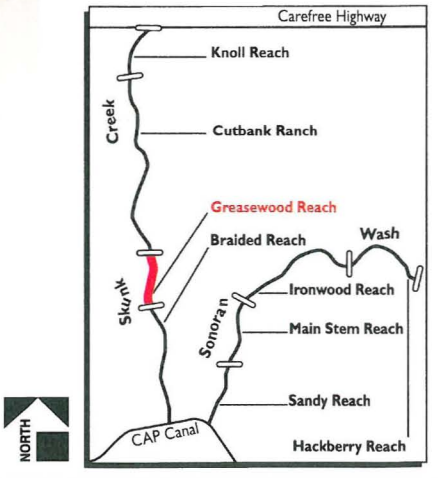


Figure 9. Skunk Creek - Greasewood Reach Landscape Character

Land Use/ Land Form

- Undeveloped land use

Special Features

- Bronco Butte
- Interstate 17
- High, cobbled embankments

Channel

- Channel width varies
- Bottom cover includes sandy cobble surfaces
- High bank height

Vegetation

- Sparse, creosotebush upland
- Open riparian vegetation

July 1999 Aerial Photograph

Phase I Key Map:

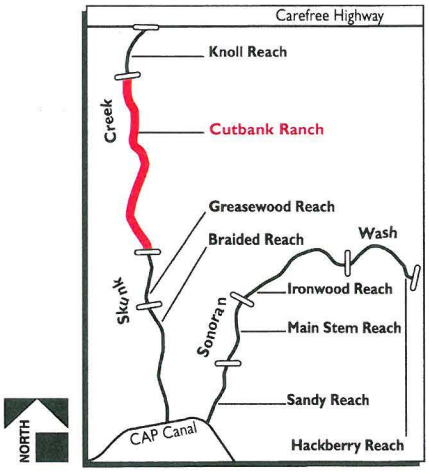


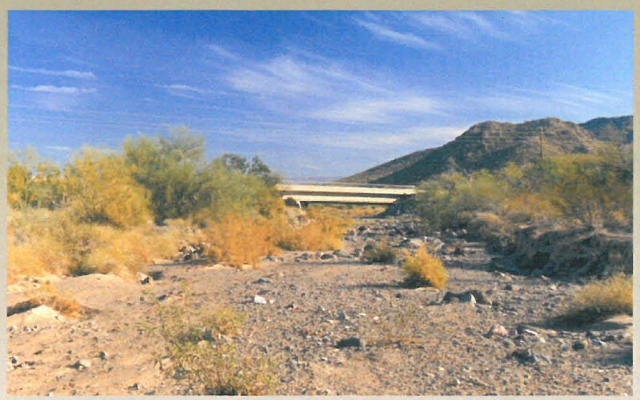
Figure 10. Skunk Creek - Cutbank Reach Landscape Character

Land Use/ Land Form

- Relatively undeveloped land use except for knoll landform

Special Features

- Carefree Highway Bridge
- Knoll landform
- Power substation



Channel

- Channel width varies
- Bottom cover includes sandy cobble surfaces
- Moderate to Low bank height

Vegetation

- Dense riparian vegetation
- Saguaros scattered on knoll

July 1999 Aerial Photograph

Phase I Key Map:

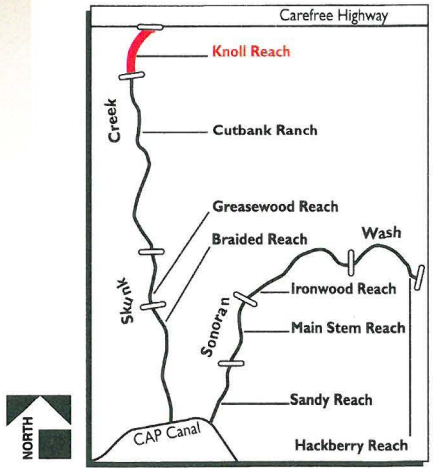


Figure 11. Skunk Creek - Knoll Reach Landscape Character

Land Use/ Land Form

- Planned community development under construction
- Relatively flat, uniform terrain

Special Features

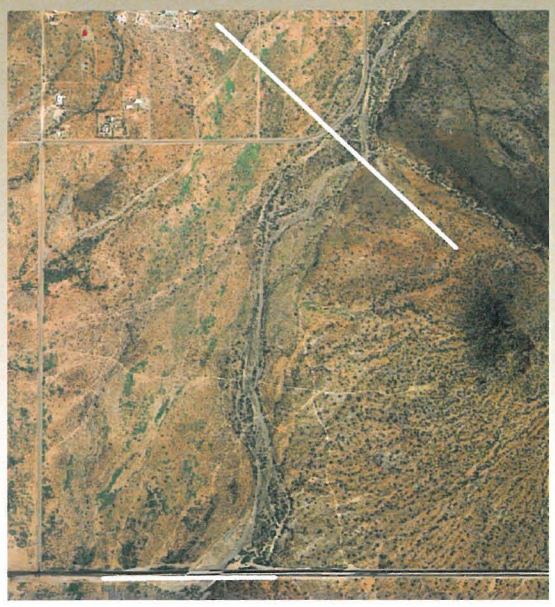
- Carefree Highway Bridge

Channel

- Channel width varies
- Bottom cover includes sandy cobble surfaces
- Low bank height

Vegetation

- Open desertscrub upland and riparian vegetation



July 1999 Aerial Photograph

Phase 2 Key Map:

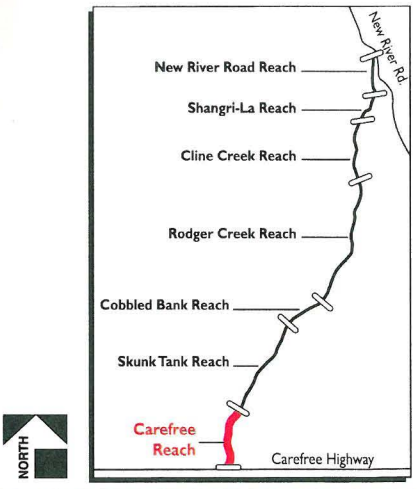
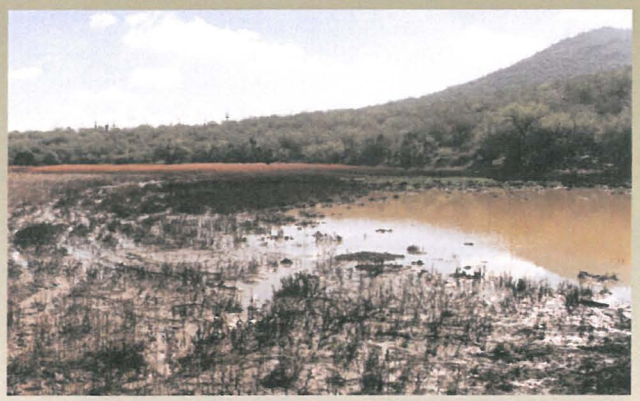


Figure 12. Skunk Creek - Carefree Highway Reach Landscape Character

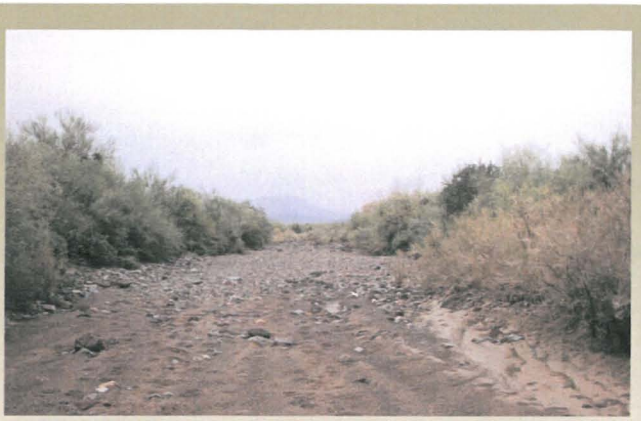


Land Use/ Land Form

- Master planned community under construction
- Adjacent scattered ranch properties
- Foothills of Daisy Mountain to west

Special Features

- Daisy Mountain
- Skunk Tank



Channel

- Braided multiple channels
- Channel width varies
- Relatively low banks

Vegetation

- Relatively sparse upland desertscrub vegetation
- Dense desert riparian vegetation along banks

July 1999 Aerial Photograph

Phase 2 Key Map:

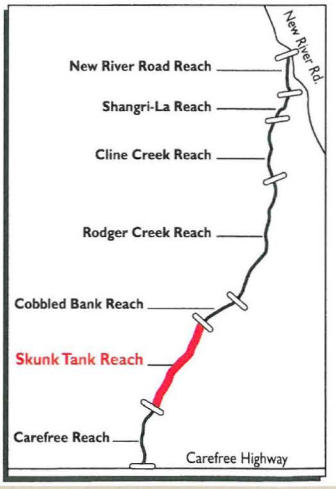


Figure 13. Skunk Creek - Skunk Tank Reach Landscape Character

Land Use/ Land Form

- Master planned community under construction
- Adjacent scattered ranch properties
- Foothills of Daisy Mountain to west

Special Features

- Daisy Mountain
- Cobbled channel banks

Channel

- Braided multiple channels
- Notable cobbled banks
- Variable channel width

Vegetation

- Notable desert riparian vegetation along banks
- Sparse upland vegetation

July 1999 Aerial Photograph

Phase 2 Key Map:

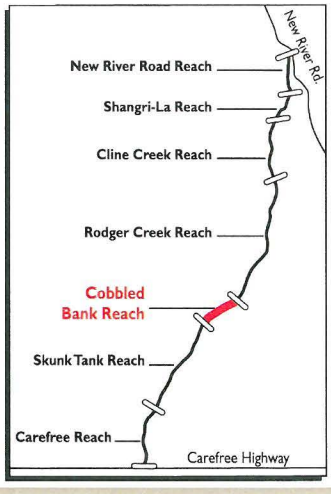


Figure 14. Skunk Creek - Cobbled Bank Reach Landscape Character

Land Use/ Land Form

- Predominately undeveloped
- Relatively flat terrain to east
- Foothills of Daisy Mountain to west

Special Features

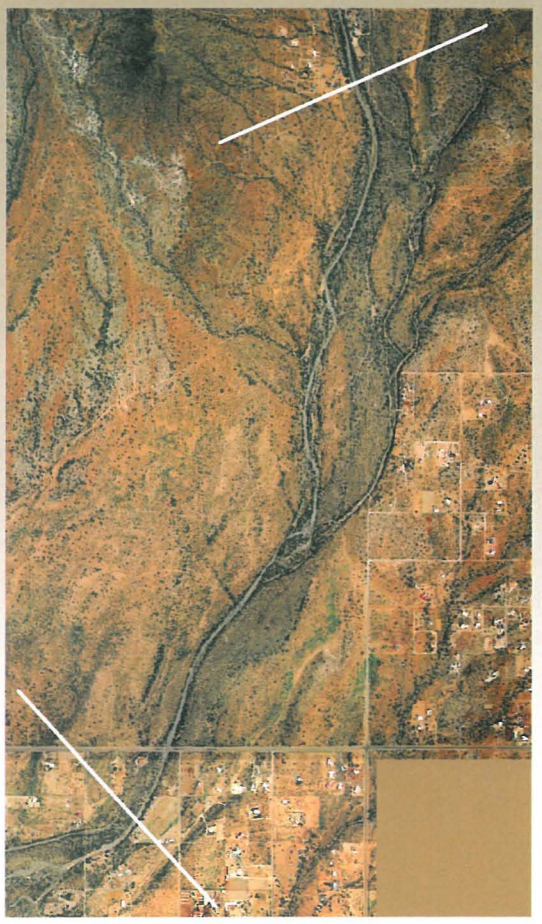
- Rodger Creek
- High, cobbled embankment

Channel

- High banks
- Uniform channel width
- Channel bottom varies from sandy to cobble surface cover

Vegetation

- Notable desert riparian vegetation along banks
- Sparse upland vegetation



July 1999 Aerial Photograph

Phase 2 Key Map:

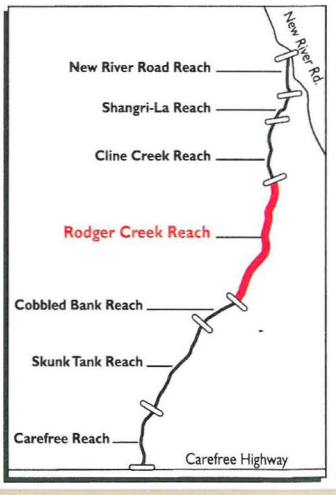
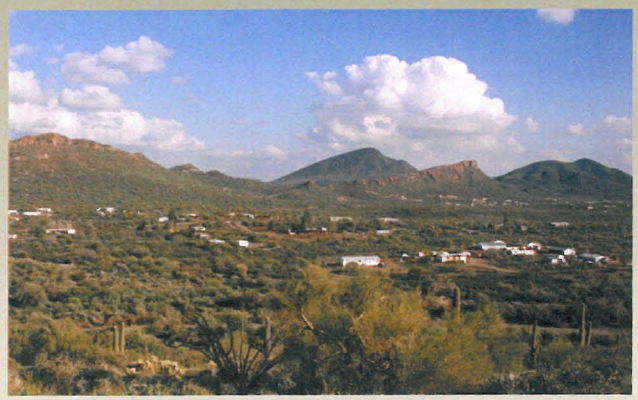


Figure 15. Skunk Creek - Rodger Creek Reach Landscape Character



Land Use/ Land Form

- Prominent hillside landform to west
- Relatively flat terrain to east
- Low density residential

Special Features

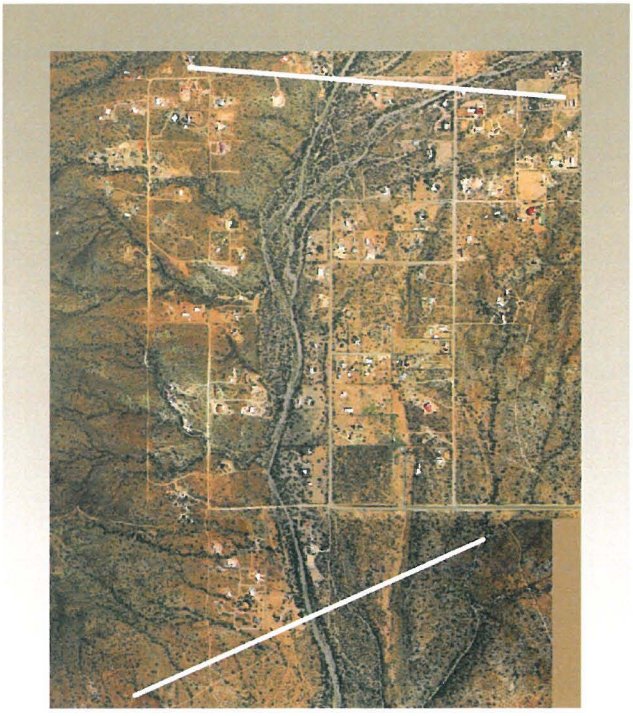
- Daisy Mountain
- Cline Creek
- Overhead transmission line

Channel

- Uniform channel branching into multiple channels at the confluence of Skunk Creek and Cline Creek
- Channel bottom varies from sandy to cobble
- Bank height varies

Vegetation

- Dense desert riparian vegetation along banks
- Notable presence of saguaro cacti



July 1999 Aerial Photograph

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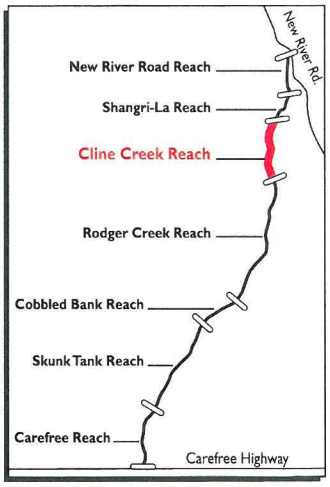
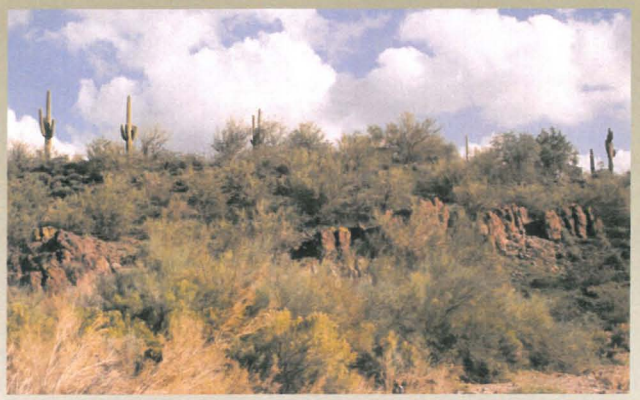


Figure 16. Skunk Creek - Cline Creek Reach Landscape Character



Land Use/ Land Form

- Low density rural residential
- Rolling terrain

Special Features

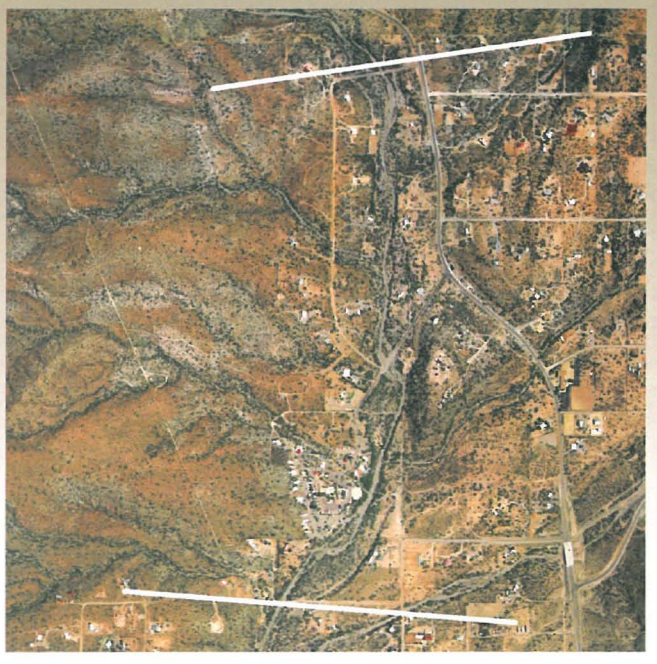
- Daisy Mountain
- Rock outcrops
- High density of saguaro cacti
- Scattered residences

Channel

- Cobble bottom channel
- High banks
- Channel width varies

Vegetation

- Dense desert riparian and upland vegetation



July 1999 Aerial Photograph

Phase 2 Key Map:

Figure 17. Skunk Creek - Shangri La Reach Landscape Character

Land Use/ Land Form

- Relatively undeveloped with scattered residential
- Gently rolling to flat terrain

Special Features

- Daisy Mountain
- New River Road Bridge

Channel

- Cobble bottom channel except at bridge
- Low bank height
- Channel width varies

Vegetation

- Dense desert riparian vegetation along banks
- Low scrubby upland vegetation

July 1999 Aerial Photograph

Phase 2 Key Map:

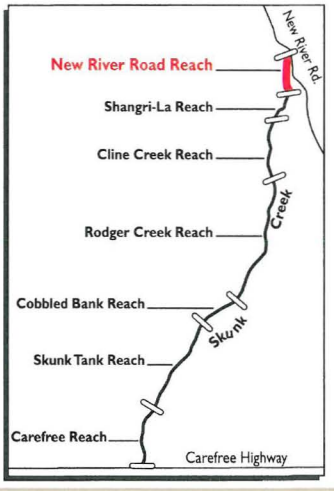


Figure 18. Skunk Creek - New River Road Reach Landscape Character

Table 2

Sonoran Wash Phase 1 Reach Descriptions

Reach (1)	Vegetation (2)	Landform (3)	Land Use (4)	Special Features (5)	Hydraulic/ Geomorphologic[1] (6)
Sandy	Vegetation consists of a variety of mesquite, palo verde, ironwood, and acacia trees. Channel banks are heavily vegetated with trees and shrubs as well as upland areas. Mesquite bosque located near backwater area of CAP Canal.	Relatively flat, uniform terrain. Watercourse has multiple channels in some locations within the reach. Channel bottom predominately sand/gravel surfaces, and bank heights are relatively low.	Relatively undeveloped land use. Numerous dirt roads cross and parallel the watercourse.	Mesquite bosque, CAP Canal and concrete overchute.	Wide, shallow main channel with sand/gravel bed. Aggrading channel. Bankfull R.I.=4-yr. D=4.2'. TW=90'. V_{mean}=4.5 fps.
Main Stem	Vegetation consists of a variety of mesquite, palo verde, ironwood, and acacia trees. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat, uniform terrain. Watercourse has wide, uniform channel with sand/gravel surface. Banks vary in height.	Relatively undeveloped land use with mining operations adjacent to watercourse.	Gravel mining operations, desert riparian vegetation, and Union Hills.	Wide, deep main channel with sand/gravel bed. Degrading channel. Bankfull R.I.=8-yr. D=6.2'. TW=79'. V_{mean}=6.5 fps.
Ironwood	Vegetation consists of a variety of mesquite, palo verde, ironwood, and acacia trees. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat, uniform terrain transitioning to foothills of the Union Hills. Watercourse has multiple channels in some locations within the reach. Channel bottom includes sandy cobble surfaces, and banks vary in height.	Relatively undeveloped land use with mining operations adjacent to watercourse. Numerous dirt roads cross and parallel the watercourse.	Gravel mining operations, desert riparian vegetation, and Union Hills.	Pool-riffle channel with gravel/cobble/rock bed. Stable channel. Bankfull R.I.=6-yr. D=5.4'. TW=60'. V_{mean}=6 fps.
Hackberry	Dense vegetation, predominately mesquite, palo verde, and hackberrys. Upland area has scattered saguaro cacti.	Relatively flat, uniform terrain transitioning to foothills of the Union Hills. Watercourse is relatively narrow with sand, and gravel and occasional cobble surface cover.	Relatively undeveloped land use with mining operations adjacent to watercourse. Numerous dirt roads parallel the watercourse.	Gravel mining operations, desert riparian vegetation, and Union Hills.	Narrow, well-defined main channel with sand/gravel bed. Aggrading channel. Bankfull R.I.=5-yr. D=4.1'. TW=50'. V_{mean}=4.8 fps.

[1] Main Channel Parameters: Bankfull R.I. = Bank Full Recurrence Interval, D = Max. Depth, TW = Top Width, V_{mean} = Mean Velocity

Table 3

Skunk Creek Phase 1 Reach Descriptions

Reach (1)	Vegetation (2)	Landform (3)	Land Use (4)	Special Features (5)	Hydraulic/ Geomorphologic (6)
Braided	Relatively uniform vegetation cover between braided channels. Vegetation primarily creosotebush with palo verde and mesquite trees associated with the watercourse.	Braided or multiple channels create low, rolling landforms. Channel bottom varies from sandy to cobble surface cover. Moderate to low bank height.	Relatively undeveloped land use.	CAP Canal, concrete overchute, and I-17.	Wide, shallow braided main channel with sand/gravel/cobble bed. Aggrading channel. Bankfull R.I.=10-yr. D=7.3'. TW=123'. V_{mean}=7.6 fps.
Greasewood	Vegetation consists of a variety of palo verde, mesquite, ironwood, and acacia trees. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat, uniform terrain. Channel width uniform and bottom cover includes sandy cobbled surfaces. Moderate bank height.	Relatively undeveloped land use.	Gravel mine operations and I-17.	Transition from single to braided main channel with pool-riffle bed. Degrading channel. Bankfull R.I.=10-yr. D=7.3'. TW=123'. V_{mean}=7.6 fps.
Cutbank	Vegetation consists of sparse creosotebush in upland areas. Open riparian vegetation with some mesquite and palo verde trees associated with the channel banks.	Relatively flat, uniform terrain. Channel width varies and bottom cover includes sandy cobble surfaces. Bank heights are high.	Relatively undeveloped land use.	Bronco Butte and I-17.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=6.5'. TW=123'. V_{mean}=9.1 fps.
Knoll	Dense vegetation, predominately mesquite, palo verde, and acacias. Upland area has scattered saguaro cacti.	Relatively flat, uniform terrain except for knoll landform adjacent to the east of the watercourse. Channel width varies. Bottom cover includes sandy cobbled surfaces with moderate to low bank heights.	Relatively undeveloped land use.	Carefree Highway Bridge, knoll landform, and power substation.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=6.5'. TW=123'. V_{mean}=9.1 fps.

[1] Main Channel Parameters: Bankfull R.I. = Bank Full Recurrence Interval, D = Max. Depth, TW = Top Width, V_{mean} = Mean Velocity

Table 4

Skunk Creek Phase 2 Reach Descriptions

Reach (1)	Vegetation (2)	Landform (3)	Land Use (4)	Special Features (5)	Hydraulic/ Geomorphologic (6)
Carefree	Vegetation consists predominately of mesquite and palo verde trees. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat, uniform terrain. Channel widths vary and bank heights are relatively low .	Master Planned community development under construction.	Carefree Highway Bridge	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=6.2'. TW=144'. V_{mean}=8.0 fps.
Skunk Tank	Vegetation consists of a variety of Arizona Upland species. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat terrain, transitioning to foothills of mountainous landforms to the west. Braided, multiple channels of varying widths. Channel bottom predominately gravel/cobble surface. Relatively low bank heights.	Master planned community under construction. Adjacent scattered ranch properties.	Prominent view of Daisy Mountain and Skunk Tank.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=7.1'. TW=113'. V_{mean}=8.6 fps.
Cobbled Bank	Channel banks are moderately vegetated with both trees and shrubs. Upland area more open, with less dense vegetation.	Relatively flat, uniform terrain, transitioning to the foothills of Daisy Mountain to the west. Braided multiple channels with notable cobbled banks. Channel widths vary and bank heights low to moderate.	Master planned community under construction. Adjacent scattered ranch properties.	Prominent view of Daisy Mountain and cobbled channel banks.	Wide, braided multiple channels with notable cobble banks. Aggrading channel. Bankfull R.I.= <10-yr. D=7.1'. TW=113'. V_{mean}=8.6 fps.
Rodger Creek	Channel banks have dense vegetation with both trees and shrubs, but upland vegetation is relatively open with few small trees.	Relatively flat, uniform terrain to the east with foothills of Daisy Mountain to the west. Uniform channel width and bottom cover includes sandy and gravel/cobble surfaces. High bank heights.	Master Planned community development under construction.	Rodger Creek and high channel embankment.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.= 10-yr. D=7.1'. TW=113'. V_{mean}=8.6 fps.
Cline Creek	Vegetation consists predominately of mesquite and palo verde trees. Channel banks are heavily vegetated with both trees and shrubs.	Relatively flat terrain to the east of the watercourse transitioning to prominent hillside landforms to the west. Uniform channel branching into multiple channels at the confluence of Skunk Creek and Cline Creek. Channel bottom varies form sandy to cobble. Bank height varies from moderate to high.	Low density residential.	Prominent view of Daisy Mountain, Cline Creek, and overhead transmission lines.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=7.6'. TW=100'. V_{mean}=7.7 fps.
Shang-ri La	Vegetation consists typical Arizona Upland species - mesquite, saguaro, cholla, palo verde, and octillo. Channel banks are heavily vegetated with both trees and shrubs.	Rolling terrain. Channel width varies and bottom cover includes cobbled/gravel surfaces. High bank height.	Low density rural residential.	Prominent view of Daisy Mountain, rock outcroppings, and saguaro cacti.	Predominately single main channel with pool-riffle gravel/cobble bed. Degrading channel. Bankfull R.I.=10-yr. D=6.7'. TW=93'. V_{mean}=7.4 fps.
New River Road	Channel banks are heavily vegetated with both trees and shrubs. Upland area consists of low, scrubby upland vegetation.	Gently rolling to relatively flat terrain. Channel width varies and bottom cover includes cobbled/gravel surfaces. Low bank height.	Relatively undeveloped with scattered rural residential development.	New River Road Bridge and prominent view of Daisy Mountain.	Multiple channels w/pool-riffle gravel/cobble/rock bed. Unstable channel. Bankfull R.I.=5 to 60-yr. D=8-9'. TW=96 to 197'. V_{mean}=7.3 to 9.6 fps.

[1] Main Channel Parameters: Bankfull R.I. = Bank Full Recurrence Interval, D = Max. Depth, TW = Top Width, V_{mean} = Mean Velocity

5 Watercourse Environmental Characteristics

A general environmental overview of the study area was prepared, specifically identifying the visual characteristics, biological and cultural resources, land use, and recreation opportunities based on existing information and reconnaissance-level field investigation. The environmental characteristics were then summarized in terms of their influence on the planning process and used in the evaluation of floodplain management alternatives.

A. Visual Analysis

The existing visual resources of the study area, which are described below, are based on readily accessible viewpoints within the study area. These viewpoints include major road crossings, the Carefree Highway and New River Bridges, and notable landforms such as Bronco Butte and Union Hills.

Bronco Butte

Visual resources of the study area are evaluated in terms of the existing conditions of the landscape. The visual analysis includes an identification of distinct features, areas of high and low scenic quality, and location of major viewpoints. Distinct features are those features in the landscape that make a memorable impression such as Skunk Tank and the cliff formations in the portion of Skunk Creek Wash near Honda Bow Road. Scenic quality, or attractiveness, is based on the human perception of the inherent beauty of visual elements such as landform (mesas, valleys, and mountains), waterform (lakes, rivers, and drainages), vegetation, and built forms within the landscape.

Maricopa County designated Carefree Highway as a Scenic Corridor in 1997 in coordination with the COP and the other jurisdictional entities adjacent to the highway. The designation as a scenic roadway was done to preserve to the extent possible the natural quality of the adjacent desert vegetation and maintain the vistas of the nearby mountains and valley areas. Both the COP and Maricopa County have established policies for development adjacent to these roadways including *watercourse*-crossing setbacks in order to preserve the natural desert environment and vistas.

1. Phase 1 Visual Analysis

The visual analysis, shown graphically in Figure 19, presents the existing visual conditions of the landscape within Phase 1 of the study area. Distinct and notable natural features include Bronco Butte, landforms associated with Unions Hills, and the high banks along Skunk Creek. The ribbon of desertscrub riparian vegetation along Skunk Creek and Sonoran Wash, scattered statuesque saguaro cacti, and dense mesquite bosques are also distinct features that create visual interest and patterns within the landscape.

View Looking North From Bronco Butte

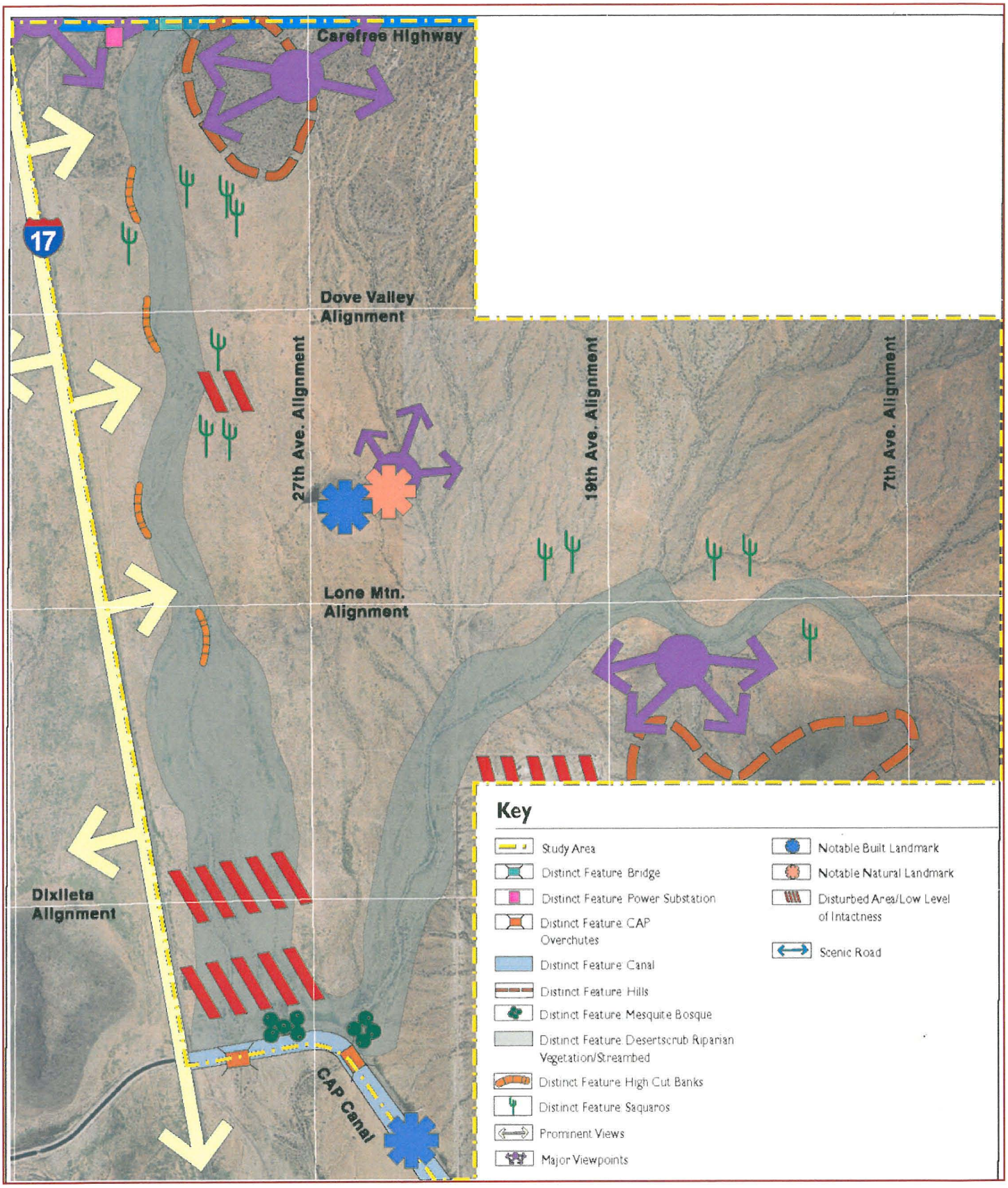


Figure 19. Phase 1 Visual Analysis

The views from within the *watercourses* are often restricted to the stream *channel* because of the dense desertscrub riparian vegetation present along the banks. The terrain is relatively flat in this portion of the study area, and there are panoramic views of distant landforms such as Pyramid Peak, the North Mountains, the Deem Hills and the Bradshaw Mountains from the study area. Bronco Butte offers an uninterrupted view of these landforms.

Built features modify the natural landscape. The distinct or memorable built features within the study area include the Carefree Highway Bridge, CAP Canal, Bronco Tank, a power substation, and numerous unpaved roads crossing randomly through the study area. Bronco Tank is a distinct feature because it is the only perennial source of water within the study area. I-17 runs parallel to the west of Skunk Creek and provides the opportunity for motorists traveling along the interstate to view the study area.

CAP Canal

Areas of low scenic integrity are generally landscapes that have been substantially modified from their natural conditions. The major area of disturbance visible from the study area is a granite mine located east of the study area, accessed by a gravel road along the 23rd Avenue alignment. The mining operations contrast in form, line, and color with the other features of the landscape. The access road and mine are anticipated to remain as a long-term use of the land. Within the study area, there are a few disturbed areas where the vegetation has been removed and the landscape's integrity notably modified.

Gravel Mine

2. Phase 2 Visual Analysis

The existing visual conditions of the landscape are illustrated in Figures 20 and 21. Outstanding natural features visible from within this portion of the study area include prominent on-site and off-site landforms, vegetation, and Skunk Creek. Skunk Creek and its tributaries, and the associated dense desertscrub riparian vegetation along their banks form a notable pattern in the landscape. Scattered along Skunk Creek are cliff formations that add interest and variety in the landscape along the stream *channel*. Distant views in the northern half of the Phase 2 study area are restricted by the presence of mountain/hill landforms to the east and west of Skunk Creek. The rolling terrain in the northern half also creates visual interest and contrast with the relatively flat terrain found in most of the other portions of the study area. Daisy Mountain and Pyramid

Rolling Terrain in the Phase 2 Area

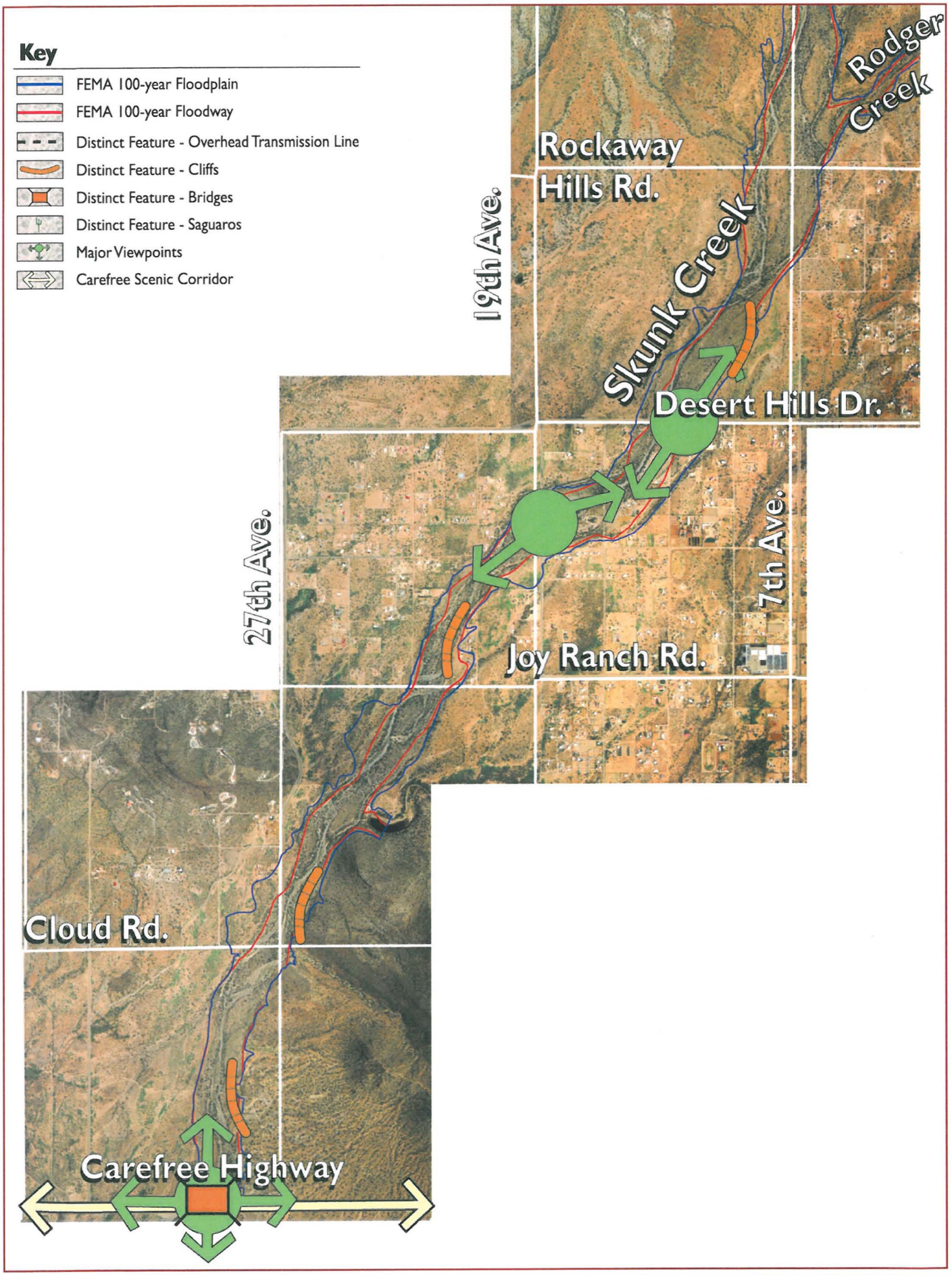


Figure 20. Phase 2 Visual Analysis (South Half)

Key

- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Distinct Feature - Overhead Transmission Line
- Distinct Feature - Cliffs
- Distinct Feature - Bridges
- Distinct Feature - Saguaros
- Major Viewpoints

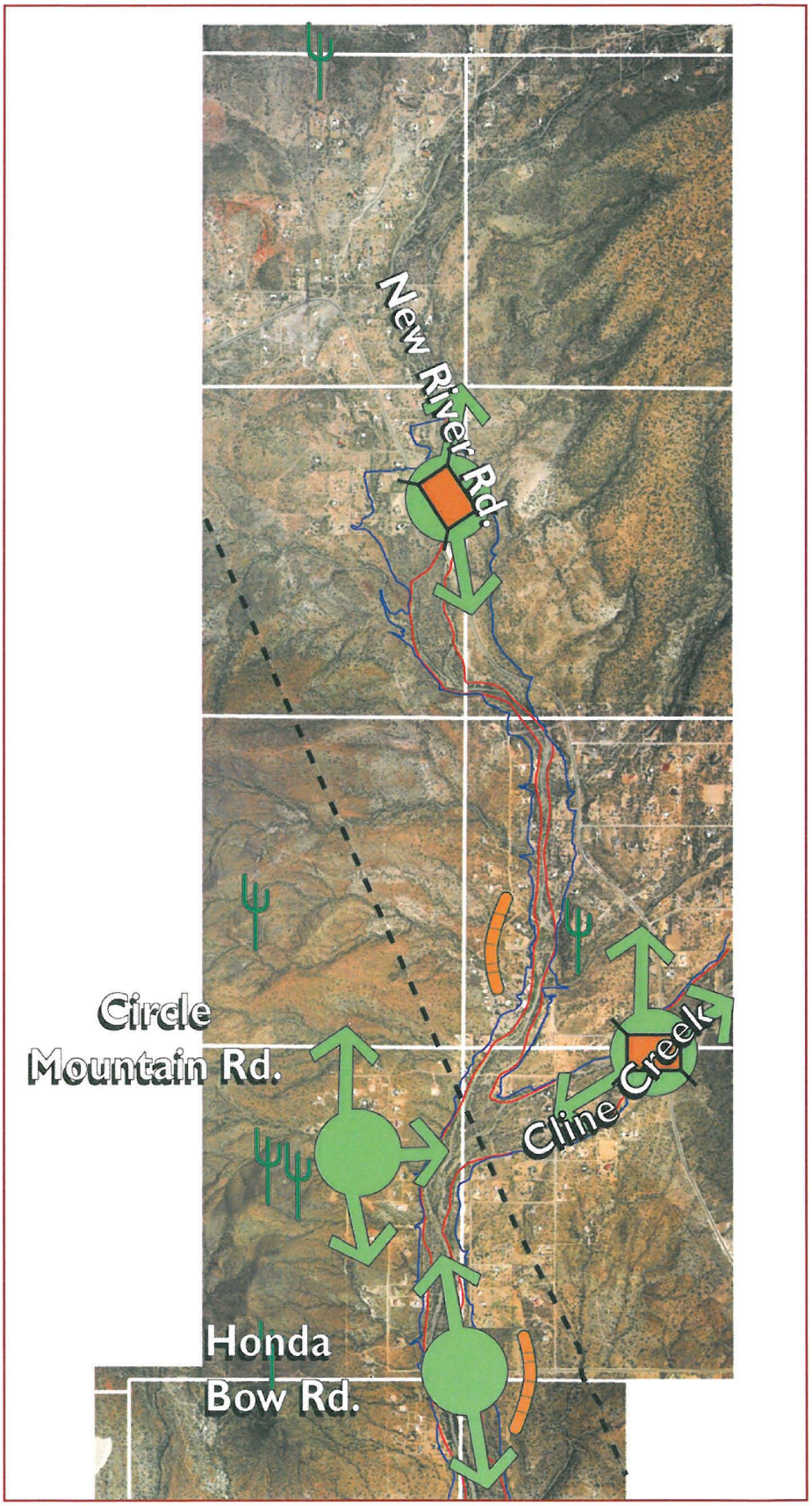


Figure 21. Phase 2 Visual Analysis (North Half)

Peak are prominent landforms that dominate the setting. Where the viewshed opens to expansive views, the New River Mountains to the north are striking features visible from the study area. The southern half of the Phase 2 study area is similar to the visual character of the Phase 1 because of the relatively flat terrain.

The distinct or memorable built features include the New River Road Bridges at Cline Creek and at Skunk Creek, Skunk Tank, and the major overhead transmission line and support towers. Skunk Tank adds an element of visual interest because it is a water feature that is a distinct change from the arid surroundings. Other built features visible from the study area include numerous residences associated with residential developments and associated infrastructure such as roads and utility lines.

Although most of the *watercourse* within the study area is relatively undisturbed by human activities, numerous road crossings exist and residential structures abut portions of the creek. In these areas, native vegetation has been cleared for residences, driveways, yards, and horse enclosures.

B. Biological and Cultural Resources

The purpose of the biological investigation was to identify current vegetative conditions in the study area and the potential existence of federally listed and proposed threatened and endangered species (T&E species), designated critical habitat for T&E species, and Wildlife of Special Concern in Arizona (WSCA) as described by the Arizona Game & Fish Department (AGFD). The cultural resource evaluation relied on existing survey reports from the various state and local agencies to provide an overview of the cultural resources within the study area. Special status species or intensive pedestrian surveys were not conducted.

1. Biological Resources

The study area is located within the Arizona Upland Subdivision of the Sonoran Desertscrub biotic community. This subdivision typically occurs on slopes, broken ground, and multi-dissected sloping plains, and receives the most rainfall of any desertscrub community in North America, averaging between 5 and 10 inches annually.

Generally, vegetation in the Arizona Uplands is dominated by species of leguminous trees, low shrubs, and cacti. Dominant tree species are foothills palo verde (*Cercidium microphyllum*), desert ironwood (*Olneya tesota*), and velvet mesquite (*Prosopis velutina*). Common shrubs include triangle-leaf bursage (*Ambrosia deltoidea*), brittle bush (*Encelia farinosa*) and creosote bush (*Larrea tridentata*). Typical cacti species include buckhorn cholla (*Opuntia acanthocarpa*), Engelmann's prickly pear (*Opuntia engelmannii*), and saguaro (*Carnegiea gigantea*). Substrates generally consist of hyperthermic arid soils with developed layers and low organic matter content.

Arizona Upland Vegetation

The study area was evaluated in terms of its relative *habitat values* and types. *Habitat value* refers to the suitability of the landscape for wildlife. Relative *habitat values* were determined for the study area and were assigned as high, medium and low. The *habitat values* within the study area are included in

Attachment 8. These values reflect the overall suitability of the landscape for a diversity of wildlife species. Habitat type categorizes the landscape in terms of landforms.

Five basic habitat types were used to categorize the existing habitat within the study area. These habitat types are:

- Creek Bed.
- Banks.
- Floodplain.
- Hillsides and Slope.
- Human-Related Disturbance.

Hillside Habitat Type

The Creek Bed Habitat Type was considered to have a *habitat value* of medium due to its importance as a movement corridor, unless the *channel* showed signs of significant human-related disturbance that would cause wildlife to avoid the area. The Bank Habitat Type could be low, medium, or high value depending on bank morphology, or density, diversity, and structural complexity of vegetation. Areas where creosote bush-bursage was prevalent along banks were assigned a value of low. Bank vegetation consisting of dense, but even-height growths of large shrubs or small trees was given a *habitat value* of medium. Structurally complex bank vegetation that is diverse and relatively dense was assigned a high value. Areas in the Floodplain Habitat Type could be given a low or medium value depending on type and density of vegetation. Areas where creosote bush-bursage dominated were given a *habitat value* of low. Areas in the floodplain that exhibited tall, diverse vegetation were given a value of medium. The Hillside or Slope Habitat Types located immediately adjacent to the creek were given a high *habitat value*. Areas within Human-Related Disturbance Habitat Type were given a low value.

Areas that were classified as high *habitat value* include areas just downstream (south) of the confluence of Skunk Creek and Cline Creek, the confluence of Skunk Creek and Rodger Creek, the area around Skunk Tank, the area just south of the Carefree Highway, the area just south of the Dove Valley Road alignment, and areas along the Sonoran Wash. Other smaller, isolated areas of high *habitat value* also exist within the study area. The areas of high habitat value are shown on Figure 22 for Phase 1 and on Figures 23 and 24 for Phase 2.

In addition to the evaluation of relative *habitat value* and type, the study area was also assessed for its ability to support sensitive species. The sensitive species are those listed under the Federal Endangered Species Act, as well as species listed by the State of Arizona as WSCA. Within the study area, four sensitive species are pertinent: Cactus Ferruginous Pygmy-owl (*Glaucidium brasilianum cactorum*), Lesser Long-nosed Bat (*Leptonycteris curasoae yerbabuenae*), Hohokam Agave (*Agave murpheyi*), and Sonoran Desert Tortoise (*Gopherus agassizzii*). There is suitable habitat in the study area for these four species. Prior to the implementation of any flood management solutions, specific species surveys following appropriate survey protocols are recommended in areas of suitable or

Rattlesnake found in Skunk Creek Channel Bank

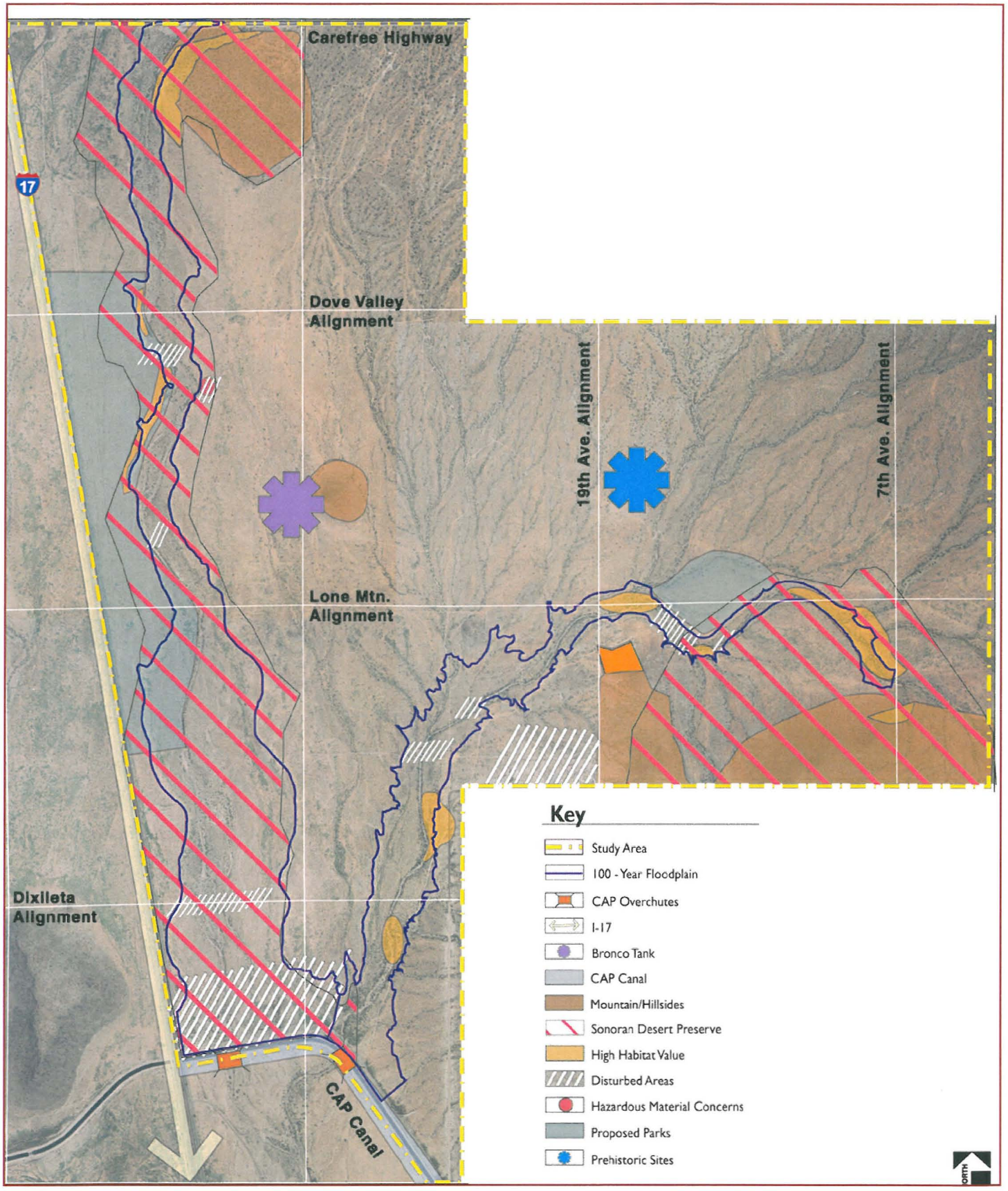


Figure 22. Phase 1 Biological and Cultural Features

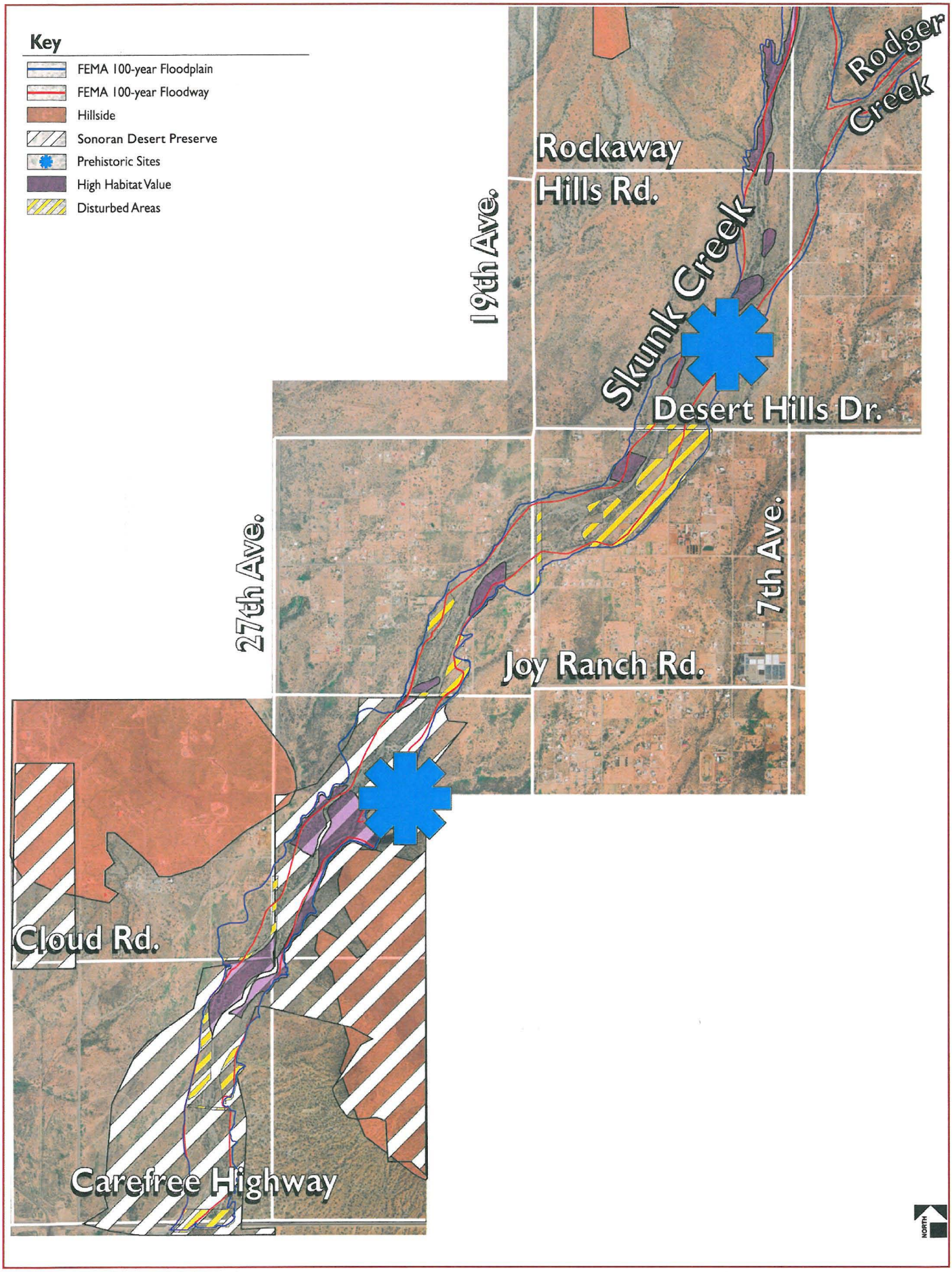


Figure 23. Phase 2 Biological and Cultural Features (South Half)

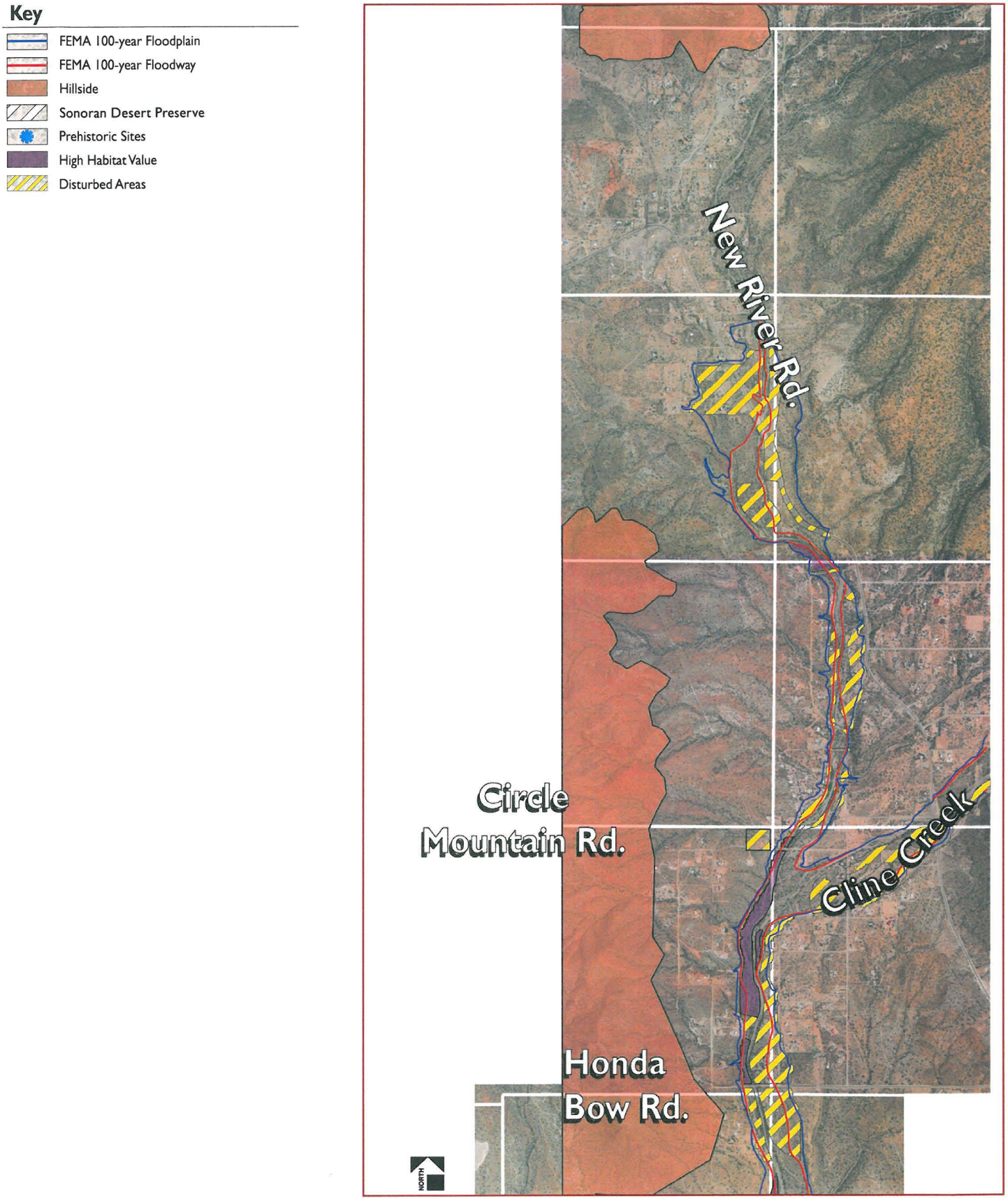


Figure 24. Phase 2 Biological and Cultural Features (North Half)

potentially suitable habitat for sensitive species. In addition, any flood control structures constructed should be designed to accommodate wildlife movement and be compatible with wildlife. Any disturbed areas should be revegetated to maximize the *habitat value*.

2. Cultural Resources

An overview of the Upper Skunk Creek area catalogued 22 previously documented archaeological sites and numerous isolated artifacts. The overview was based on existing records from the State Historic Preservation Office, Arizona State Museum, Arizona State University, the Bureau of Land Management (BLM) office in Phoenix, and review of previous archaeological reports for this area (studies extending from the 1910s to the 1990s). Approximately 35 percent of the study area has been covered by previous archaeological survey.

Of the 22 identified sites, ten sites are within the study area boundary. Five of these are undesignated dirt roads. These roads have most likely been destroyed by subsequent use and are most likely no longer eligible for nomination to the National Register of Historic Places (NRHP). The remaining five sites within the study area are characterized as prehistoric Hohokam sites, which can be dated to the Sedentary period (A.D. 950 to 1150) of the Hohokam cultural sequence. Three of the sites are small campsites, and the remaining two sites are single surface habitations of cobble masonry that were probably used in conjunction with local farming. Artifacts noted at the agricultural/habitation sites include ceramics, chipped stone and groundstone artifacts. All of these sites are believed to be eligible for nomination to the NHRP. These sites all have, or have the potential, or to yield important information pertaining to the prehistory of the upper Skunk Creek region of northern Maricopa County.

In addition to the sites described above, many of the previous archaeological surveys have discovered isolated artifacts. The 23 archaeological surveys conducted in the area have produced 91 loci of isolated artifacts. Most of these locations contained sparse quantities of artifacts such as Hohokam pottery or stone flakes resulting from tool manufacture. Based on the review of existing survey reports, any flood management features that would require excavation could potentially impact prehistoric resources within the study. Prior to any ground disturbing activity or geotechnical work, the area should be professionally surveyed, reported, and reviewed by appropriate agencies. The general location of cultural sites that affect the WCMP are shown on Figure 22 for Phase 1, and Figures 23 and 24 for Phase 2.

C. Land Use and Recreation

The existing land use and existing and planned recreation facilities were inventoried for the study area. Land use is a representation of existing occupation and/or a physical use of land. Land uses in the study area were determined by using recent aerial photography, City and County existing land use maps and a 1995 existing land use Geographic Information System (GIS) coverage, created by MAG. Planned recreation opportunities within the WCMP study area take two forms: active and passive. Active recreation generally refers to activities like sports courts, ball fields, and group activity areas. Passive recreation generally refers to recreation associated with trails and un-organized, informal activities.

Undeveloped Land adjacent to Sonoran Wash

1. Phase 1 Land Use

Land in the Phase 1 portion of the WCMP falls under the jurisdiction of the COP. Private holders, BOR, and the ASLD own the land in the study area. Current land use is undeveloped land, range, and mining. In the COP's General Plan, planned land uses include mixed-use/commerce park, residential of varying density, public, commercial, and floodplain. Areas within the floodplain of Skunk Creek are included in land slated for the Sonoran Desert Preserve as part of the Arizona Preserve Initiative (API). The goals of the Sonoran Desert Preserve Plan are to:

- ★ Connect significant public open spaces.
- ★ Preserve wildlife corridors and significant desert ecosystems along drainage ways.
- ★ Provide passive recreational opportunities.
- ★ Provide alternative transportation corridors.
- ★ Preserve significant views, cultural resources, and visual landmarks.
- ★ Establish management, maintenance, acquisition, and funding guidelines to increase open space standards.
- ★ Encourage access for people of all abilities to appreciate and enjoy the Sonoran Desert.

Those lands owned by the ASLD will be purchased with part of the bond funding provided for the plan; private parcels will be purchased with other funds. Funding for the purchase of private lands will be provided in part by a bond that provides the COP Parks, Recreation and Library Department with five million dollars over five years.

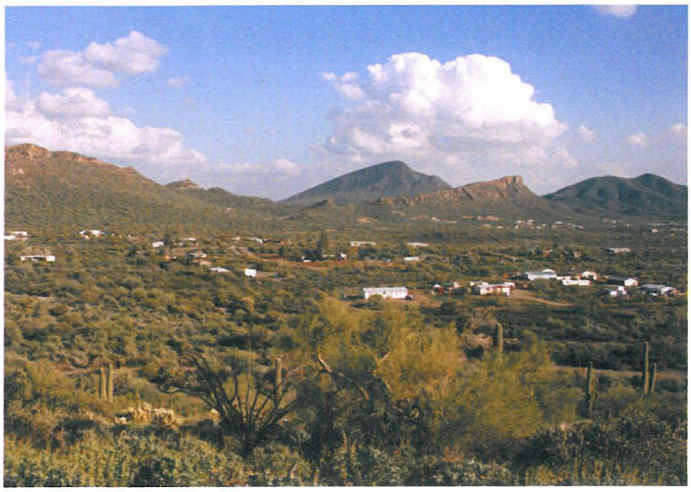
2. Phase 2 Land Use

Land use within the study area is primarily composed of vacant or undeveloped parcels and scattered low-density residential areas. Land within the study area is owned by either private ventures or held in State Trust. The majority of the study area falls under the jurisdiction of Maricopa County. A smaller portion on the southern end of the study area is under the jurisdiction of the COP.

Areas within the jurisdiction of the COP are described in the COP's General Plan (December 1999) as hillside, water, residential (2-5 du/ac), several areas of higher density residential (10+ du/ac), and commercial uses. Additionally areas along Skunk Creek and on the hillsides east of the Tramonto development are designated as parts of the proposed Sonoran Desert Preserve.

Sonoran Desert Preserve Land at Skunk Creek

Areas under the jurisdiction of Maricopa County are addressed in the New River Area Plan part of the Maricopa County 2020 Eye to the Future Comprehensive Plan. Planned land uses in the study area include rural residential (0-1.0 du/ac), large lot residential (1.0-2.0 du/ac), Development Master Planned communities (2.56 du/ac), and open space. The southern edge of the project is located in the Carefree Highway Scenic Corridor.



Typical Phase 2 Residential Land Use

3. Phase 1 Recreation

Planned recreation in the study is covered in the North Black Canyon Corridor Plan: prepared by the COP. In the plan, recreation uses include the Sonoran Desert Preserve, developed parks, and trails. The Sonoran Desert Preserve encompasses over 20,000 acres of hillside, washes and open desert. Skunk Creek is one of the major *watercourses* included in the Sonoran Desert Preserve. Three future access points, including parking, trails, picnicking, outdoor recreation and visitor services, will be located near the current study area. Additionally eight secondary access points with parking areas will be located near the study area. Bronco Butte serves as a landmark and waypoint. A trail from the planned commercial areas to the butte is anticipated.

Three levels of parks are planned for in the North Black Canyon Corridor Plan; district, community, and neighborhood parks. A district park is a large park of 100 acres or more in size and serves 100,000 or more persons within a five-mile radius. The proposed site for the district park would be located south of the Dove Valley Road alignment for 0.5 miles and from I-17 on the west to Skunk Creek on the east. Skunk Creek creates a natural buffer between the park and the planned commercial development and also acts as a major trail corridor in the area. Additionally community parks and neighborhood parks will be provided as development increases. Community and neighborhood parks will be located adjacent to the Sonoran Desert Preserve whenever possible to create a buffer for the preserve and an access point for users.

Trails in the area will be located along Skunk Creek, along the CAP canal, and along major roadways. In the transportation plan of the North Black Canyon Corridor Plan, bike lanes are incorporated into the typical cross section of the streets. Increased width sidewalks are planned in the areas to provide for increased pedestrian use that is anticipated in the area.

Future COP District Park Site

4. Phase 2 Recreation

Currently there are no proposed or planned active recreation sites or parks within the study area. The potential for passive recreation opportunities are extensive as the area is relatively undeveloped.

Adjacent to the Maricopa County New River Planning Area are four established trail systems. The BLM operates the Emory Henderson Trail to the west of the New River Planning area. In the south, the COP has a developed system of trails. An existing trail system is at Cave Creek Park, located east of the study area. Additionally the Tonto National Forest operates a trail system to the north. Trails and public access in the study area were identified in the New River Area Plan. A citizens group in 1998 identified trails that were widely used by equestrians, hikers, and recreational vehicles, as well as wildlife. A developed trail system would provide

travel for both citizens and wildlife, and preserve the equestrian lifestyle of the area. In addition, a developed trail system in the New River area would also provide the opportunity to link together the already developed surrounding trail systems.

In the New River Area Plan Maricopa County identifies several suggested conservation trails and several proposed trails in the study area as part of the transportation plan. These trails are to provide public access that will reasonably accommodate non-motorized travel modes along roadways. These paths are aligned on existing roadways or washes. The *channel* of Skunk Creek is identified as an alignment for a proposed trail. Additionally paths are proposed along Carefree Highway, Desert Hills Drive, 7th Ave, and New River Road. Several suggested conservation trails are located along alignments west of Circle Mountain Road (Deadman's Wash) within the study area for hiker and equestrian use. Additionally the plan calls for a non-motorized trail way system between Lake Pleasant and Cave Creek Park, which would cross the WCMP study area.

D. Planning Influences

The planning influences shown on Figure 25 for Phase 1, and Figures 26 and 27 for Phase 2, illustrate the primary factors that should be considered during the development of floodplain management alternatives. The Proposed Sonoran Desert Preserve lands would limit development and its associated infrastructure requirements immediately adjacent to and through the *watercourses* in the southern portion of the study area. Opportunities to incorporate multi-use trails along the *watercourses* in accordance with Maricopa County's New River Area Plan, the COP's General Plan, and Sonoran Desert Preserve goals should be considered, and minimally not excluded, from any proposed flood control facilities. In addition, any flood facilities visible from any road crossing or overlook should be designed to minimize visual contrast with the surround landscape in terms of color, scale, and texture. Preservation areas include the proposed Sonoran Desert Preserve lands, and areas of high habitat, inherent scenic quality, and cultural resource (both historic and prehistoric) value. Areas are also noted where the landscape would benefit from restoration of disturbed vegetation and/or landforms.

High Habitat Area

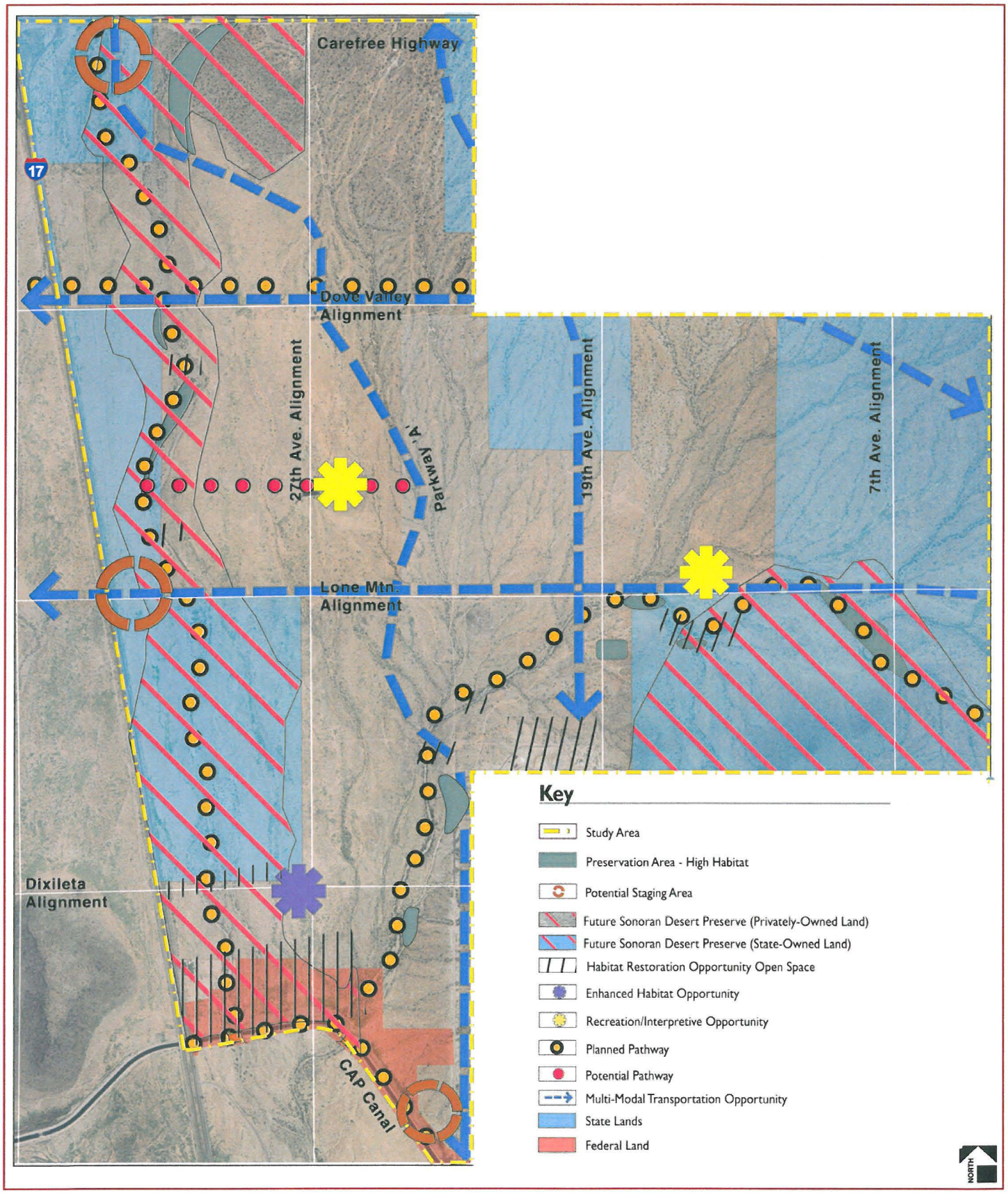


Figure 25. Phase 1 Planning Influences

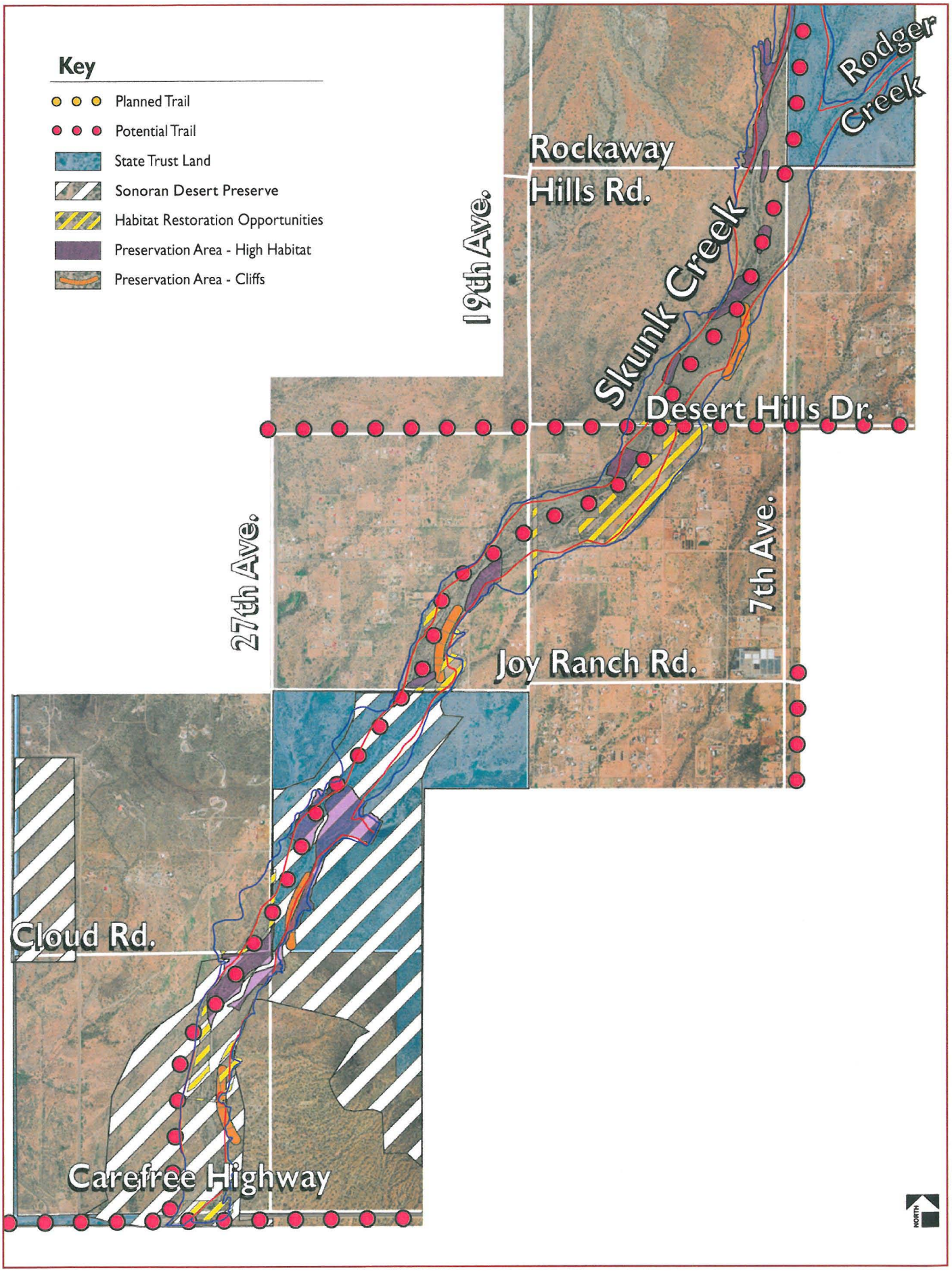


Figure 26. Phase 2 Planning Influences (South Half)

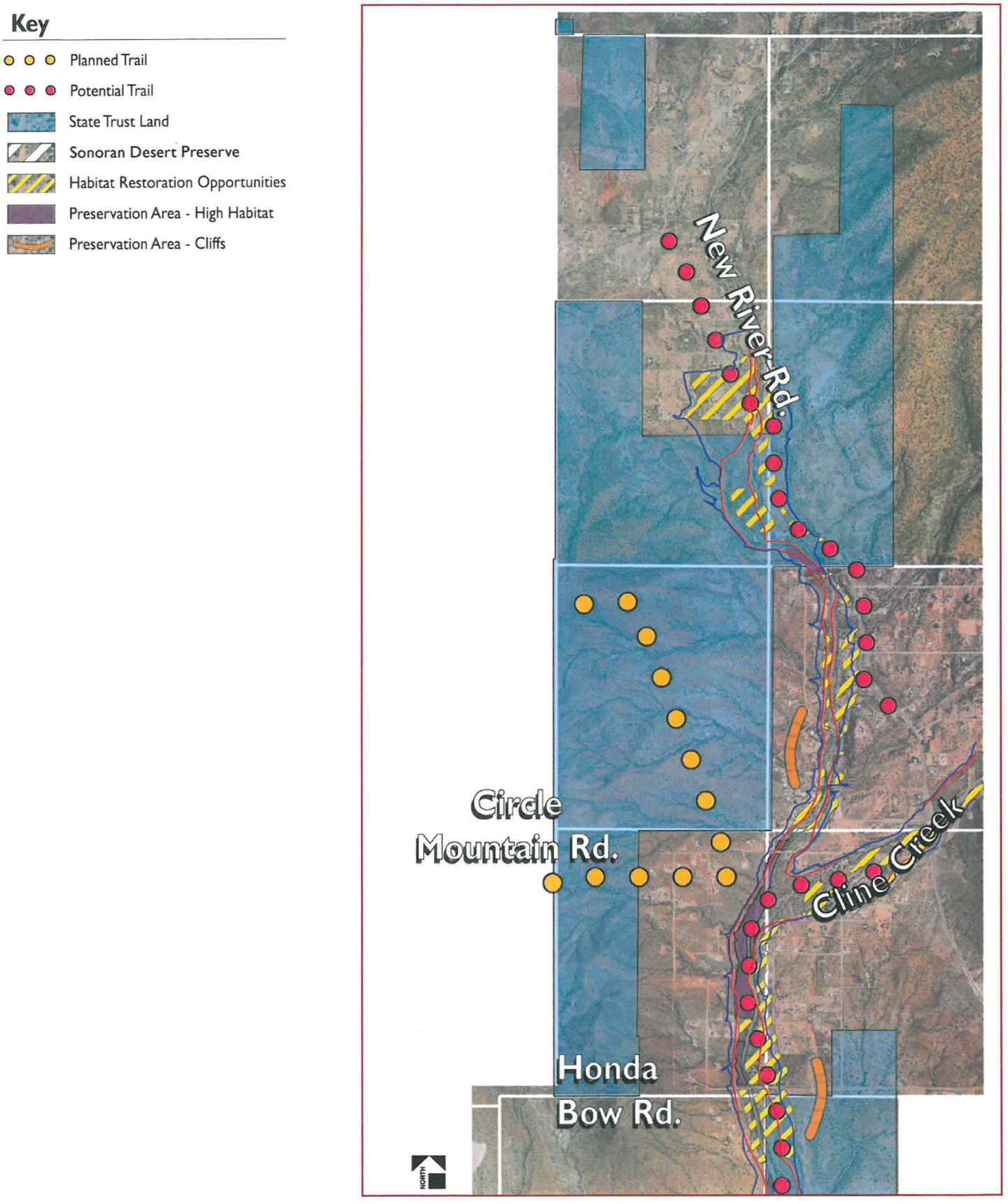


Figure 27. Phase 2 Planning Influences (North Half)

6 Watercourse Technical Characteristics

Detailed technical analyses were performed as a basis for development of the WCMP. Existing watershed and *watercourse conditions* were compared with anticipated future watershed and *watercourse conditions* for the purpose of planning, not just build-out in the watershed, but for the transition between existing and future conditions. The technical analyses performed are based on key assumptions regarding the management of the watershed. Successful implementation of the WCMP is therefore contingent upon management of the watershed in accordance with those assumptions.

The District plans to coordinate with communities in the WCMP study area to implement the appropriate watershed planning components. This is done as a part of the District's Area Drainage Master Study (ADMS) and Area Drainage Master Plan (ADMP) processes. An ADMP is planned for the Skunk Creek watershed upstream of Adobe Dam to address the watershed issues. The key assumptions made for this study regarding management of the watershed are that land managers will:

- Implement the COP and Maricopa County's 100-year, 2-hour retention ordinance requirement for zoning classifications with densities greater than 1 unit per acre.
- Preserve the natural *watercourse* system wherever possible. An ADMP for the watershed should quantify the *watercourses* to be preserved. If channelization or *floodplain encroachment* becomes necessary, travel times through the watershed should match existing natural conditions as closely as possible.
- Sediment loads in the natural *watercourse* system should not increase or decrease significantly as a result of development or other human disturbances in the watershed.
- Where significant changes may result, appropriate mitigation measures must be implemented to maintain long-term *watercourse* stability.
- Maintain peak discharges for the 2-year, 10-year and *100-year storms* at or below the future watershed condition levels estimated in the WCMP.
- Maintain the release of future condition runoff volumes to the *watercourses* from the 2-year, 10-year and *100-year storms* as close as possible to the WCMP estimated existing watershed condition runoff volumes. This approach is necessary to help meet the goal of minimizing changes to *sediment yield*, and to support natural riparian vegetation along the *watercourses*.
- Implement the North Black Canyon Corridor Plan and the MAG 1995 General Land Use Plan for the watershed.

The WCMP considers the natural processes of *erosion*, *sedimentation* and *channel* migration. These processes are major safety concerns that current FEMA regulations as illustrated in Figure 28 do not adequately address. The *channel* bottom may erode or fill as a result of flooding. If it erodes, *channel* banks may become unstable and collapse. If the *channel* bottom fills through *sedimentation*, the floodplain can widen, potentially damaging property and structures and endangering lives. Therefore, the WCMP must consider the natural movement of the

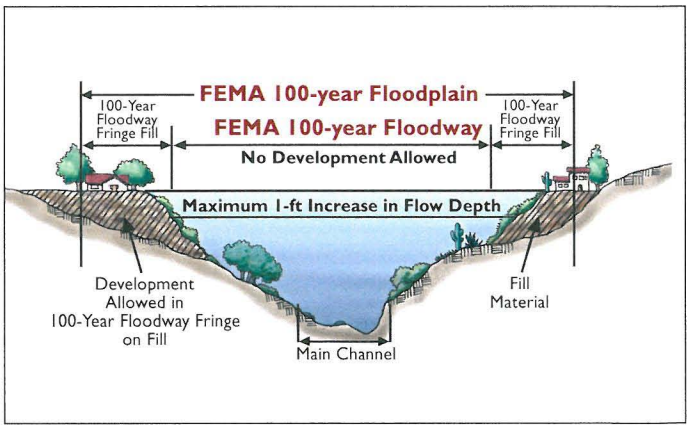


Figure 28. Typical Section of FEMA Regulatory Criteria

watercourse. In addition, *watercourses* need a riparian corridor in which to function naturally. Because the *watercourse* constantly changes over time as shown in Figure 29, the WCMP incorporates a riparian corridor to help protect adjacent property from the impacts of these natural processes. Understanding *erosion*, *sedimentation*, and *channel* migration and identifying appropriate methods to analyze these processes are critical to creating viable alternatives for managing the *watercourses*. Technical considerations relating to this understanding are described in the following sections.

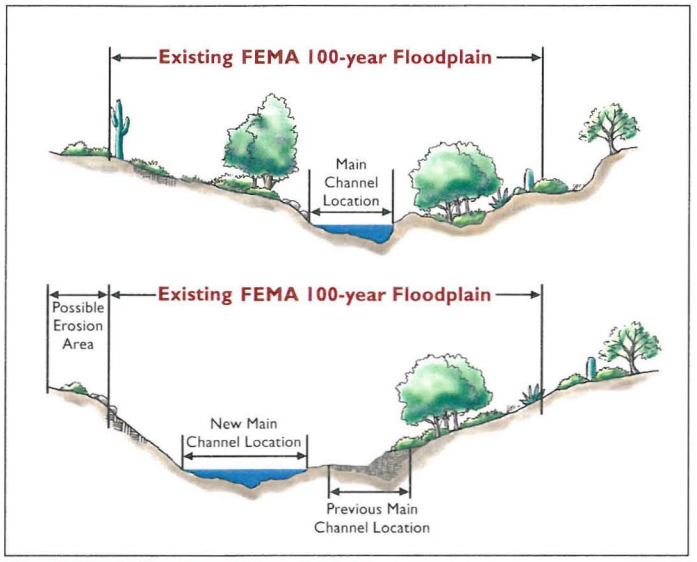


Figure 29. Cross Section of Potential Channel Migration

A. Hydrology

Hydrology is a very important consideration because it is used to define the link between the watershed and the *watercourse*. The other technical considerations such as *hydraulics*, sediment transport modeling and lateral migration analyses are applied specifically to the *watercourse*. Those considerations rely on input from *hydrology* to define how the *watercourse* will respond to changes occurring in the watershed. The hydrologic analyses conducted as a part of this study are as follows:

- *Hydrology* for existing and future watershed conditions for the 2-, 10- and 100-year *recurrence interval* storms for Skunk Creek.
- *Hydrology* for existing and future watershed conditions for the 2-, 10-, 25- and 100-year *recurrence interval* storms for Sonoran Wash.
- Testing of alternative *watercourse* management plans to estimate cumulative impacts on peak discharges in the study area resulting from *floodplain encroachments*.
- Calculation of watershed response time to actual storms of record for estimation of the available time for warning residents residing within the *FEMA 100-year floodway* of an impending flood.

The hydrologic models are used to estimate the volume and peak discharge of stormwater runoff that can be expected from storms of varying magnitude. The current FEMA HEC-1 *computer models* for Skunk Creek (Montgomery Watson, 1997) are used as models of *existing watershed conditions*, and are modified to simulate *future watershed conditions*. A storm duration of 24-hours is used for all models. New *hydrology* models are developed for the Sonoran Wash watershed, based on current District methodology, for *existing watershed conditions*. Those models are modified to simulate *future watershed conditions*. The Sonoran Wash existing watershed condition *hydrology* models are also used for preparation of a floodplain delineation study for Sonoran Wash completed as a part of the WCMP. The *hydrology* models are building blocks used for development of the hydraulic and sediment transport models described in the following section, and the analyses of potential *lateral channel migration* described in the *Lateral Channel Migration* section. Refer to Figure 30 for a map illustrating the watersheds of Skunk Creek and Sonoran Wash.

The *future watershed conditions* are modeled by applying an impervious area factor (RTIMP) to each sub-basin. The RTIMP value is estimated by using the allowable land use densities defined in the North Black Canyon Corridor Plan and the MAG 1995 General Land Use Plan. The amount of impervious area for each land use, including roofs, driveways and streets, is estimated and totaled for each, and an

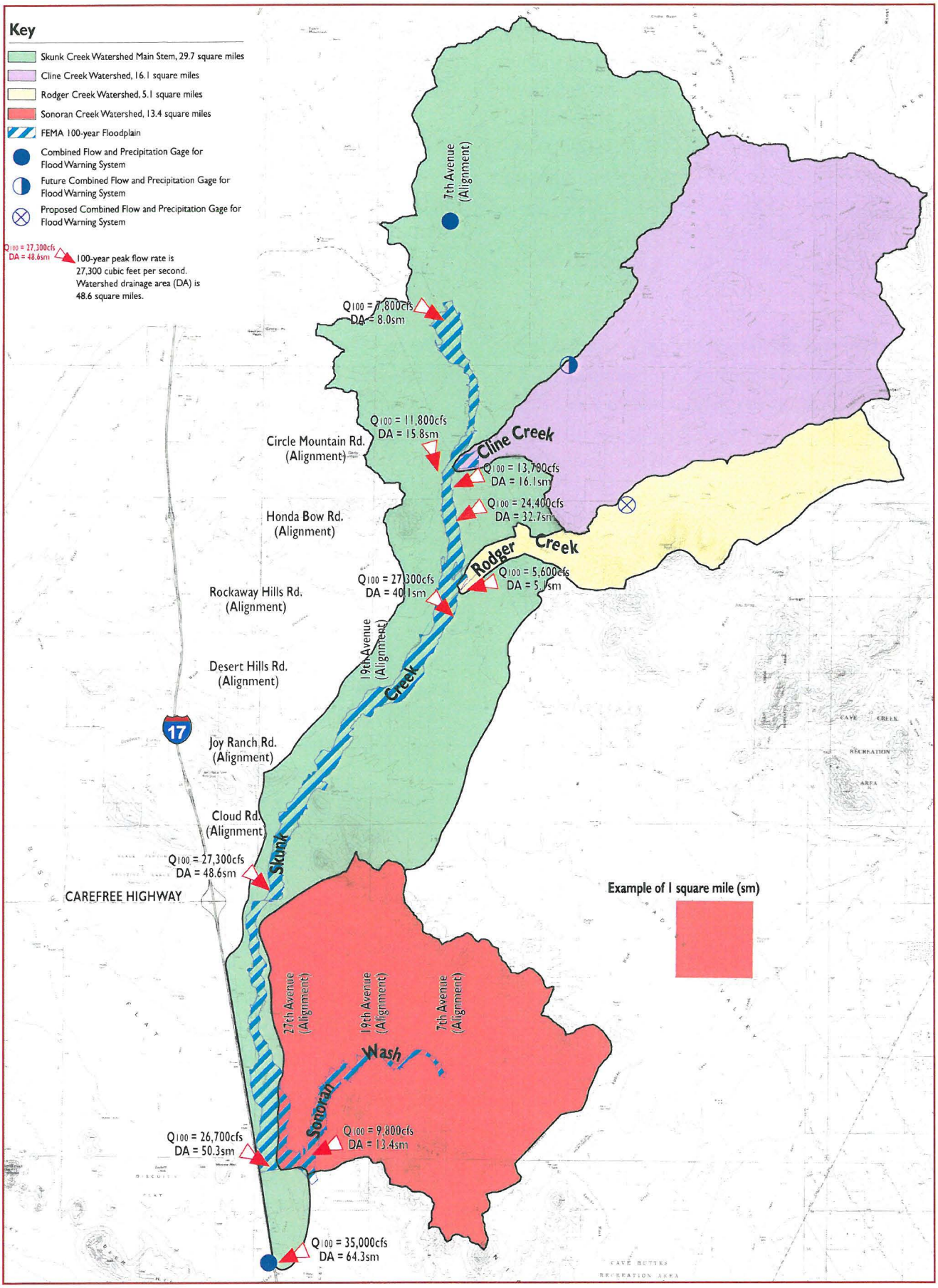


Figure 30. Watershed Map

RTIMP value calculated. Parameters were also adjusted to account for changes in watershed response times resulting from development. The tributary watershed drainage *channels* are assumed to remain in their natural condition, and not be channeled by development. The COP is implementing these assumptions in the North Black Canyon Corridor Plan area through zoning regulations. Implementation of these assumptions in the unincorporated areas is critical to the success of the WCMP.

Both the COP and Maricopa County require new developments to construct retention basins designed to store the entire 100-year 2-hour storm runoff volume from the areas disturbed within the development. This policy is only applied where subdivisions are created. A large portion of the watershed is not developable because it is too steep, or lies within the Tonto National Forest. Other portions are developing rapidly through minor land divisions. It is assumed that the retention policy will not be applied to the National Forest and minor land divisions. Refer to Figure 31 for a depiction of the watershed sub-basins where it is assumed the retention policy is applied. The effect of this assumption is that peak discharges increase as a result of development in the upper *reaches* of the *watercourse* study areas, and decrease in the lower *reaches*. This can be seen in Table 5, which is a summary of the results of the WCMP *hydrology* modeling.

The hydrologic models are also used to test for *cumulative impacts* resulting from *floodplain encroachment* proposed under management alternatives. There are four management alternatives for Phase 1 and three management alternatives for Phase 2. Refer to Section 7 for information on the development of the proposed alternatives. Each alternative proposes a different level of encroachment into the *FEMA 100-year floodplain*. Such encroachment results in loss of storage in the *main channel* over-bank areas and increased flow depths and velocities. The affects of these changes accumulate along the *watercourse* and result in increases in peak discharge, particularly for large floods such as the 100-year flood. Increases in peak discharge result in further increases in flow depth and velocity, which in turn affect *erosion* and *sedimentation* along the *watercourse*. The key indicator that *floodplain encroachment* is causing *cumulative impacts* is peak discharge. The results of the testing of management alternatives for *cumulative impacts* are shown in Table 6. Note that the Full-Structural

Table 5

Summary of Hydrologic Modeling Results

Location (1)	HEC-1 ID (2)	Drainage Area sq. mi. (3)	Peak Discharge in cfs					
			2-year		10-year		100-year	
			Ex. (4)	Fut. (5)	Ex. (6)	Fut. (7)	Ex. (8)	Fut. (9)
Skunk Creek								
Above Jenny Lin Road	S6C	8.1	1,500	2,000	4,100	4,800	7,800	8,800
Below Jenny Lin Road	S10C	12.9	1,700	2,600	4,900	6,400	9,700	11,800
Circle Mountain Road	S13C	15.9	2,100	2,700	6,000	6,800	11,800	12,600
Above Honda Bow Road	S14C	32.6	3,800	4,000	12,300	10,800	24,400	20,900
Below Joy Ranch Road	S21C	42.3	4,700	5,000	13,600	12,400	26,700	23,500
Carefree Highway	S22C	48.7	4,900	4,900	13,800	12,700	27,300	24,500
Upstream of the CAP Canal	S23L	50.3	4,700	4,700	13,400	12,500	26,500	24,100
Combined at the CAP Canal	CAP	63.7	5,400	4,700	14,600	12,700	28,500	25,800
Downstream of the CAP Canal	CAPR2	63.7	5,300	4,500	14,400	12,500	28,200	25,200
Skunk Creek at I17	S24C	64.3	5,300	4,500	14,400	12,500	28,200	25,200
Sonoran Wash								
Above Confluence at Lone Mountain Road	C002L	3.3	1,100	120	2,000	560	3,300	3,500
Below Confluence at Lone Mountain Road	C002	4.3	2,000	120	3,900	860	6,500	7,200
19th Avenue	C003	8.0	2,200	70	4,800	860	8,400	6,900
Below Lone Mountain Road	C007	16.6	2,300	60	5,100	770	9,700	6,700
Above the CAP Canal	C010	13.4	2,100	50	4,900	720	9,800	6,100

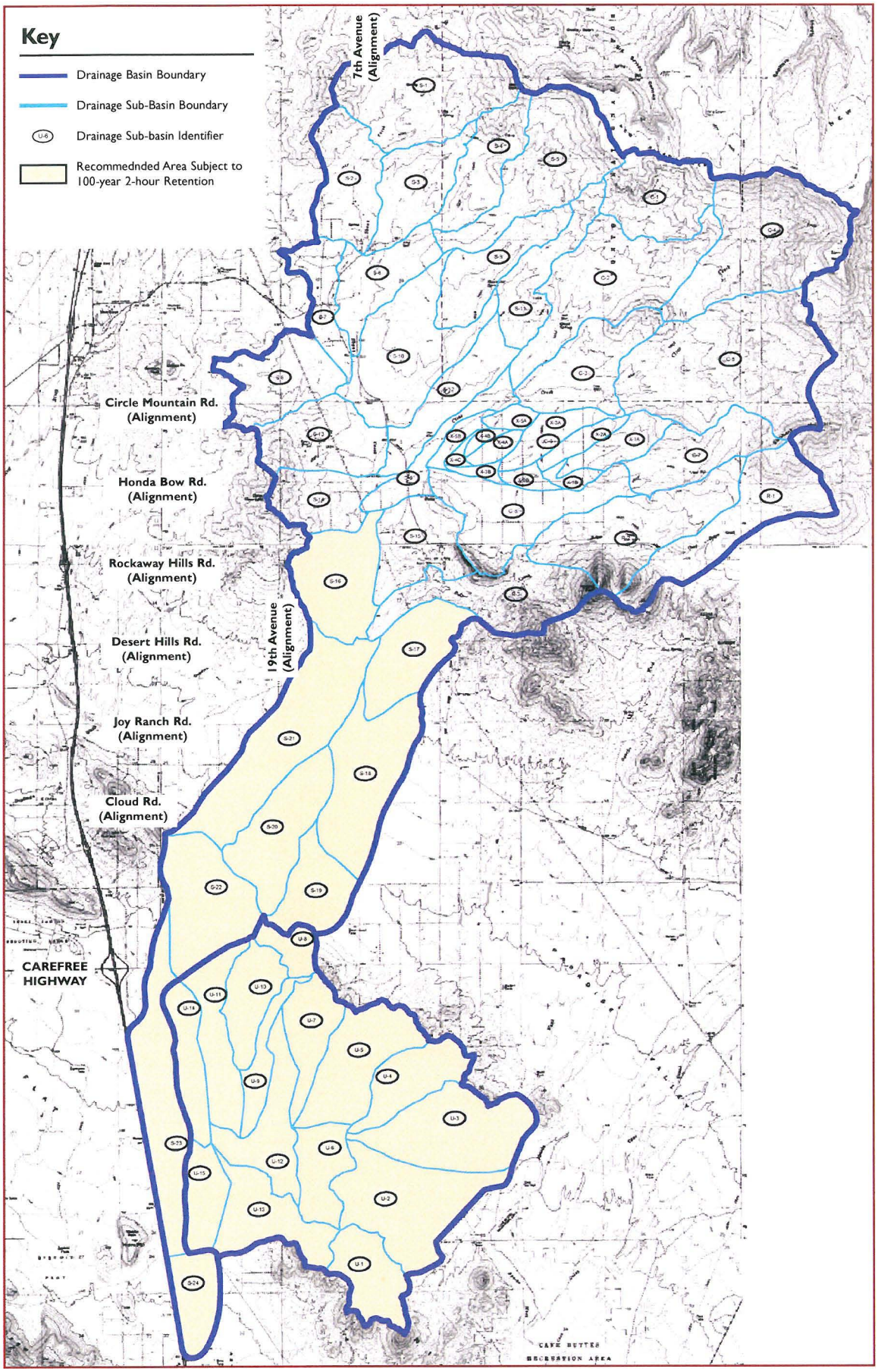


Figure 31. Watershed Sub-basins Subject to 100-year 2-hour Retention

Alternative results in the greatest *cumulative impacts*, and the Nonstructural Alternative in no *cumulative impacts* based on the percent increase in peak discharge resulting from *floodplain encroachment*. The complete documentation of the hydrologic modeling is contained in Attachment 3.

B. Hydraulics, Erosion and Sedimentation

Hydraulics, erosion, and sedimentation information are needed for understanding the physical aspects of how *watercourses* function in the study area. Hydraulic and sedimentation models are created and then used as two of the engineering techniques for estimating the potential for *lateral channel migration* as well as for other purposes. The models are also used to test the *watercourse* management alternatives. Complete documentation of the study *hydraulics*, *erosion*, and *sedimentation* modeling is provided in Attachment 4 and Attachment 5.

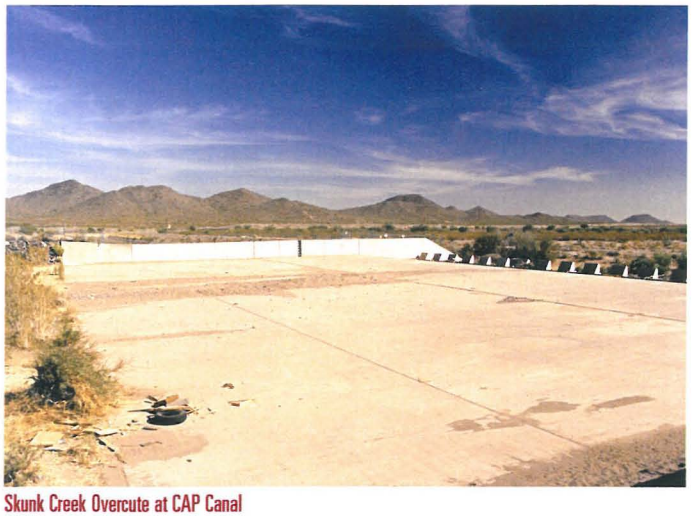
1. Hydraulics

Computer models developed for the current *FEMA 100-year floodplain* delineation study are used as a basis for hydraulic modeling of the study *watercourses*. The FEMA *computer models* are adjusted for the purposes of this study, and then modified to simulate estimated *future watershed conditions*. The *computer models* are also used to estimate results for 2-year and 10-year *recurrence interval* storms for Skunk Creek, and for 2-year, 10-year and 25-year *recurrence interval* storms for Sonoran Wash. The results of these *computer models* are then used to provide base input data for the sediment models, as well as to identify water surface elevations, provide hydraulic data for *scour* computations and potential lateral migration analyses, and provide a baseline for testing management alternatives.

During the development of the hydraulic modeling for the WCMP, the area immediately upstream of the CAP Canal where Skunk Creek and Sonoran Wash commingle could not be accurately modeled using a one-dimensional flow model such as HEC-RAS. It was found that a breakout occurs at that location because of the backwater constriction caused by limited hydraulic capacity of the Skunk Creek and Sonoran Wash overchutes at the CAP Canal. This breakout results in stormwater being diverted west over I-17, and the CAP Canal overchutes being overwhelmed by discharges from floods more frequent than the 26-year event. This breakout has the potential to flood existing residences that were previously thought safe and residences currently under

Table 6
Summary of Management Alternative Testing for Cumulative Impacts

Location (1)	HEC-1 Concentration Point (2)	Watercourse Management Alternative							
		Nonstructural		Full-Structural		Stakeholders		Low-Impact (Team)	
		Q (cfs) (3)	% Change (4)	Q (cfs) (5)	% Change (6)	Q (cfs) (7)	% Change (8)	Q (cfs) (9)	% Change (10)
Skunk Creek, upstream of CAP Canal									
Skunk Creek at Fig Spring Road	S3C	4,899	0.0%	4,899	0.0%	4,899	0.0%	4,899	0.0%
Skunk Creek at New River Road bridge	S6C	7,840	0.0%	7,840	0.0%	7,840	0.0%	7,840	0.0%
Skunk Creek at RM 24.74	S10C	8,219	0.0%	9,676	17.7%	9,676	17.7%	8,476	3.1%
Skunk Creek upstream of Cline Creek	S13C	10,174	0.0%	11,802	16.0%	11,802	16.0%	10,176	0.0%
Skunk Creek downstream of Cline Creek	S14C	22,622	0.0%	24,170	6.8%	24,170	6.8%	22,655	0.1%
Skunk Creek downstream of Rodger Creek	S16C	24,429	0.0%	26,571	8.8%	26,571	8.8%	24,566	0.6%
Skunk Creek at Skunk Tank	S21C2	23,830	0.0%	26,410	10.8%	26,410	10.8%	24,329	2.1%
Skunk Creek at Carefree Highway	S22C	22,603	0.0%	25,908	14.6%	25,901	14.6%	23,582	4.3%
Skunk Creek at CAP Canal	S23L	20,830	0.0%	23,155	11.2%	22,770	9.3%	21,234	1.9%
Sonoran Wash									
Sonoran Wash at RM 3.54	C002	6,492	0.0%	6,492	0.0%	6,492	0.0%	6,492	0.0%
Sonoran Wash at RM 2.69	C003	8,431	0.0%	8,467	0.4%	8,609	2.1%	8,460	0.3%
Sonoran Wash at RM 1.77	C007	9,398	0.0%	10,480	11.5%	10,370	10.3%	9,656	2.7%
Sonoran Wash at CAP Canal	C010	9,114	0.0%	10,247	12.4%	10,131	11.2%	9,293	2.0%
Skunk Creek, downstream from CAP Canal									
Skunk Creek & Sonoran Wash at CAP Canal	CAP	21,426	0.0%	24,341	13.6%	23,896	11.5%	22,213	3.7%
Skunk Creek Downstream of CAP Canal	CAPR2	21,271	0.0%	24,059	13.1%	23,626	11.1%	22,013	3.5%
Skunk Creek at I-17	S24C	21,270	0.0%	24,059	13.1%	23,626	11.1%	22,013	3.5%



Skunk Creek Overcute at CAP Canal

construction. The overwhelming of the overchutes could result in failure of the CAP Canal embankment. For these reasons, a detailed hydraulic analysis of the breakout became necessary to accurately define the problem. A two-dimensional flow model of this area was developed for the purpose of estimating the magnitude of breakout and CAP Canal overtopping flows, and to estimate the extent of the breakout and the estimated frequency where the breakout begins to occur. The FLO-2D computer model was used. In summary, flow begins to breakout over I-17 at an estimated 26-year flood frequency (12,500 cfs in Skunk Creek). The estimated peak discharge over I-17 during the *100-year storm* is 6,400 cfs, with a total breakout volume of approximately 77,000 *acre-feet*. The estimated average flow depth over I-17 during the 100-year event is 2.5 feet. Refer to Attachment 7 for complete details of the two-dimensional hydraulic model results.

A similar situation was identified near the north limit of the study area upstream of the New River Road Bridge. The FEMA hydraulic model is built with the assumption that the majority of the flow is contained in the *main channel* and is conveyed to the bridge. It was acknowledged by FEMA that a breakout occurs along both *main channel* banks upstream of the bridge, and that adjacent areas are flooded. However, the adjacent areas are mapped as areas subject to flooding depths of only about 1 foot. Cursory investigation revealed that actual breakout flow rates may be significant, and the adjacent areas may be subject to more frequent flooding. A split flow analysis for both the east and west *main channel* banks is done using HEC-RAS. The breakout peak flow rate during the 100-year flood over the east bank is approximately 200 cfs. The breakout peak flow rate during the 100-year flood over the west bank is estimated to range from 4,000 cfs to 4,500 cfs, over one-half of the total peak flow rate of 7,800 cfs. The west bank breakout begins at approximately a 10-year frequency. Refer to Section 9 and Attachment 11 for details of recommendations regarding this area.

2. Erosion and Sedimentation

Erosion and *sedimentation* analyses were performed for the Skunk Creek and Sonoran Wash *watercourses*. The components of the *erosion* and *sedimentation* analyses are:

- ★ Estimating *erosion* or *sedimentation* in the *watercourses* during floods.
- ★ Estimating the potential impacts of *erosion* and *sedimentation* on the structural components proposed for the WCMP alternatives. These components include existing and proposed structures, such as bank protection, *channel* grade-control structures and bridges.

Erosion at Skunk Tank

The U.S. Army Corps of Engineers HEC-6 computer model is used to estimate the *erosion* and *sedimentation* trends and magnitudes of the study *watercourses* for the 10- and 100-year floods for Skunk

Creek, and the 25- and 100-year floods for Sonoran Wash. The HEC-6 models address *channel* bed vertical movement. *Main channel erosion* and *channel* migration is interpreted from those results. Review of the modeling results provides insight into the range of general *scour* or deposition that can be expected to occur during a single flood in individual *reaches* of each *watercourse*. Results of the computer modeling analysis indicate that Skunk Creek could experience general *scour* as much as 2 feet, or deposition of up to 4 feet during a major flood such as a 100-year flood. The results for Sonoran Wash indicate general *scour* could be as much as 1 foot and deposition as much as 1 foot, during a 100-year flood.

The *erosion* and *sedimentation* analyses also included *scour* analysis computations. *Scour* computations are used to determine the maximum potential *scour* and, hence, the depth for designing the structural components of the various WCMP alternative management plans considered. For this study, the design *scour* depths included single-event *scour* and long-term *degradation* (*erosion* expected to occur over the life of a structural component). The maximum single-event *scour* consists of the sum of several components:

- ★ General *scour* depths.
- ★ *Bed-form scour*.
- ★ Bend *scour* (added only on the outside of bends).
- ★ Local *scour* (added where *channel* grade-control structures are proposed).

Long-term *degradation* occurs in *reaches* where the *channel* bottom is continually lowering from storm to storm due to *erosion*. The estimated drop in the *channel* over time is added to the maximum single-event *scour* components to obtain the total design *scour* depth. If the long-term *degradation* depth is found to be excessive, grade-control structures along the *channel* bottom become necessary. For the purpose of this study, the term "excessive" was defined as the point when the cost to increase the depth of required bank protection exceeds the cost of installing grade-control structures to control bed *degradation*. For the purpose of this study, the depths of required bank protection are considered to be reasonable. No grade-control structures are found to be necessary for implementation of the *watercourse* management alternatives for the study *watercourses*, except the Stakeholders Alternative for the Main Stem Reach of Sonoran Wash.

Eroding Bank in Skunk Creek

The primary structural flood control measure used in the *watercourse* management alternatives is bank protection. Bank protection is a constructed lining designed to prevent the *main channel* banks from eroding horizontally and damaging improvements made within the *FEMA 100-year floodway fringe* or an *erosion* hazard area. Bank protection must be constructed to extend below the lowest point in the natural *channel* bottom, which includes accounting for total *scour*. This depth is commonly referred to as the toe-down depth. Generally, bank protection is also extended above the 100-year water surface elevation. Bank protection is typically part of structural features designed to remove land located within the *FEMA 100-year floodway fringe* from the *FEMA 100-year floodplain*. As described above, the required toe-down depth below the *channel* bottom is determined using the design *scour* depth. The required height above the 100-year water surface elevation is based on a factor of safety referred to as freeboard. Two types of bank protection, relative to the potential for *erosion* to occur, are described for the purpose of this study. They are *maximum depth* and *minimum depth bank protection*.

The ranges of design *scour* depths for *maximum depth bank protection* for each *reach* of the WCMP are shown in Tables 7 and 8. The depths listed are the below-ground requirements measured from the bottom of the *main channel* at a specific location. The required depths vary within each *reach* and along each bank. The minimum and maximum *scour* depth values are the shallowest and deepest requirement, respectively, in the reach. The average provides an estimate of the average depth, weighted by length of *channel* over which it applies. Refer to Attachment 6 and Attachment 12 for detailed documentation of *scour* computations performed for proposed structural components of the management alternatives.

C. Lateral Stability Analysis

The potential for *lateral channel migration* is extensively evaluated for the Skunk Creek and Sonoran Wash *watercourses*. The components for this evaluation include:

- Study area characteristics.
- Historical analyses.
- Geomorphic analyses.
- Engineering analyses.

The results of the lateral stability analyses are used to delineate *erosion* hazard zones. Refer to Attachment 6 for documentation of the lateral stability analyses.

1. Study Area Characteristics

The stability of the Skunk Creek and Sonoran Wash systems is directly affected by several characteristics of the study area. Understanding the watershed characteristics, regional geologic setting, hydrologic inputs, and stream classification is fundamental for explaining past stream behavior, for predicting future river processes, and for selecting appropriate tools for analysis of the stream behavior. These fundamental data represent the most important independent variables that control lateral migration.

The first characteristic studied is the watershed. The lateral stability of the Skunk Creek system is directly impacted by watershed characteristics such as drainage area, type of development, vegetative cover, elevation, and other physiographic parameters. Skunk Creek and its principal tributaries form a moderately large stream system (about 64 mi.^{2}) that heads in the New River Mountains east of the town of New River and flows into the northern Phoenix metropolitan area. All of the streams within the study area are *ephemeral watercourses*. In addition to several smaller *watercourses*, the significant tributaries of Skunk Creek upstream of the CAP Canal include the following:

- Cline Creek (16.1 mi.^{2}).
- Rodger Creek (5.1 mi.^{2}).
- Skunk Tank Wash (4.8 mi.^{2}).
- Sonoran Wash (13.4 mi.^{2}).

Table 7

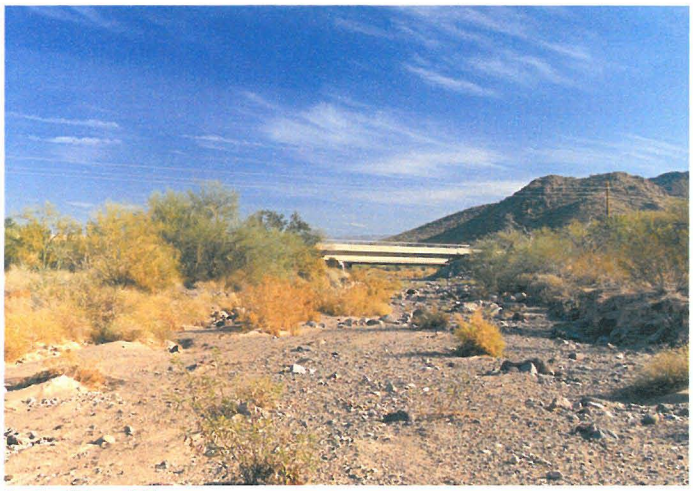
Design Scour Depths for Skunk Creek Phase 1 by Reach

Reach Name (1)	Total Design Scour in feet		
	Minimum (2)	Maximum (3)	Average (4)
Skunk Creek Braided Reach	3.0	5.5	3.4
Skunk Creek Greasewood Reach	4.3	6.1	5.2
Skunk Creek Cutbank Reach	3.0	10.3	6.6
Skunk Creek Knoll Reach	3.0	8.3	5.5
Sonoran Wash Sandy Reach	3.0	5.9	3.4
Sonoran Wash Main Stem Reach	3.0	8.2	3.8
Sonoran Wash Ironwood Reach	3.0	8.7	4.4
Sonoran Wash Hackberry Reach	3.0	7.5	4.1

Table 8 Design Scour Depths for Skunk Creek Phase 2 by Reach			
Reach Name (1)	Total Design Scour in feet Minimum (2)	 Maximum (3)	 Average (4)
Skunk Creek Carefree Reach	3.1	6.7	5.5
Skunk Creek Skunk Tank Reach	3.0	7.7	4.6
Skunk Creek Cobbled Bank Reach	3.0	7.2	4.6
Skunk Creek Rodger Creek Reach	3.0	11.2	5.4
Skunk Creek Cline Creek Reach	3.5	8.5	5.6
Skunk Creek Shang-ri La Reach	3.0	6.8	4.1
Skunk Creek New River Road Reach	3.0	9.5	3.8

All of these tributaries enter Skunk Creek from the east. No significant tributaries join Skunk Creek within the study limits from the west side of the watershed. The watershed area for Skunk Creek is about 50.3 mi.^{2} at the CAP Canal, and about 32.7 mi.^{2} just downstream of the confluence with Cline Creek. The confluence of Cline Creek with Skunk Creek is near the upper study limit, so the majority of the watershed (65%) drains to Skunk Creek at that point. The upper watershed is bulbous in shape and encompasses the higher mountain areas. The watershed below the confluence with Cline Creek is long and narrow. Refer to Figure 30. The Sonoran Wash watershed is rectangular in shape and feeds fairly uniformly into the wash. The Sonoran Wash *main channel* joins Skunk Creek about 0.5 miles downstream of the CAP Canal, but the floodplains of the two *watercourses* intermingle upstream of the CAP Canal because of the backwater effects resulting from the constrictions at the CAP Canal drainage over-chutes.

Both the Skunk Creek and Sonoran Wash watersheds were relatively undeveloped at the start of the WCMP study in 1999. The watershed is rapidly urbanizing as witnessed by the Tramonto development upstream of the Carefree Highway, and the Anthem development between Desert Hills Drive and Honda Bow Road. Both of these developments are currently under construction. Major developments are also now under construction in the Sonoran Wash watershed. It is expected that the watershed downstream of the Carefree Highway will be heavily urbanized, and the watershed upstream of the Carefree Highway will continue to develop as rural residential, with the exception of the Tramonto and Anthem projects. The Tonto National Forest is expected to remain in its natural condition from a development standpoint. Existing forest management uses such as recreation and grazing are assumed not to change drastically in the future.



Carefree Highway Bridge

The second characteristic studied is the geologic setting, the understanding of which is fundamental to predicting the *lateral channel migration* potential of the study *watercourses*. The geologically recent Holocene (< 10,000 years before present) aged fluvial deposits along the Skunk Creek and Sonoran Wash corridors are bounded by middle Pleistocene (> 10,000 years before present) piedmont surfaces or bedrock outcrops. Late Pleistocene and Holocene-aged terraces along Skunk Creek and Sonoran Wash record geologically brief episodes of *aggradation* that occurred within the overall degradational history of the past 500,000 years. After

these brief periods of deposition, the main streams continued to degrade, leaving terrace surfaces along the stream corridor that record former floodplain elevations.

Within the study area, geologic evidence shows the existing *channels* of Skunk Creek and Sonoran Wash have experienced net *degradation* over the past 500,000 years. Therefore, net *degradation* is expected to continue in the future. Entrenchment during recent geologic time has created a series of older, stable terraces that confine the existing active *channels* within a relatively well-defined corridor. Likewise, future *channel* movement is most likely to be confined within the corridor of geologically recent surfaces located near the *main channels*.

The presence and characteristics of the fluvial terraces along Skunk Creek and Sonoran Wash provide the following types of information about the existing and future risk of lateral *erosion*:

- *Erosion* limits. Over the past 500,000 years, lateral *erosion* has been limited to the area of the 500 to 3,500 foot wide stream corridors located between the middle Pleistocene surfaces. Within the past 10,000 years, lateral *erosion* has been limited to the area of the 500 to 2,000 foot wide stream corridors located between the late Pleistocene surfaces. Future lateral *erosion* is most likely to occur within areas composed of the most recent geomorphic surfaces.

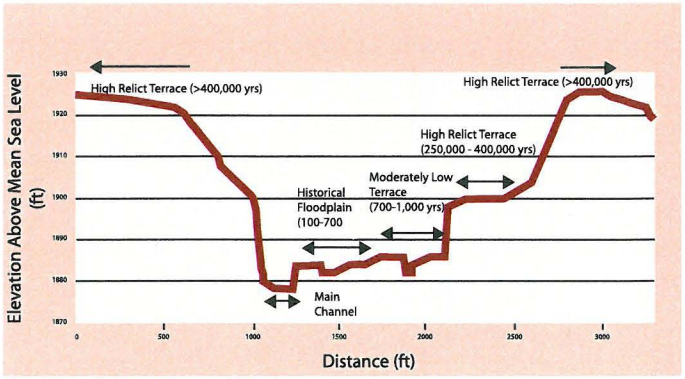
- *Erosion* corridor width. The width of the modern geomorphic surfaces increases and the height of the fluvial terraces generally decreases in the downstream direction, indicating an increased potential for lateral *erosion* in the downstream direction.

- Net *degradation*. The height of the fluvial terraces above the existing *channel* bed suggests that a maximum of about 25 feet of net vertical *erosion* has occurred since the middle Pleistocene, with a maximum of about 10 feet since the late Pleistocene.

- Episodes of *aggradation*. Episodes of *aggradation* (e.g., *channel* filling, floodplain deposition) have occurred at numerous times in the past, and should be expected in the future. During periods of *aggradation*, the stream corridor tends to occupy a wider portion of the geologic floodplain.

- Cline Creek terraces. The terraces along Cline Creek appear to be more closely correlated with the Skunk Creek terraces downstream of the Skunk/Cline confluence than are the terraces along Skunk Creek upstream of the confluence. Therefore, it is assumed that Cline Creek may be a more important source of runoff and sediment than Skunk Creek upstream of the confluence.

The third characteristic studied is *hydrology*. The hydrologic evaluation includes use of the hydrologic model data, the study of *watercourse* and precipitation gage records, and the seasonality of precipitation, and historical floods. Evaluation of hydrologic data suggests that the *watercourses* are normally dry, and that most significant *channel* changes will occur during large floods.



Typical Cross Section of Geomorphic Surfaces

The fourth characteristic studied is stream classification. The primary objective of stream classification is to match measurable *watercourse* characteristics with expected *watercourse* responses. This evaluation is used as an indication of whether or not a detailed study of lateral migration is warranted for these *watercourses*. The Brice and Rosgen stream classification systems results indicate that Skunk Creek and Sonoran Wash have many characteristics

typical of *braided watercourses* and *ephemeral watercourses*. Lateral movement should be expected for both *watercourses*, and a more detailed evaluation of lateral stability is warranted based on the stream classifications from the Brice and Rosgen systems.

2. Historical Analysis

A basic assumption of any geologic analysis is that "understanding the past, as preserved in the geologic record, is the key to understanding the future" (NRC, 1996). In the case of the WCMP historical analyses, this means that to predict the potential future lateral migration, past river behavior must be thoroughly understood. The following data sources are used to obtain this understanding:

- ★ Published summaries of the archaeological record.
- ★ Published descriptions of regional geology.
- ★ Historical maps and aerial photographs.
- ★ *Channel* descriptions from historical General Land Office (GLO) surveys.
- ★ Field evidence of past *channel* and floodplain changes.

Historical information illustrates the types of *channel* changes that have occurred in the study area during the past, and suggests the types of *channel* change that can be expected in the future. Archaeological records imply that *channel erosion* has affected Skunk Creek for at least 10,000 years. That is, *channel erosion* is not simply the result of modern human impacts on the *channel* and watershed. Therefore, natural cycles of stream *degradation*, local *aggradation*, lateral migration, and climate change must be accounted for in development of the *erosion* hazard zones and the WCMP. Climate change is considered a significant cause of long-term lateral *erosion* and *channel* incision.

Review of features observed on historical aerial photographs indicates that direct human impacts on Skunk Creek have been limited to construction of bridge and at-grade road crossings, construction of the CAP, and minor sand and gravel excavations.

Post-flood at 19th Avenue and Skunk Creek

Direct human impacts on Sonoran Wash are limited to construction of the CAP and several at-grade ranch road crossings. Indirect human impacts on Skunk Creek and Sonoran Wash include construction of stock ponds, moderate urbanization of the watershed, and cattle grazing. The degree of urbanization in the watershed has accelerated during the past several years relative to the pace of development prior to 1988. The types of *channel* changes observed on the aerial photographs include *avulsions*, bank failure, channelization, *channel* width changes, formation of multiple *channels*, braiding, deposition, and movement of distributary flow areas.

Historical *channel* width and *channel* position are compared on historical aerial photographs dating to 1940 and General Land Office (GLO) survey records dating to 1894. On Skunk Creek, the maximum change in total width as expressed by the distance between the furthest left and furthest right banks or braids is 414 feet due to development of a *channel avulsion* in what was an overbank floodplain. More than 100 feet of lateral *erosion* is recorded by the aerial photographs in several locations, despite having few major floods during the period of record. The primary mechanism for the most significant *channel* movement is *avulsion*, with an upper limit of single event *erosion* on Skunk Creek of about 400 feet, and the maximum rate of lateral movement of about 18 feet per year. The average long-term rate of lateral movement over the entire study area is about 1 foot per year.

Vertical *channel* changes are analyzed by comparing topographic records dating to 1962. The record indicates that net *aggradation* has occurred on Skunk Creek since 1962 from approximately the Lone Mountain Road alignment to the Cline Creek confluence, with net *degradation* upstream and downstream. Topographic data regarding long-term *channel* elevation changes for Sonoran Wash are inconclusive. Geologic evidence implies that net long-term *degradation* has averaged 10^{-4} to 10^{-5} feet per year over the past several hundred thousand years. However, the observed rate of *degradation* during the period of historical record exceeds the implied long-term geologic rate by several orders of magnitude, and *aggradation* has also been recorded in some *reaches*. It is concluded that the elevations of the *channel* beds will fluctuate around a slight degradational trend.

Changes in *channel* width of Sonoran Wash and Skunk Creek during the 37-year period of photographic records are small relative to the scale of changes determined by consideration of GLO records extending back an additional 68 years. Despite an overall average narrowing of Skunk Creek and Sonoran Wash in the 100-year period of record, the maximum change in width is more than 400 feet. Width increases someplace in the study area were recorded during every time period considered. Therefore, significant *erosion* should be expected somewhere on Skunk Creek during any significant flood. The greatest measured width changes correspond to formation of new *channels* within the floodplain by avulsive processes. No significant changes in *channel* pattern or sinuosity are detected. The historical descriptions by the GLO surveyors indicate that *channel* conditions between 1890 and 1933 probably are not much different than modern conditions.

3. Geomorphic Analyses

The geomorphic analyses used in this study evaluate the topography of the *watercourses* and the adjacent terrain in order to estimate past and future *channel* movement. These estimates are then used to define the land area subject to *erosion* and required by the watercourse to preserve its natural function. Three basic geomorphic analyses are completed:

- ★ Field assessment techniques.
- ★ Geomorphic mapping.
- ★ Geomorphic assessment techniques.

The geomorphic analysis techniques employed use field observations, interpretation of the surficial geology, and application of empirical and theoretical data to evaluate the lateral stability of Skunk Creek and Sonoran Wash. Field observations made in the study area indicate that the study *reaches* are subject to lateral *erosion*, *channel avulsions*, *scour*, and have experienced some historical *channel degradation*. Evidence of human impacts is minimal. Observations made along Sonoran Wash indicate that it is more laterally stable than Skunk Creek. Field data suggest that the frequency of *channel avulsions* on Skunk Creek is greater than on Sonoran Wash.

The ages and relative heights of the geomorphic surfaces along Skunk Creek and Sonoran Wash provide information on how recently they have been subject to flood and *erosion* hazards. Since the late Pleistocene, riverine *erosion* and floodplain *sedimentation* processes dominate the study area. Prior to the late Pleistocene, alluvial fan processes that deposited the alluvium in which the streams are formed dominated. The geologic record also indicates that Skunk Creek and Sonoran Wash have been subject to *channel avulsions* for at least the past

Skunk Creek Field Observation

10,000 years. Both streams have experienced net *degradation* over the last million years. Except in *reaches* affected by *channel avulsions*, geologic evidence indicates that the rate of net *channel* change has been slow (< 1ft/yr laterally, <0.01 ft/year vertically), although episodes of faster local change undoubtedly occurred. The scale of lateral *channel* change observed in the recent geologic record is not significantly different than the scale of historical changes documented in the historical analyses. The rates of lateral movement have been fastest on the youngest, less indurated and most frequently inundated surfaces, and slowest along the margins of the older, more well indurated and less frequently flooded surfaces. The older terrace margins serve as a practical limit for predicted future rapid *channel* change, although the older terraces are also subject to (slower) lateral *erosion*. The low terraces of Holocene age have a high potential for being flooded and are highly susceptible to lateral stream *erosion*. Evaluation of information obtained from the soil pits excavated during the field assessment indicates that the active *channel* has shifted rapidly across the low terrace surfaces within the past several hundred to one thousand years. This type of *erosion* should be expected in the future.

The longitudinal profiles of the Skunk Creek and Sonoran Wash indicate that long-term *scour* due to responses to existing slope perturbations is not likely. Other analyses indicate that long-term *scour* due to other factors and processes are likely, as described below. These analyses include bankfull discharge, bank erodibility, *channel* pattern equations, *channel* geometry equations and hydraulic geometry equations. Irregularities in the longitudinal profile indicate that future lateral movement will be related to depositional processes in the downstream *reaches*, *avulsions* in *reaches* of irregular slope, and local *scour* throughout the study area.

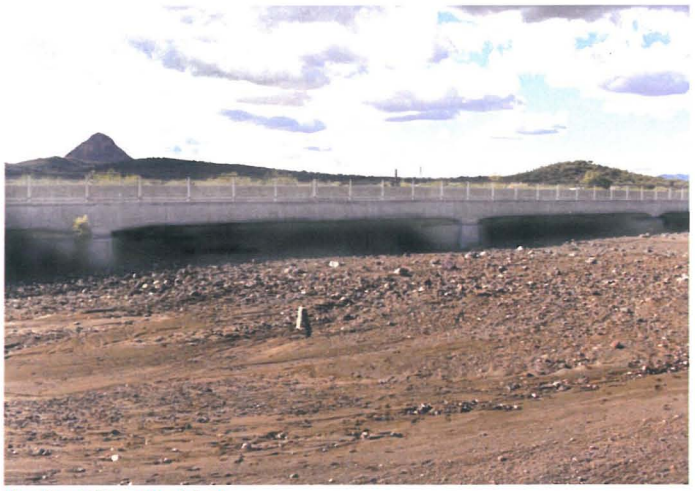
Skunk Creek North of Honda Bow Road

The average bankfull discharge recurrence interval for the study watercourses ranges from 5- to 10-years, except where the channels have been extensively modified by humans. However, there is poor continuity in bankfull discharge magnitude and frequency between individual adjacent cross sections in many areas. This discontinuity is interpreted to indicate that the study watercourses tend to recover slowly from local erosion. For example, one form of local erosion is bank failures that lead to channel widening. In Skunk Creek, it is noted from examination of historical aerial photographs that these intermittent widenings tend to persist over long periods of time. Furthermore, the bankfull discharge data indicate that primarily the large floods (recurrence intervals greater than 5-years) shape the channel geometry of the streams in the study area. Small floods tend not to fill the channels or flow against the banks, and thus cannot perform significant geomorphic work. An extreme example is noted in the reach of Skunk Creek adjacent to the Anthem development parcel. The bankfull discharge in that reach is significantly higher than in adjacent reaches. As a result, future changes in channel geometry are expected as the channel adjusts to a lower bankfull discharge that is more typical of the upstream and downstream reaches.

Bank erodibility estimated using a Rosgen classification scheme indicated that bank *erosion* potential for Skunk Creek ranges from moderate to high, and from low to moderate for Sonoran Wash. These results are consistent with field observations of greater bank stability along Sonoran Wash compared to Skunk Creek.

Application of *channel* pattern equations to the study area indicate that for Skunk Creek, the measured slope for the entire study *reach* is about twice the threshold slope for a braided *channel* pattern.

This is substantiated by field observations that suggest that flow in Skunk Creek is often braided, especially at below bankfull flow rates. At higher flows, many *reaches* have an intermediate, straight or *anastomosing channel* pattern. For Sonoran Wash, the measured slope is approximately equal to the threshold for a braided *channel* pattern. Field observations suggest that flow in Sonoran Wash has braided characteristics at low flow rates, but has more of a straight or intermediate pattern at bankfull or higher discharges. Because Sonoran Wash is close to the threshold for braiding, slight changes in watershed or *channel* characteristics could lead to major changes in *channel* pattern.



New River Bridge at Skunk Creek

Channel geometry equations indicate the *main channel* width of Skunk Creek and Sonoran Wash appears to be adjusted to the 2-year event. Therefore, at flow rates exceeding the 10-year *recurrence interval*, the *channel* will tend to widen. That is, small floods will not significantly change the *channel* width. Most of the geomorphic work will be accomplished during large floods. The existing *channel* width in the bridge sections of Skunk Creek at New River Road and the Carefree Highway are wider than the 100-year expected width. Therefore, most floods will tend to narrow the *channel* section by depositing sediment, resulting in loss of conveyance through the bridge section. Predicted Skunk Creek *channel* depths are generally greater than the flow depths computed by HEC-RAS modeling. Therefore, *degradation* during most floods should be expected in the future. The predicted *channel* slopes are flatter than the existing *channel* slope in all *reaches* of Skunk Creek. Therefore, long-term *degradation* should be expected. The predicted velocities are lower than the velocities computed by HEC-RAS modeling. Therefore, *scour* and high rates of sediment transport should be expected. In the two bridge sections, the predicted velocities for the 2-year event are higher than the HEC-RAS modeling of the existing *channel*. Therefore, sediment deposition and long-term *aggradation* should be expected in the bridge sections.

The existing and predicted *main channel* width for Sonoran Wash differ by a factor of two to three for the 100-year event, indicating a strong tendency for lateral movement during extreme floods. The predicted *channel* depths for Sonoran Wash are generally greater than the flow depths computed by HEC-RAS modeling for the 2-year event, but less than the HEC-RAS values for the 10- and 100-year events. Therefore, *degradation* during most frequent floods should be expected in the future. The predicted 10- and 100-year depth data probably reflect historic incision, which deepened the *main channel* of Sonoran Wash. The predicted *channel* slope is flatter than the existing *channel* slope in all *reaches* of Sonoran Wash. Therefore, long-term *degradation* should be expected. The predicted velocities are lower than the velocities computed by HEC-RAS modeling of the 10- and 100-year events, but about equal to the 2-year HEC-RAS *channel* velocities. Therefore, *scour* and high rates of sediment transport should be expected during the largest floods, but minimal *erosion* during the smallest floods. The trends of predicted *channel* characteristics are similar throughout the Sonoran Wash study *reach*, with evidence of minimal disturbance by non-natural factors.

The hydraulic geometry regression equation results also provided insight into the stability of the stream *channels* in the study area. A faster increase in depth and a slower increase in width indicate a *channel* configuration that is deeper and narrower than average, a conclusion that is supported by the *channel* geometry equations. A slower increase in width as discharge increases implies that the *channel* has

well-consolidated banks, constraining lateral *erosion* while concentrating erosive work on the bed of the *channel*, as was hypothesized by Parker (1979). These factors, along with a faster increase in depth, might indicate that the *channels* are more incised than those of the average ephemeral wash.

4. Engineering Approaches to Lateral Stability Assessment

The engineering approaches used for lateral stability assessment were focused on estimating the potential for, and magnitude of, future bank *erosion*. The approaches used were based on the following:

- Hydraulic data.
- Sediment data.
- Engineering methodologies.

Hydraulic data used in the engineering and geomorphic analyses were obtained from HEC-RAS modeling. Hydraulic data typically required for lateral stability assessments and *sedimentation*-engineering studies include the following basic *channel* parameters:

- Width.
- Depth.
- Velocity.
- Discharge.
- Roughness.

The objectives of the HEC-RAS hydraulic analyses for the study area are to estimate the hydraulic characteristics of the study *reach*, to identify hydraulically similar sub-*reaches* within the study area, and to identify sub-*reaches* with limited conveyance capacity. Specific tasks include the following:

- Provide basic data for use in engineering and geomorphic analyses.
- Identify hydraulically similar *channel reaches*.
- Estimate existing *channel* capacity relative to return period.

Sediment data collected for use in the lateral stability assessment reveal two trends. First, there is a significant difference in the size of the bed materials in riffles compared to the size of the bed materials in pools. Therefore, the engineering analyses used in this study are dependent on whether bed samples are obtained from pools or riffles. Second, the data from Sonoran Wash indicate that mean sediment size varies by about an order of magnitude over the study length.

Cobbled Bed Riffle in Sonoran Wash

The specific engineering methodologies used to assess lateral stability indicate that Skunk Creek and Sonoran Wash are subject to bank *erosion* during floods. The Arizona Department of Water Resources (ADWR) State Standard Level 1 *erosion* hazard methodology (ADWR, 1996) was generally not applicable to the study area and had poor correlation to the Level 3 type analyses used in this study.

Bank *erosion* estimates are generated using the results of HEC-6 sediment continuity modeling. The HEC-6 model does not explicitly consider bank *erosion*, although because HEC-6 is a sediment continuity model, it computes the sediment deficit or surplus within each stream segment. The computed sediment deficit can be applied to the banks to estimate possible lateral *erosion* potential. Using this approach, examination of the HEC-6 results indicates that bank *erosion* can be expected throughout the study area during large floods. The HEC-6 results reasonably simulate the bank *erosion* distances observed in the study *reach* during the field

visits. Allowable velocity criteria provide general information on the likelihood of bank and *channel erosion*. Broadly interpreted, the allowable velocity data indicate that all of the *channel* banks in the study area will erode even in small floods if the banks are not cohesive, but will resist *erosion* if they are cohesive. Additional uncertainty in allowable velocity predictions is caused by the effects of bank vegetation (increase stability), stratified bank sediments (decrease stability), and other local variations (calcium carbonate content, piping, bed *scour*, etc.).

The *scour* and deposition caused by the *channel's* adjustment to an equilibrium slope indicate that long-term *aggradation* is predicted for the periods dominated by small floods, with long-term *degradation* more likely to occur during periods dominated by large floods. The greatest amount of expected slope adjustments would occur in the *reaches* disturbed by bridge construction. In the bridge *reaches*, the equilibrium slope equations predict long-term *aggradation*. The actual magnitude of the expected bed elevation changes is based in part on the potential for armoring, sediment supply, and the magnitude and frequency of the flows experienced in the future. The armoring analyses indicate that *channel* bed *scour* depth is probably limited by armoring during frequent flows and small floods, but the average bed material is too small to prevent *scour* during large flood events. Other results of the armoring analysis include evidence that the *channel* bed material is mobile, and will be transported during moderate to large flood events. Effective armor layers were not observed in the field or in the *channel* soil pits. General and long-term *scour* estimates for the streams in the study area indicate that moderate *scour* should be expected for Skunk Creek, especially in *channel* bends. Somewhat lower *scour* depths should be expected for Sonoran Wash. When *scour* occurs, it undermines the *channel* banks and increases the rate of lateral *erosion*. Therefore, the greatest amount of *scour*-induced bank *erosion* in the study area should be expected at *channel* bends, near obstructions, or where the *channel* has been excavated. Estimated bank *erosion* distances should be revised upward where bed *scour* is significant.

The engineering analyses described in this section predict mixed trends of *aggradation* and *degradation* for Skunk Creek and Sonoran Wash. These mixed trends indicate that the streams are subject to erosive conditions during floods, and will experience *scour* and slope adjustments best depicted by the types of *erosion* and deposition documented in the recent historical record.

D. Erosion Hazard Zones

The results of Subsections 6A through 6C were used as the basis to define *erosion hazard zones* for the *watercourses* in the study area. The *erosion* hazard boundaries were defined based on consideration of the following information:

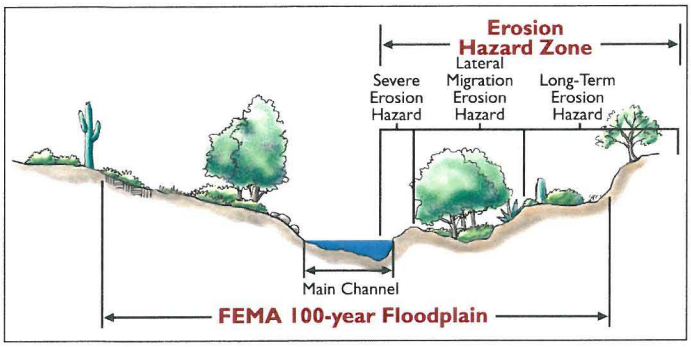
- Field data.
- Stream Classification.
- Historical *Channel* Changes.
- Archaeological Data.
- Mapping of Geomorphic Surfaces.
- Longitudinal Profile Analysis.
- Hydraulic Geometry and Regime Equations.
- Expected *Channel* Patterns.
- Allowable Velocity.
- Equilibrium *Channel* Slope.
- Armoring Potential.
- Stable Bank Slope.
- HEC-6 Modeling Results.
- Expected Lateral *Erosion* Mechanisms.
- Impacts of Mining-Induced Entrenchment.

Three *erosion* hazard zones have been defined and are shown on Figures 32 through 46. These are:

- Severe Erosion Hazard Zone.
- Lateral Migration Erosion Hazard Zone.
- Long-Term Erosion Hazard Zone.

1. Severe Erosion Hazard Zone

The Severe Erosion Hazard Zone is comprised of the active *watercourse channels* and adjacent areas likely to be eroded during a single major event, such as



Typical Section of Erosion Hazard Zones

the 100-year flood. The Severe Erosion Hazard Zone is also comprised of the area likely to be removed if the bank angle were to be reduced to the *natural angle of repose*. The basis of mapping for the Severe Erosion Hazard Zone included the following:

- Bank *erosion* equivalent to the 100-year HEC-6 future conditions sediment deficit.
- Bank *erosion* resulting in a 3:1 bank slope (approximate *natural angle of repose*).
- 2- or 10-year regimes *channel* width, if wider than the existing active *channel*, for Skunk Creek.
- 2- or 25-year regimes *channel* width, if wider than the existing active *channel*, for Sonoran Wash.
- Areas within the bed and banks of existing active *channels*.

In addition, areas within the limits of existing sand and gravel-mining operations were considered to be in the Severe Erosion Hazard Zone, since no engineered *erosion* protection was observed near the mine pits during field visits.

2. Lateral Migration Erosion Hazard Zone

The Lateral Migration Erosion Hazard Zone consists of the area adjacent to the *main channel* likely to be eroded by a "typical" series of floods over a 60-year planning period, plus the *erosion* that would be caused by a single major event such as the 100-year flood. The Lateral Migration Erosion Hazard Zone also includes the natural *channel* movement due to geomorphic processes such as meander migration or *channel avulsion*. The basis of mapping for the Lateral Migration Erosion Hazard Zone included the following:

- Probability-weighted bank *erosion* that is equivalent to the HEC-6 future conditions sediment deficit applied over a 60-year planning period, plus the 100-year HEC-6 future conditions sediment deficit.
- 2-, 10-, 25- or 100-year regimes *channel* width, if wider than the existing active *channel*.
- Limits of historical *channel* movement and geologically recent *channel avulsions*.

The limits of the Lateral Migration Erosion Hazard Zone were widened in *reaches* where the field assessment indicated a high potential for future *erosion*, where evidence of ongoing *erosion* was observed, and in *reaches* where accelerated *erosion* was expected due to *channel* bends or over-steep banks. In general, the Lateral Migration Erosion Hazard Zone included areas outside, but adjacent to, the active *channels* of Skunk Creek and Sonoran Wash.


Erosion Deposition at Skunk Creek and Desert Hills Drive

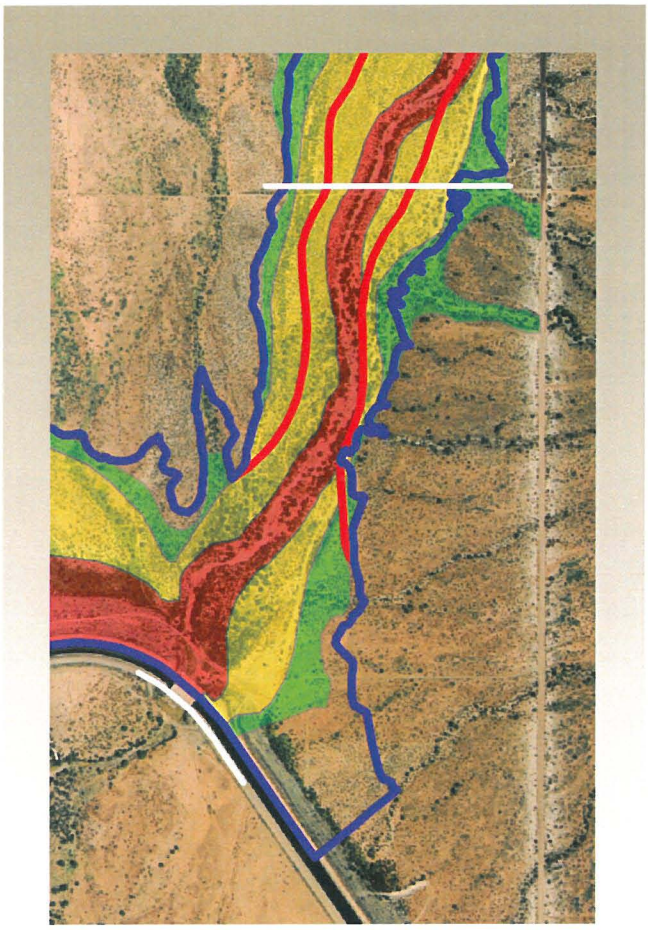
3. Long-Term Erosion Hazard Zone

The Long-Term Erosion Hazard Zone consists of the floodplain margin area defined by geologic evidence of *channel* movement over the past 60- to 1,000-years, and represents expected or potential *channel* movement over the next 60- to 1,000-years in the future. The boundary of the expected Long-Term Erosion Hazard Zone envelopes the results of all the predictive methods used to assess *channel* stability, in addition to application of engineering judgment and interpretation of the site *geomorphology*. The basis of mapping the Long-Term Erosion Hazard Zone is the following:

- Geomorphic mapping.
- *Channel* pattern development.
- "Meander" migration trend.
- Interpretation of potential impact from human activities.

Portions of areas mapped as older geomorphic surfaces, but adjacent to active *channels* and floodplains, are generally included in the Long-Term Erosion Hazard Zone.

Typical Point of Avulsion



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 1 Key Map:

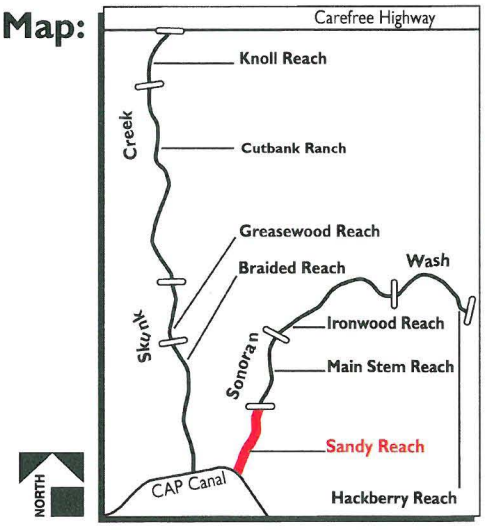
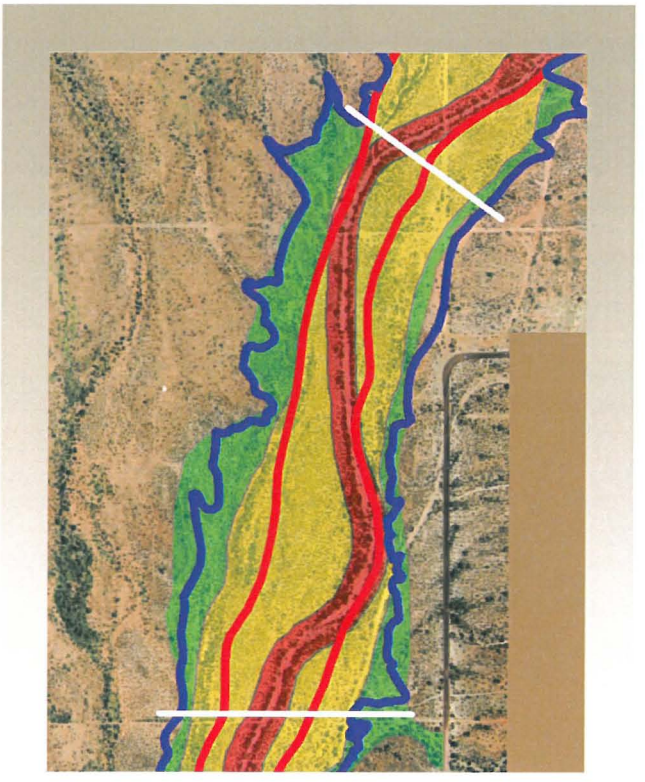


Figure 32. Sonoran Wash - Sandy Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

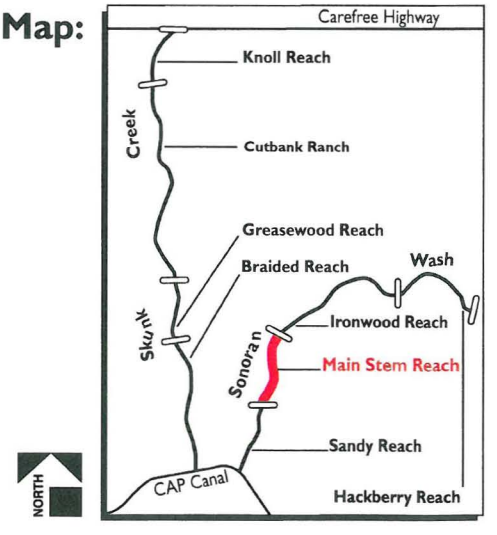
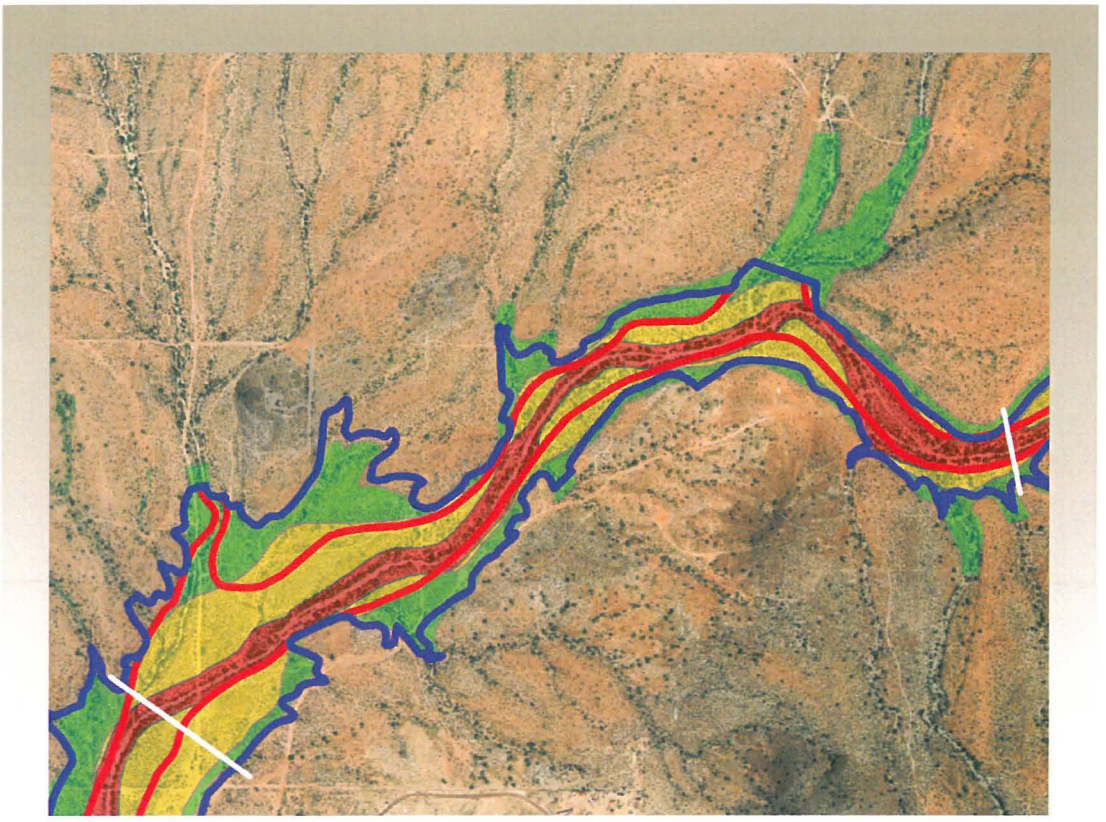


Figure 33. Sonoran Wash - Main Stem Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

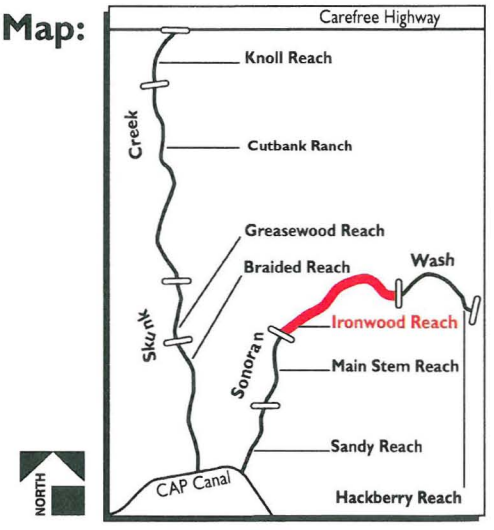
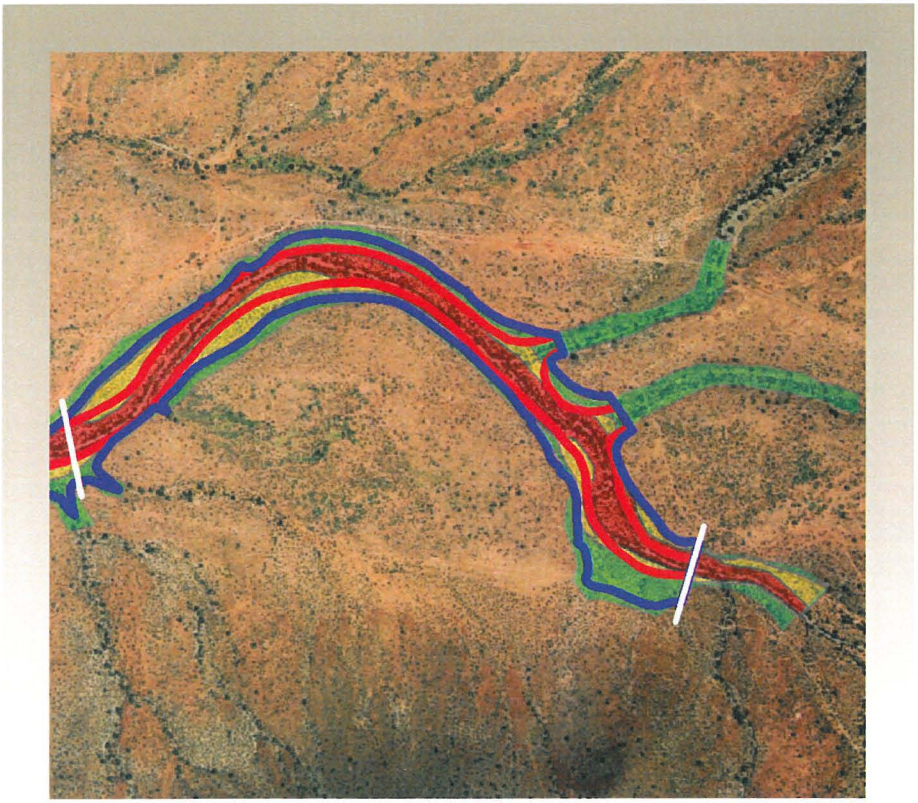


Figure 34. Sonoran Wash - Ironwood Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

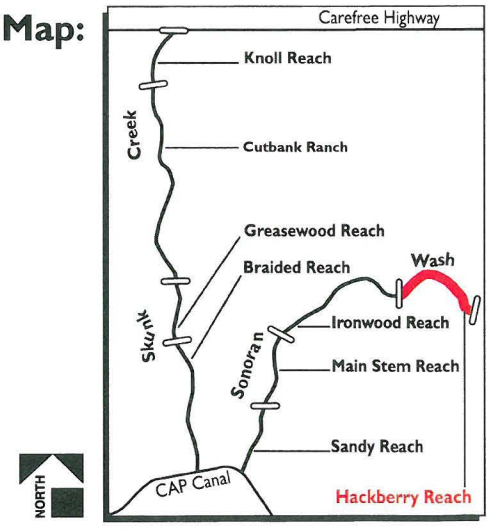


Figure 35. Sonoran Wash - Hackberry Reach Erosion Hazard Zones

July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

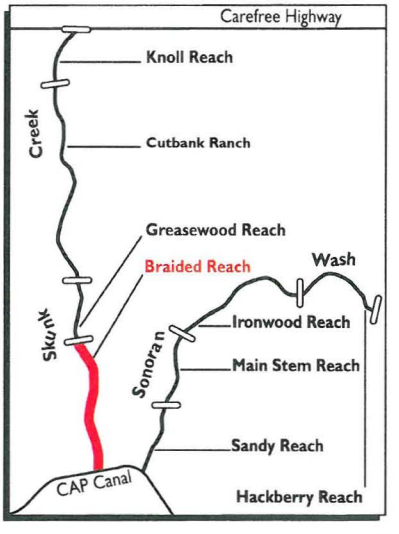
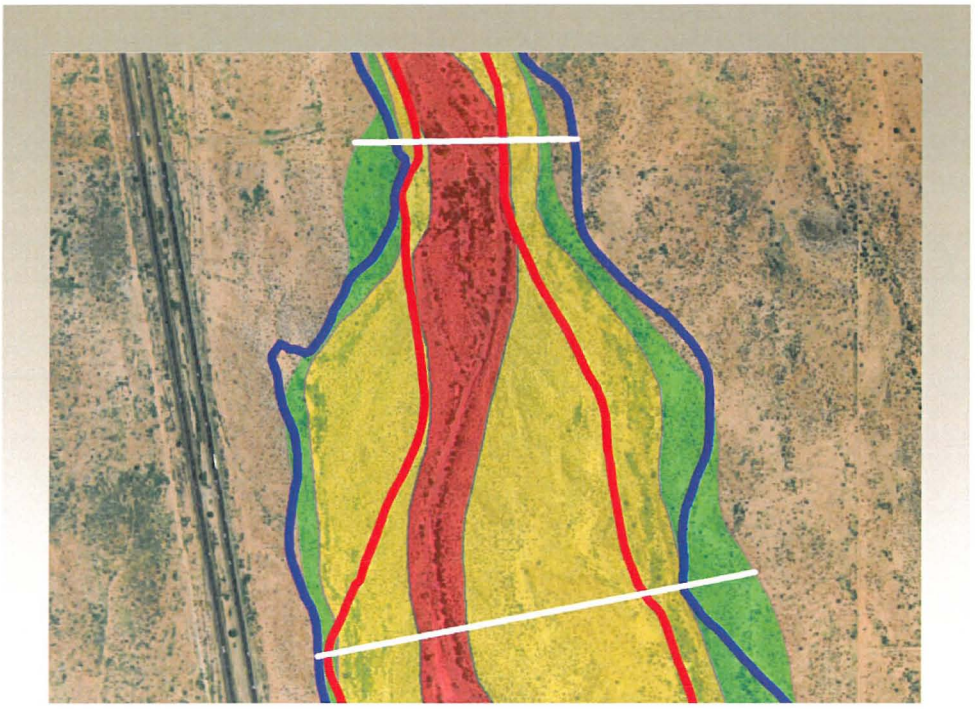


Figure 36. Skunk Creek - Braided Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

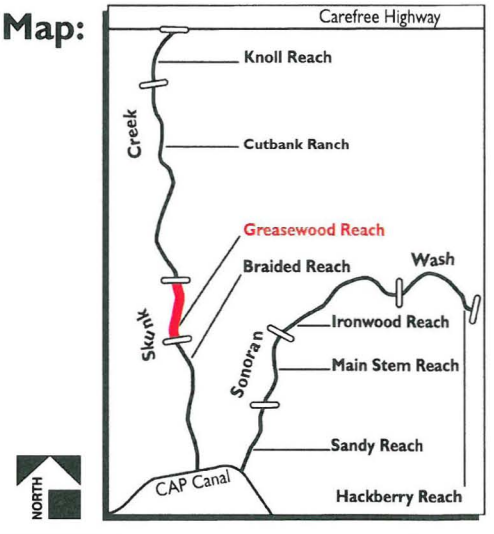


Figure 37. Skunk Creek - Greasewood Reach Erosion Hazard Zones

July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase I Key Map:

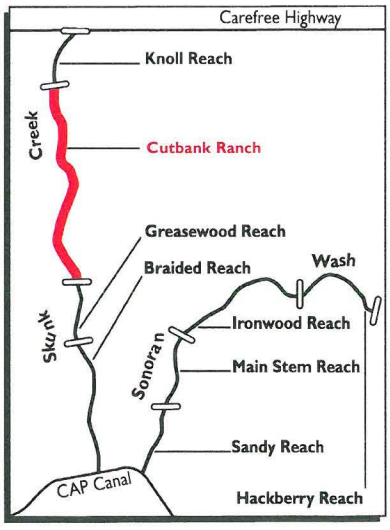
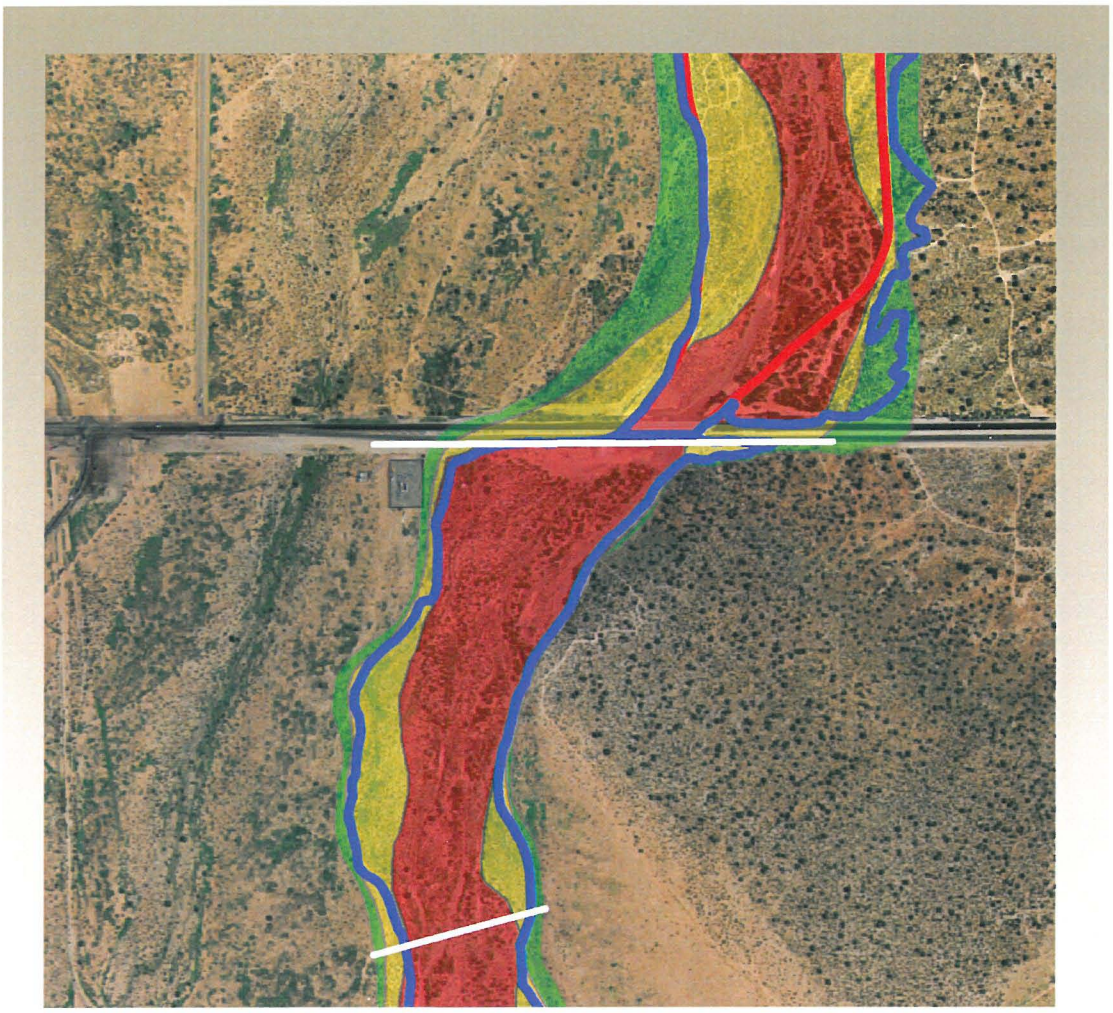


Figure 38. Skunk Creek - Cutbank Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 1 Key Map:

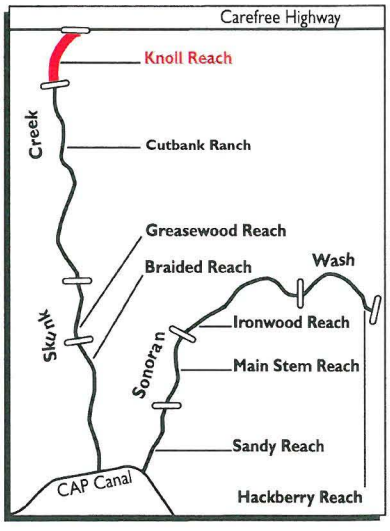
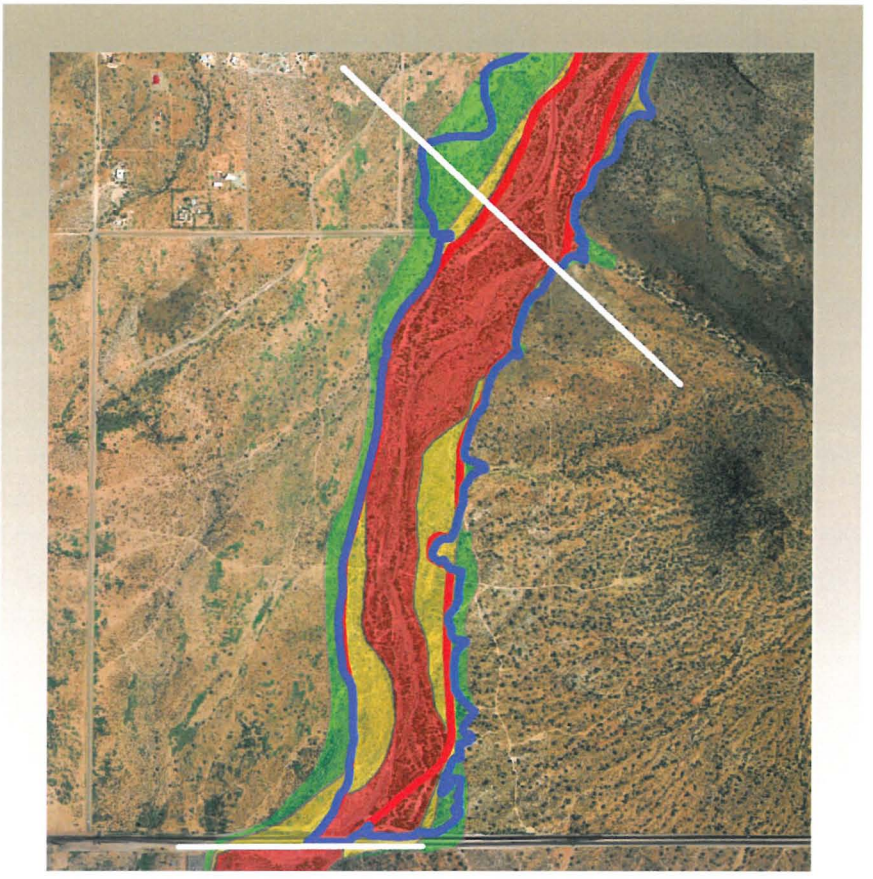


Figure 39. Skunk Creek – Knoll Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

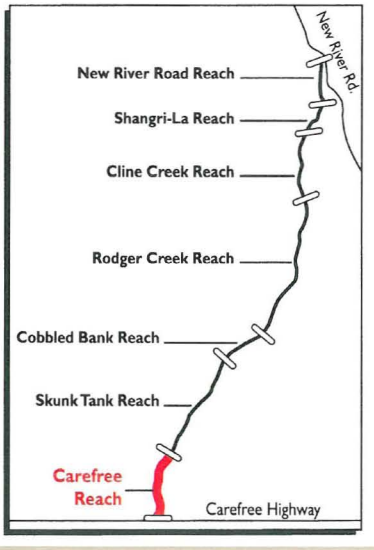
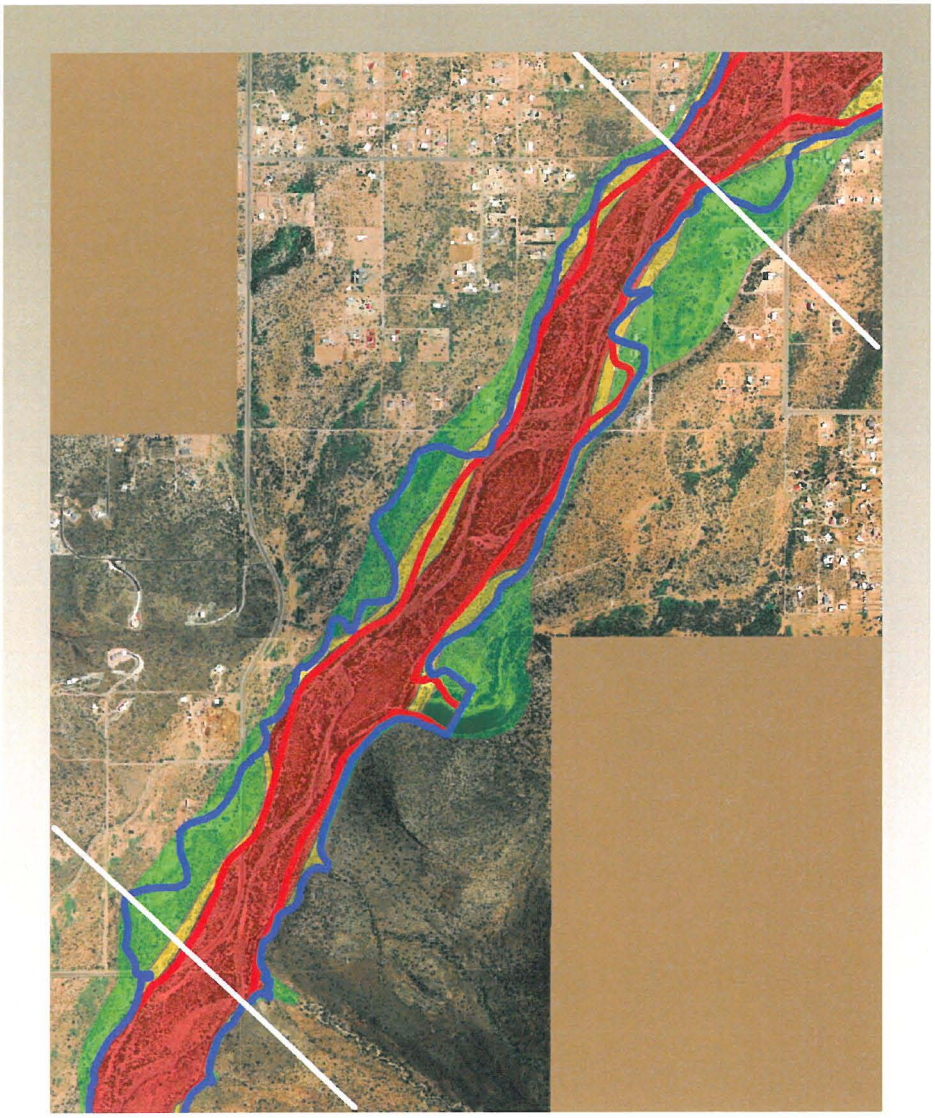


Figure 40. Skunk Creek - Carefree Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

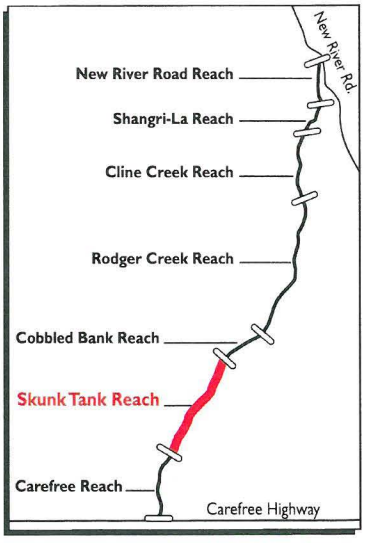
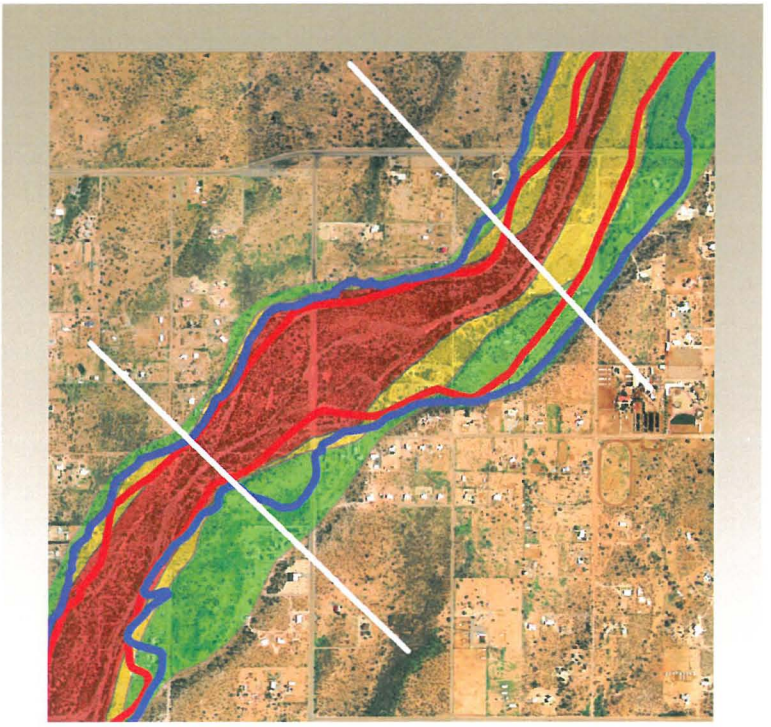


Figure 41. Skunk Creek - Skunk Tank Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

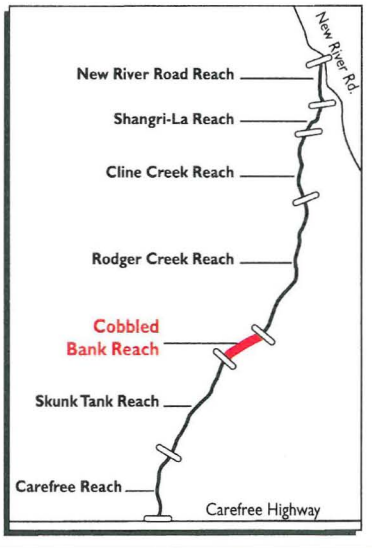
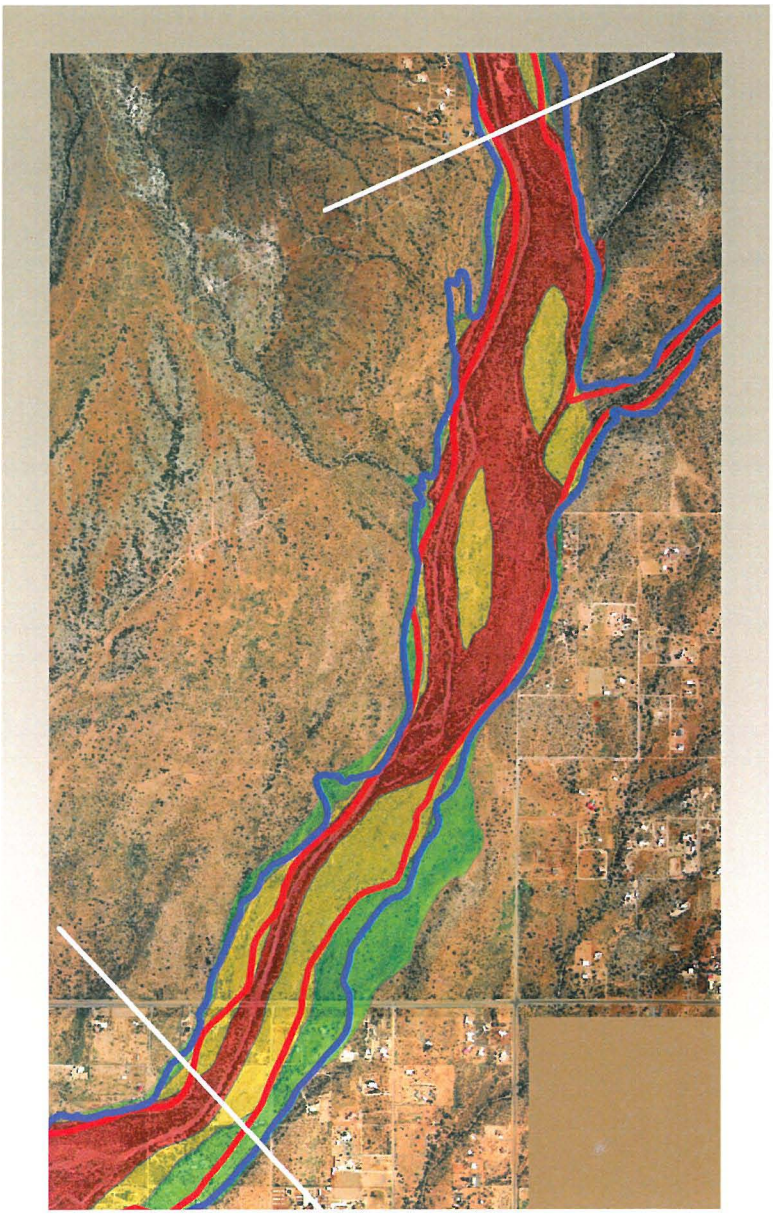


Figure 42. Skunk Creek - Cobbled Bank Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

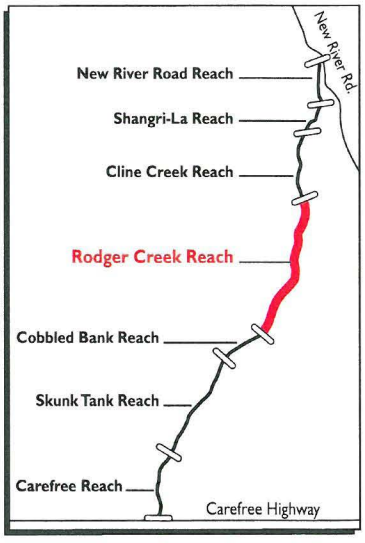
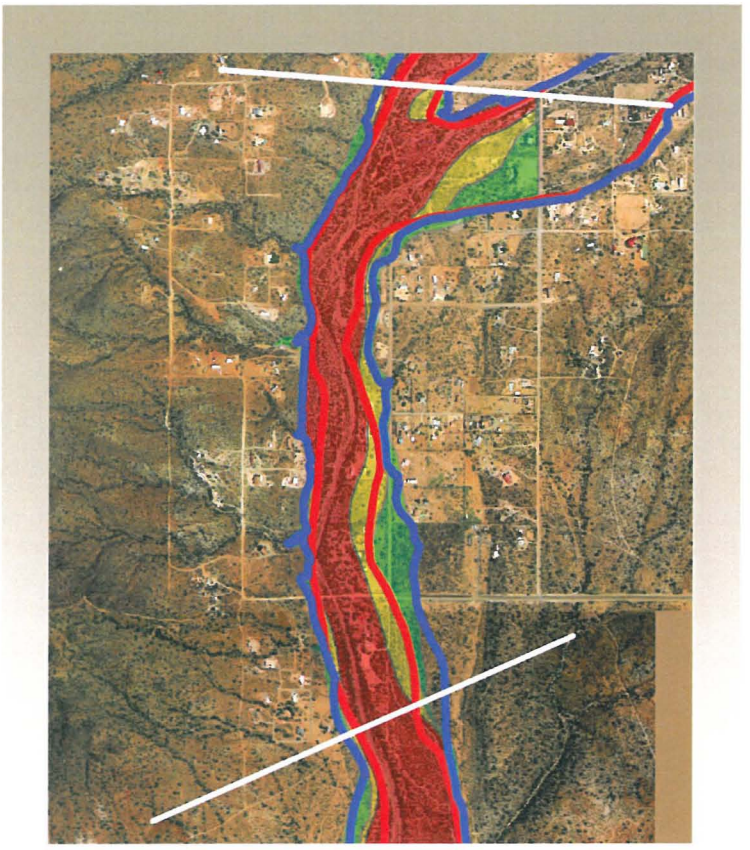


Figure 43. Skunk Creek - Rodger Creek Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

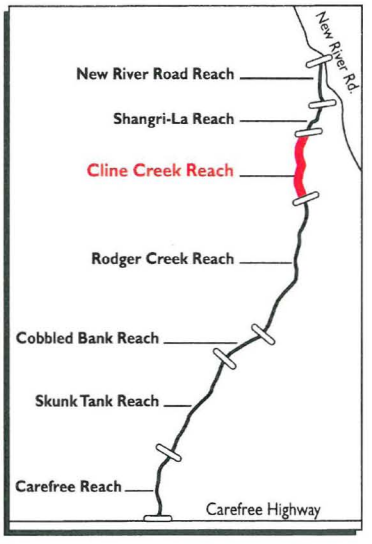
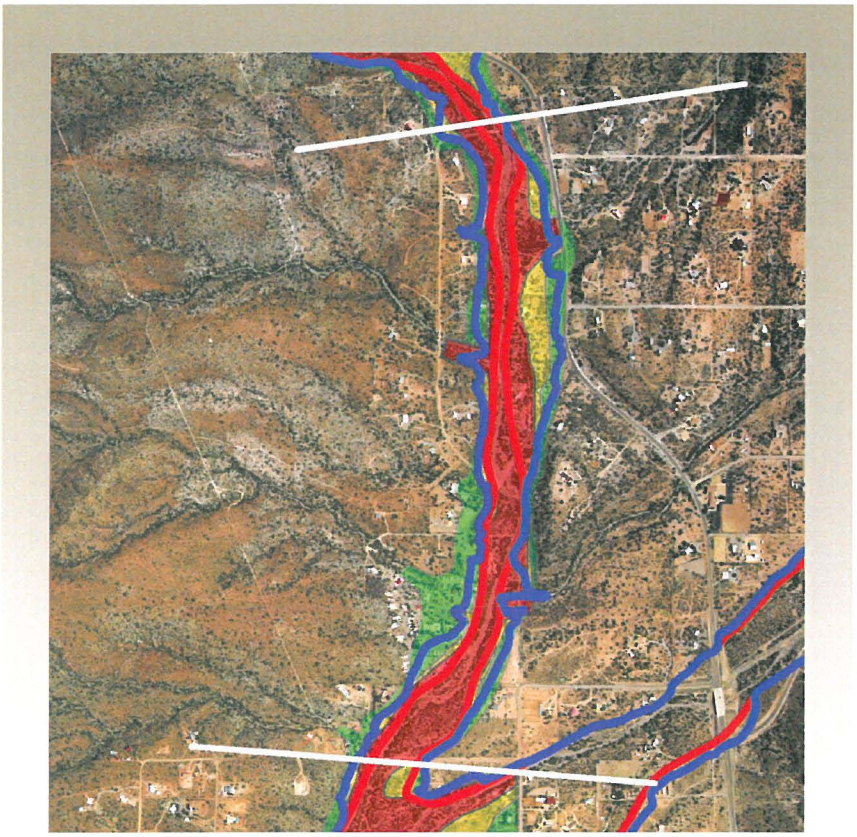


Figure 44. Skunk Creek - Cline Creek Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

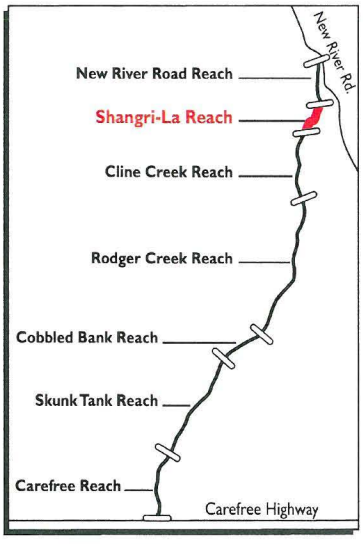
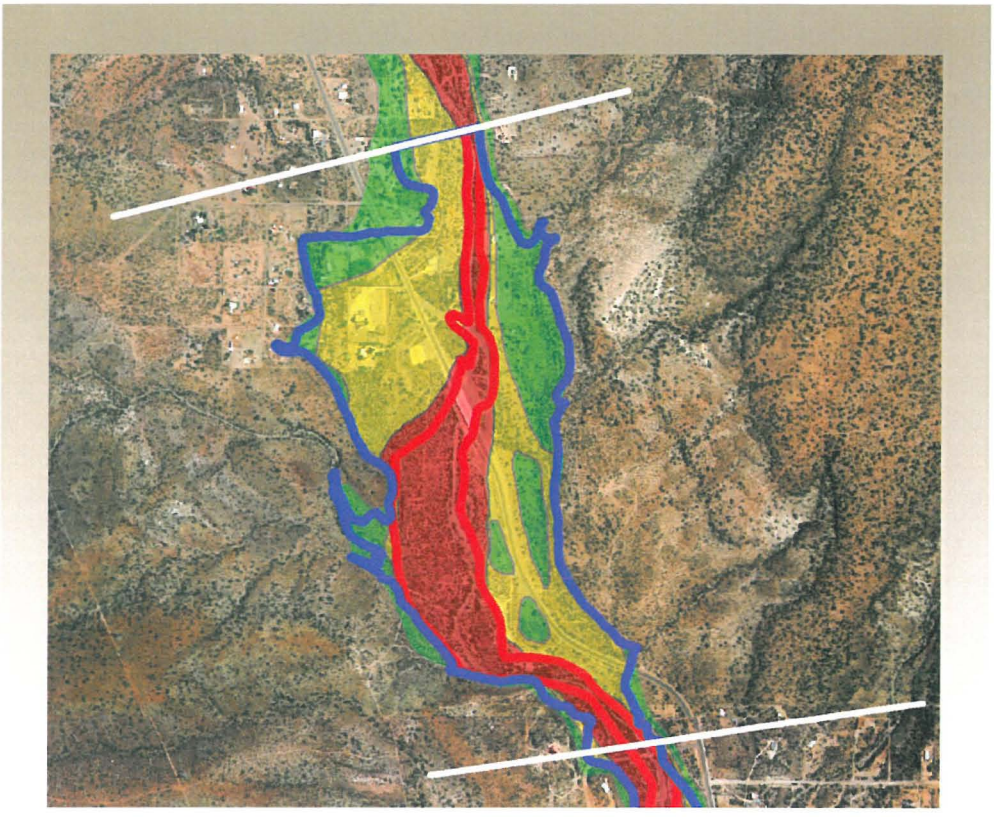


Figure 45. Skunk Creek - Shangri La Reach Erosion Hazard Zones



July 1999 Aerial Photograph

Key

- Severe Erosion Hazard Zone
- Lateral Migration Erosion Hazard Zone
- Long-Term Erosion Hazard Zone
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Reach Boundary

Phase 2 Key Map:

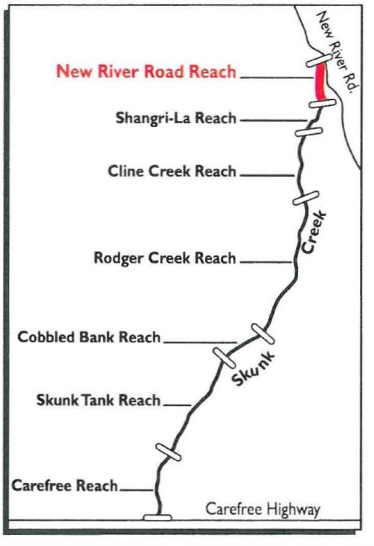


Figure 46. Skunk Creek - New River Road Reach Erosion Hazard Zones

7 Alternatives Development and Evaluation

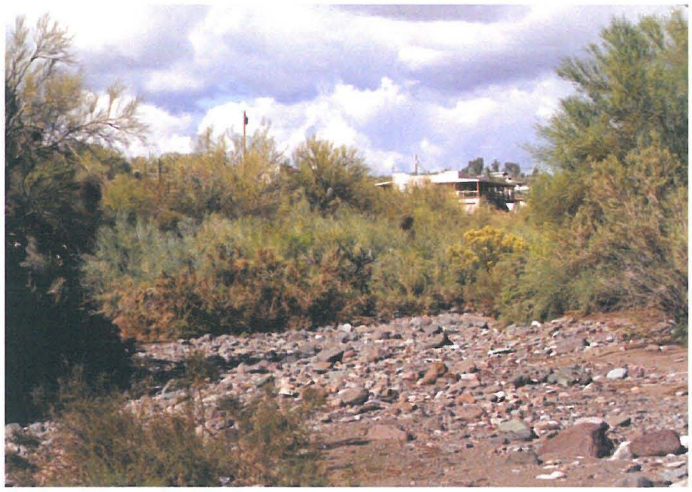
The purpose of the alternatives analysis is to formulate and evaluate a range of plans for providing flood and *erosion* control, determine the costs and benefits of each, identify opportunities for nonstructural solutions, and to recommend a preferred *watercourse* management alternative for regulating the study *watercourses*.

It is anticipated that some structural control measures may be necessary in a nonstructural solution; however, the objective is to minimize their use. Full-structural and nonstructural alternatives for flood control management are developed and evaluated to meet the goals of the WCMP. For the purposes of this study, a structural measure is one that includes construction of flood protection facilities and/or maintenance activities that result in ground disturbance. Structural solutions include engineered bank protection, channelization, grade-controls, and bio-remediation or bio-engineering such as re-vegetation activities.

The combination of the Severe and Lateral-Migration Erosion Hazard Zones, as described in Section 5, represents the *Erosion Control Zone* defined by the Floodplain Regulations of Maricopa County. Land within this *erosion* hazard zone or the *FEMA 100-year floodplain* is subject to flood and/or *erosion* hazards that threaten public safety. Accordingly, any development on such lands must be compatible with the potential hazards or be protected from those hazards through the construction of structural flood and/or *erosion* control measures. A line, referred as the *Regulatory Line*, is established on each side of the study *watercourses* to delineate these hazardous areas for public awareness and regulation purposes. The *Regulatory Line* follows the *FEMA 100-year floodplain* boundary or the Lateral Migration Erosion Hazard Zone boundary; whichever is farther from the *main channel*. In addition to delineating the hazardous area, the *Regulatory Line* is used:

- As the basis for computing the area of land that must be purchased or regulated to implement a given alternative.
- To define the area of land that can be reclaimed from the *FEMA 100-year floodplain* or the Lateral Migration Erosion Hazard Zone, as a result of implementing a given alternative.

The *Regulatory Line* is identified on the various exhibits developed for each phase. Alternatives for providing flood control and *erosion* protection are identified for each phase of the study. The Full-Structural Alternative is used as the traditional flood control alternative and was developed to provide a baseline from which to judge the benefits, opportunities, and weaknesses of other alternatives. Non-traditional flood control alternatives are developed based upon the investigation and determination of potential lateral migration and *scour* along the study *watercourses* and compared to the traditional alternative. Accordingly, the non-traditional flood control alternatives go beyond traditional floodplain management strategies by protecting adjacent properties from the 100-year flood event and the possible damages associated with potential lateral migration and *scour*.



Residence Adjacent to Skunk Creek

Limits of allowable encroachment within the regulatory area of each *watercourse* in the study area are defined for each alternative. The type and extent of structural features needed to allow the proposed encroachment are then identified for each

alternative. *Scour* analyses are conducted on the necessary structural features to determine design parameters. Conceptual designs are developed with the structural quantities, costs, benefits, and habitat impacts defined. Criteria and procedures are developed to evaluate the alternatives, and recommendations for implementation are made accordingly. The alternatives analysis conducted for each phase is discussed separately, because the phases of the study are effectively in different jurisdictions, and the number of alternatives developed and evaluated for each phase is different.

A. Assumptions, Limitations, and Constraints

The following assumptions are used in the alternative analysis for each phase of the study:

- The construction of all structural improvements associated with a given alternative are assumed to be constructed at one time for cost estimating and evaluation purposes (i.e., no piecemeal construction).
- Encroachments will be accomplished either through the use of earthen levees with three feet of freeboard or fill with one foot of freeboard above the 100-year water surface, and suitable bank protection armor. The alternatives will typically be described using the levee scenario.
- The bed and bank materials of the *watercourses* are assumed to be erodible to the full depth of estimated *scour* and *erosion*, unless there is obvious evidence to the contrary.
- Any future transportation crossings will be designed and built to accommodate the recommended alternative, in accordance with the recommendations made herein.
- When the recommended management alternative is actually implemented, the existing land use will have changed to reflect the low-density residential area (1-2 units/acre) used as the baseline for this study, and that the infrastructure necessary to support such land use will be in place.

B. Phase 1 Formulation of Alternatives

The alternatives for Phase 1 are formulated through a combination of consultation and meetings with stakeholders, a Study Team planning retreat, input from the public through a public involvement process, and presentations to the COP and the North Gateway Village Planning Committee. The alternatives considered range from a totally natural, undisturbed *watercourse*, to a full traditional approach with encroachment to the *FEMA 100-year floodway* limit. Reclamation and re-vegetation of the areas disturbed by human activities are considered for all alternatives. The selection criteria developed for the alternatives is as follows:

- A traditional armored levee with encroachment into the *FEMA 100-year floodplain* and full development of the floodway fringe area.
- No structural features located in the floodplain except those required to preserve the natural integrity of the *watercourse*. This alternative is to result in no future *cumulative impacts* from *floodplain encroachment*.
- A combination of the preceding alternatives that would incorporate structural features, where necessary, to accommodate selected areas reclaimed from the *FEMA 100-year floodway fringe* area. This alternative is to minimize *cumulative impacts* resulting from encroachment.
- An alternative that reflects and accommodates the development intentions of the adjacent landowners (stakeholders).

After receiving input from the stakeholders and the affected public, a Full-Structural Alternative, a Stakeholders Alternative, a Team Alternative, and a Nonstructural Alternative are selected for more detailed study. An overview of each selected alternative follows.

1. Phase 1 Full-Structural Alternative

The Full-Structural Alternative reflects the traditional approach to floodplain management that allows encroachment to the regulatory floodway, as defined by the FEMA. Unless the current floodway limit is modified through the appropriate regulatory process, it represents the maximum allowable encroachment into the floodplain and provides the maximum amount of land for development. The proposed *non-encroachment area* limits are shown by *reach* for this alternative on Figures 47 through 54.

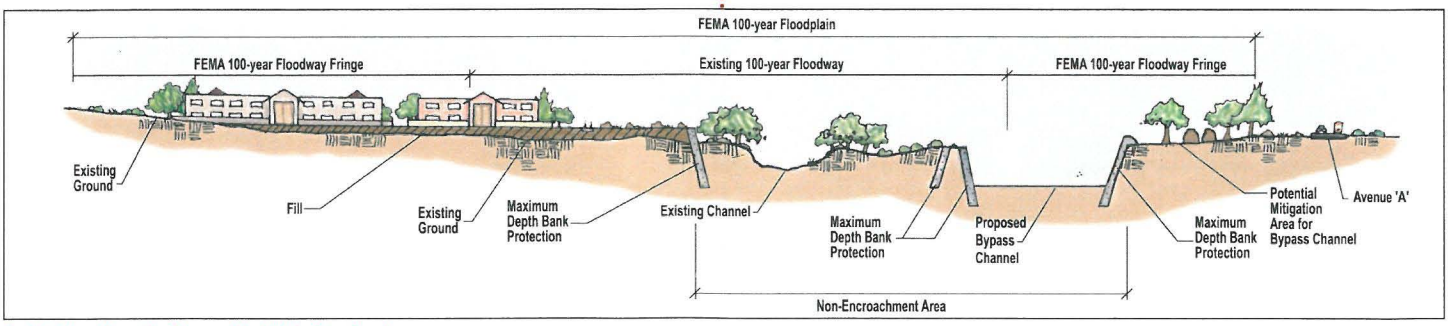
Encroachments into floodplains are typically accomplished using earthen fill material or, if the volume of fill is excessive, through the construction of earthen levees. In either case, the *channel* side of the fill or levee embankment should be protected from *erosion* by placing suitable armor material on the bank. The armor material should extend above the 100-year water-surface elevation a minimum of one foot for fill and three feet for levees. Examples of suitable bank protection armor considered in this study include rock *riprap*; rock-filled wire baskets, commonly referred to as gabions or *gabion mattresses*; or cement stabilized alluvium (CSA), which is a coarser version of the more common *soil cement*. To compare the effectiveness of the alternatives considered in this study, it is assumed that levees are to be constructed to provide the desired encroachments.

For the Full-Structural Alternative, the proposed levees effectively follow the existing *FEMA 100-year floodway* boundaries along each *watercourse*. The levees are to be constructed of earthen embankment material, compacted to 95 percent of maximum density, with three feet of freeboard above the 100-year water surface, as required by FEMA. Freeboard is based on the highest water surface resulting from either the existing or future condition peak discharges. A minimum ten-foot top width and 2:1 side slopes are recommended. The *channel* side of the levee is provided with bank protection to prevent *erosion* and *channel* migration. Refer to Figure 55 for a typical section for the Phase 1 Full-Structural Alternative.

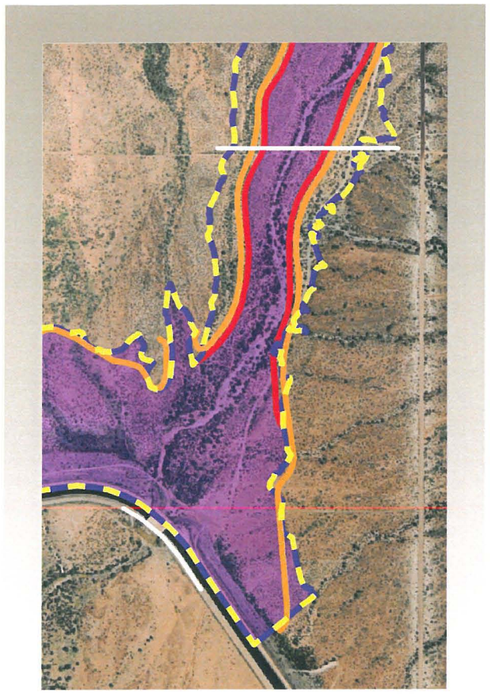
The primary advantage of the Full-Structural Alternative is that it maximizes the amount of land available for development in the current *FEMA 100-year floodway fringe* area. The primary disadvantages are that it does so at a high construction cost, and risk to the public because of the resulting higher velocity of water moving through the *watercourse*, excessive *cumulative impacts* and the potential for structural failure. The finished product typically has an unnatural appearance and function, and results in significant disturbance of riparian habitat and cultural features.

2. Phase 1 Stakeholders Alternative

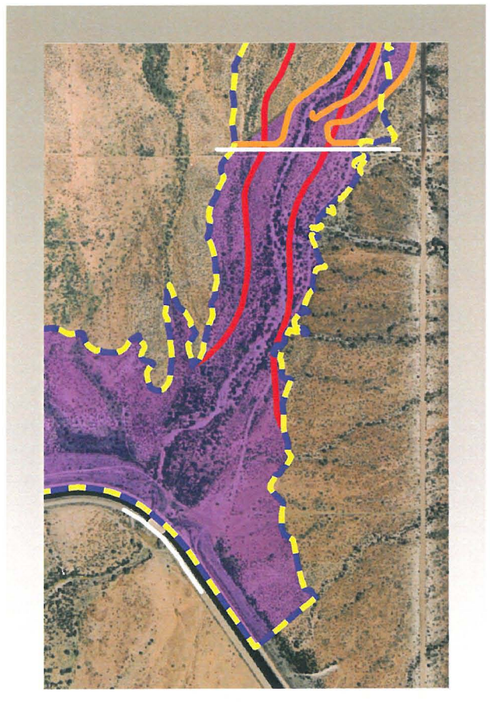
The Phase 1 Stakeholders Alternative is included to evaluate the development plans of private landowners and the impact of those plans on the stability of Skunk Creek and Sonoran Wash. The landowners were informed that any plans to encroach into the *FEMA 100-year floodplain* would have to abide by the FEMA regulations governing such actions. This typically means that proposed development cannot encroach within the *FEMA 100-year floodway*, and a request for a floodplain map revision would have to be approved by FEMA. In addition, if any encroachment into the *FEMA 100-year floodplain* is proposed, it must include structural transitions to the upstream and downstream properties that will not produce adverse hydraulic impacts on those properties. If any



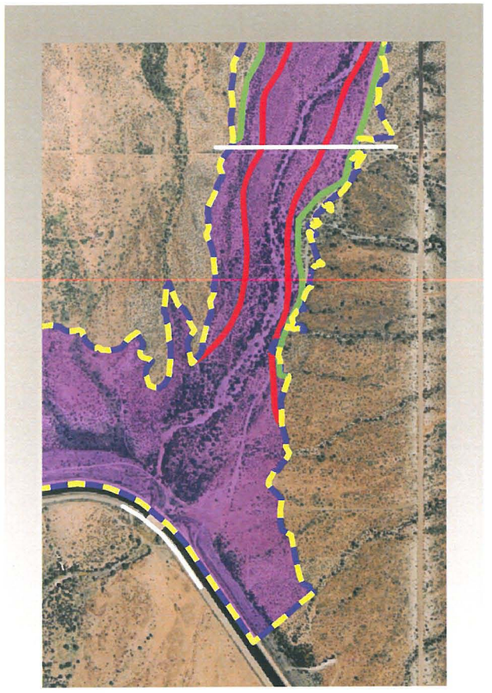
Stakeholders Alternative Sonoran Wash Main Stem Reach



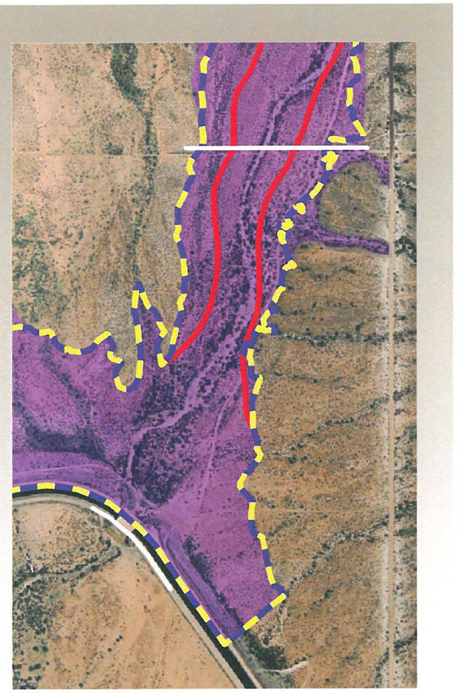
Full-Structural Alternative



Stakeholders Alternative



Team Alternative

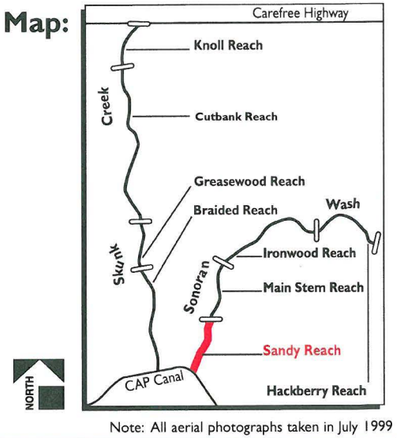


Nonstructural Alternative

Key

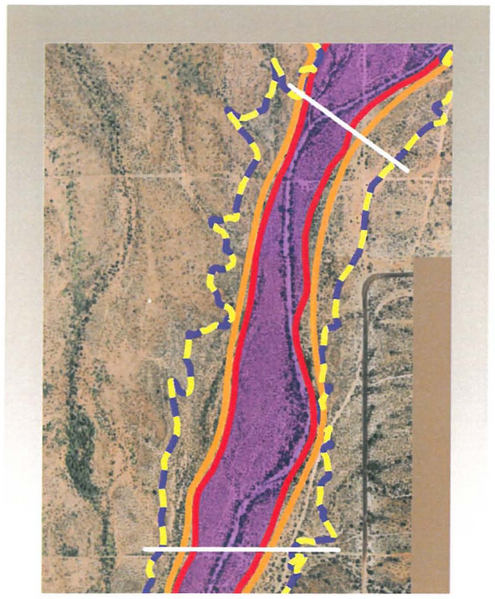
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase I Key Map:

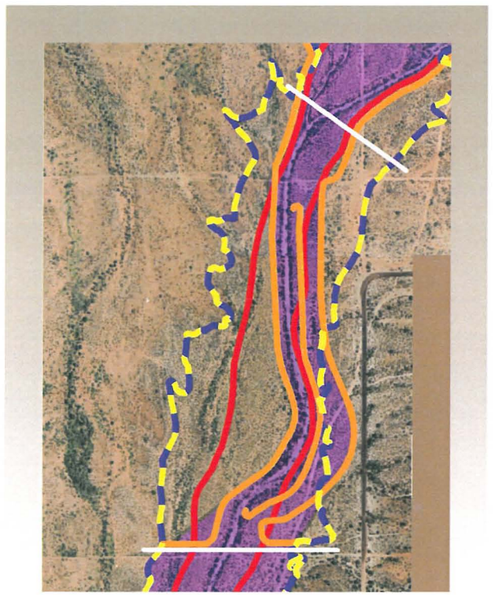


Note: All aerial photographs taken in July 1999

Figure 47. Sonoran Wash - Sandy Reach Alternatives (Phase 1)

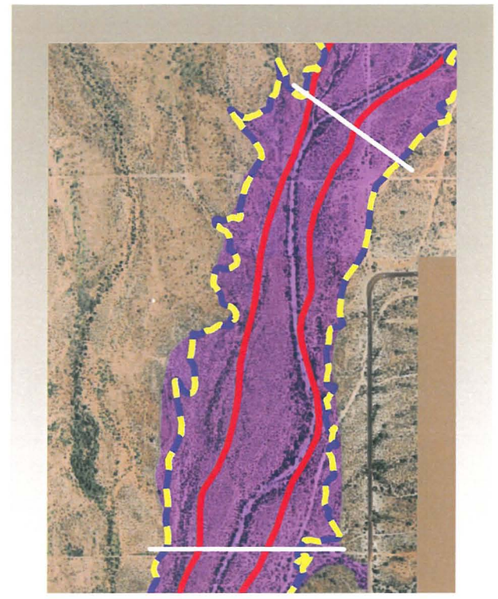


Full-Structural Alternative



Stakeholders Alternative

Team Alternative

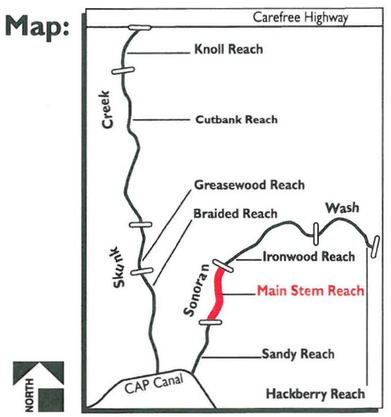


Nonstructural Alternative

Key

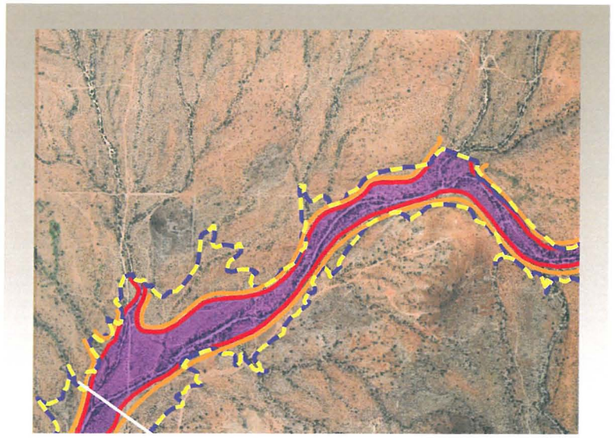
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 1 Key Map:

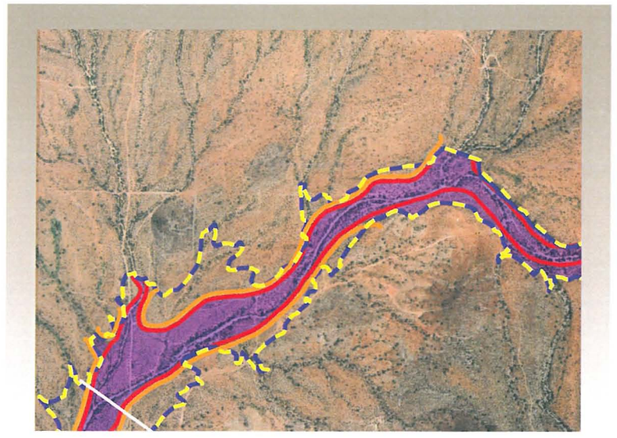


Note: All aerial photographs taken in July 1999

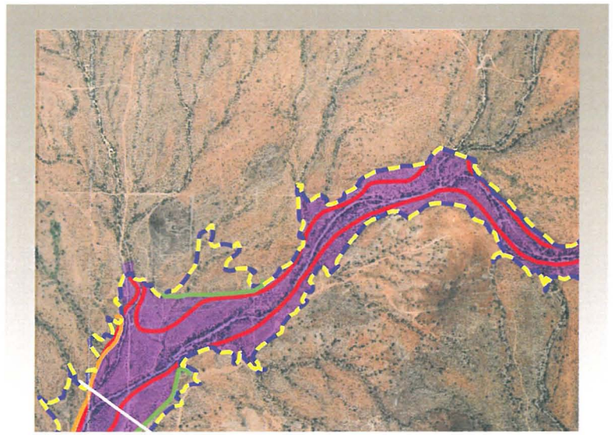
Figure 48. Sonoran Wash - Main Stem Reach Alternatives (Phase 1)



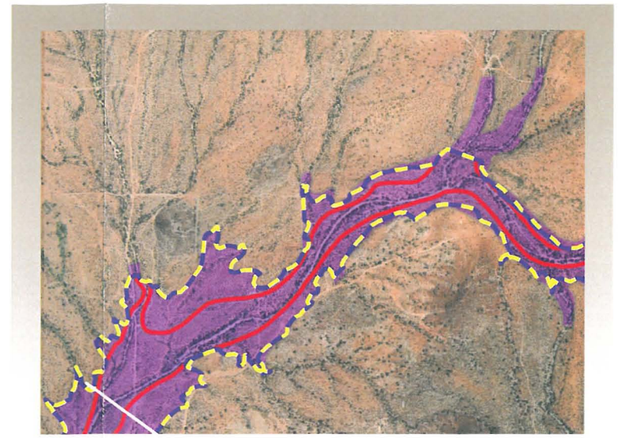
Full-Structural Alternative



Stakeholders Alternative



Team Alternative

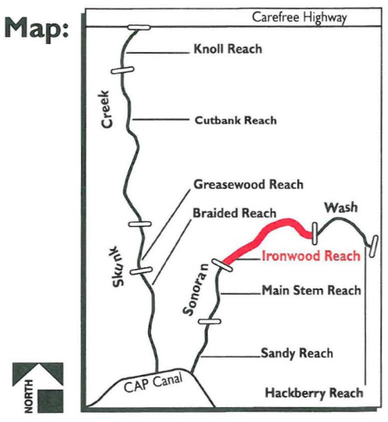


Nonstructural Alternative

Key

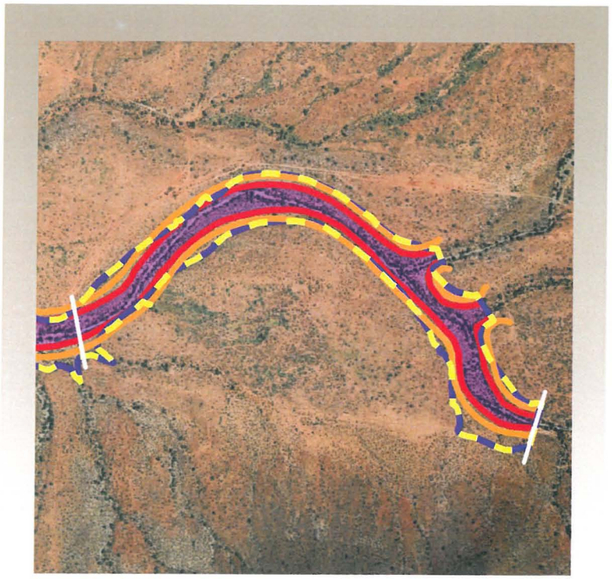
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 1 Key Map:

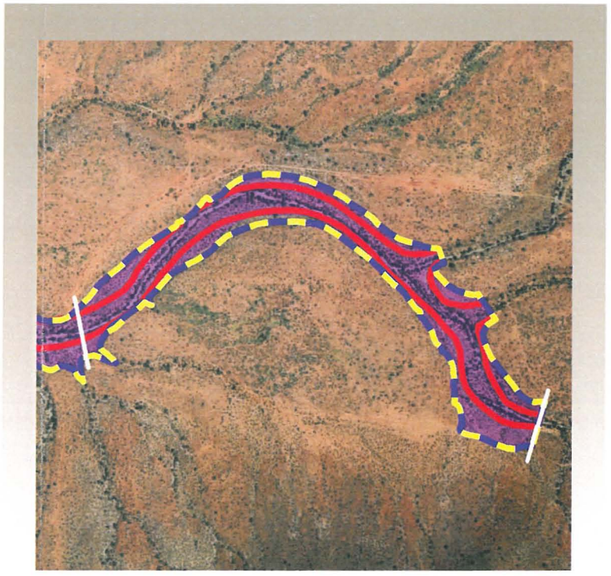


Note: All aerial photographs taken in July 1999

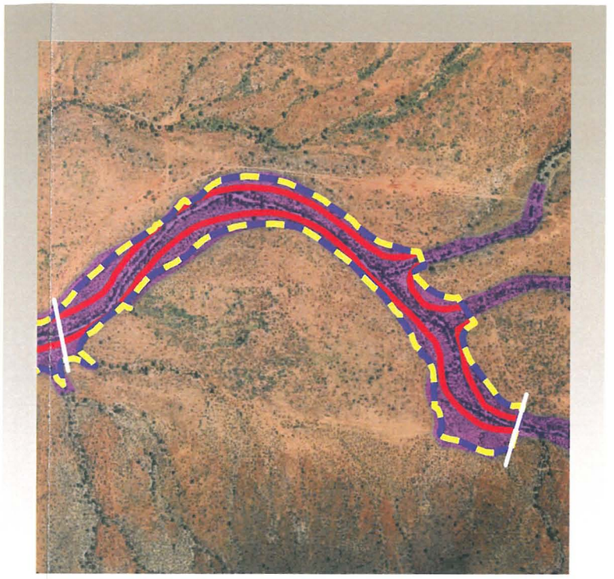
Figure 49. Sonoran Wash - Ironwood Reach Alternatives (Phase 1)



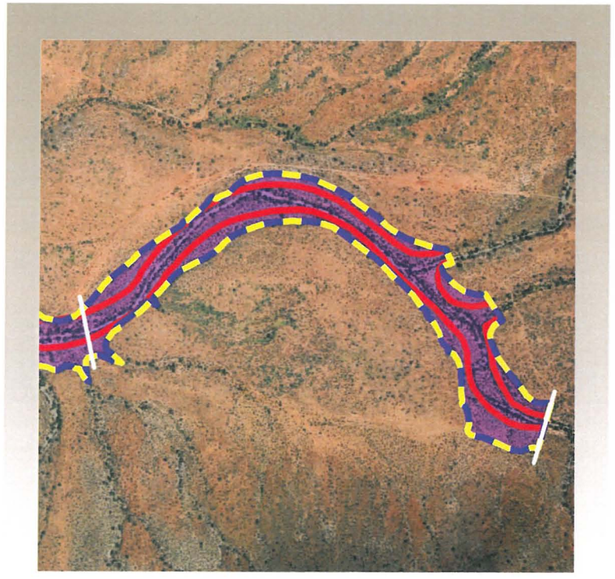
Full-Structural Alternative



Team Alternative



Nonstructural Alternative

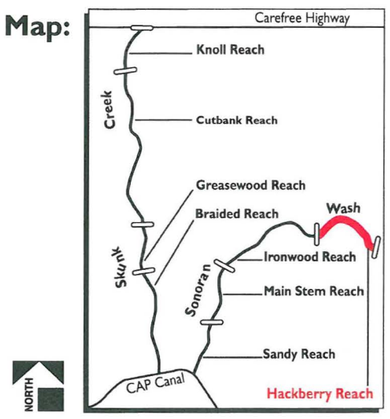


Stakeholders Alternative

Key

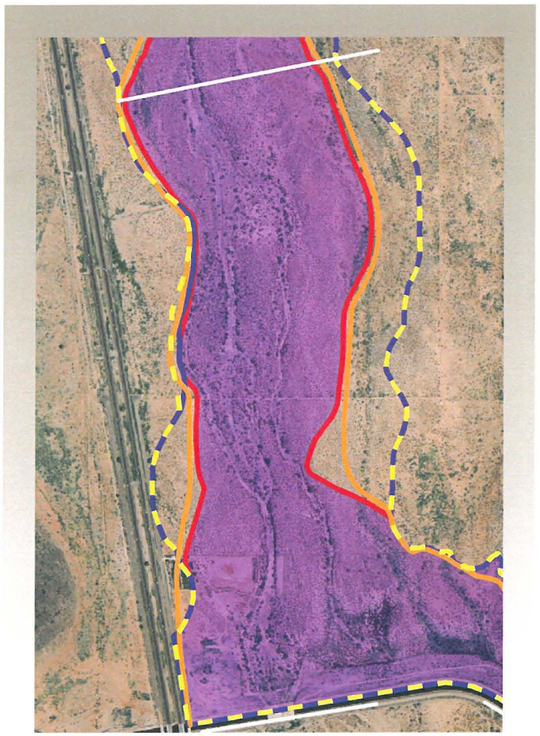
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

Phase I Key Map:

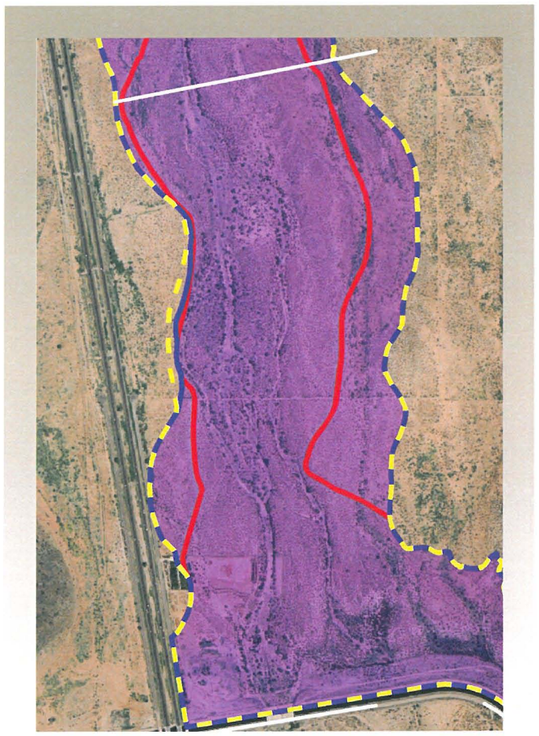


Note: All aerial photographs taken in July 1999

Figure 50. Sonoran Wash - Hackberry Reach Alternatives (Phase 1)



Full-Structural Alternative



Stakeholders Alternative

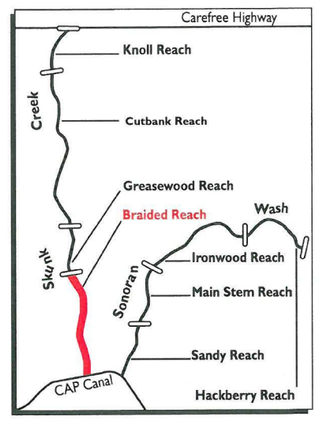
Team Alternative

Nonstructural Alternative

Key

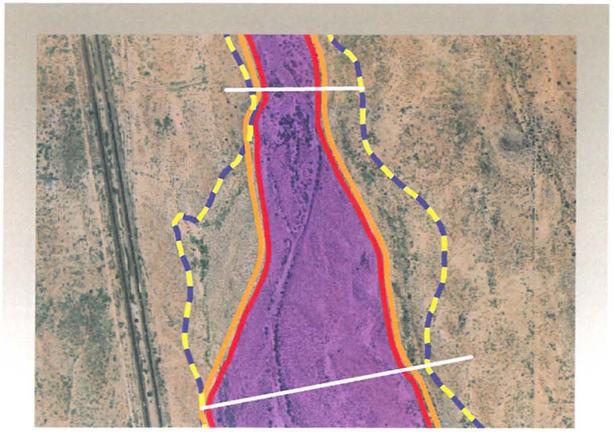
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

Phase I Key Map:

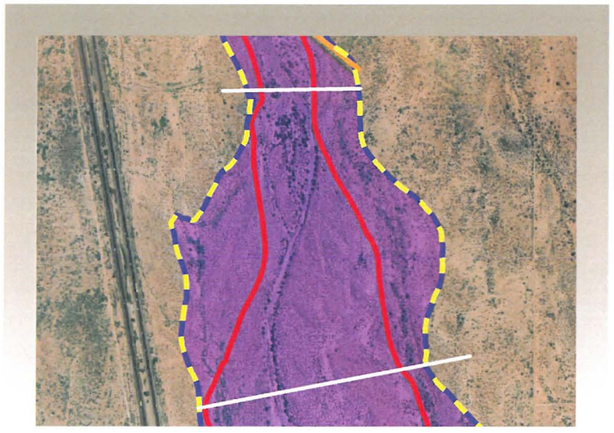


Note: All aerial photographs taken in July 1999

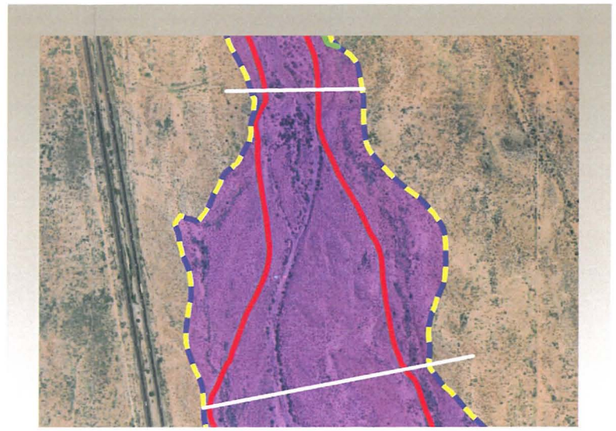
Figure 51. Skunk Creek - Braided Reach Alternatives (Phase 1)



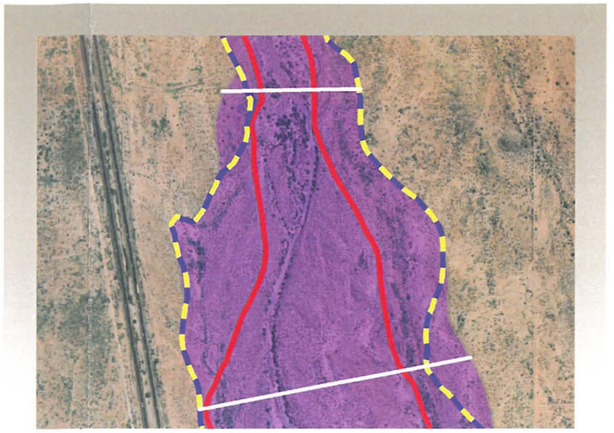
Full-Structural Alternative



Stakeholders Alternative



Team Alternative

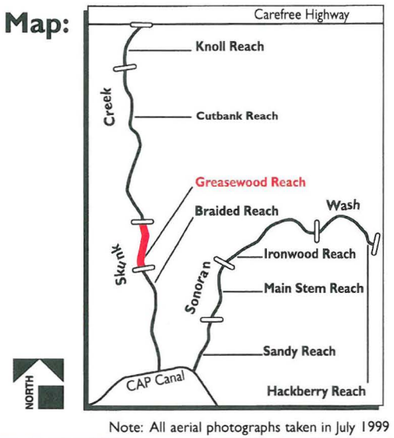


Nonstructural Alternative

Key

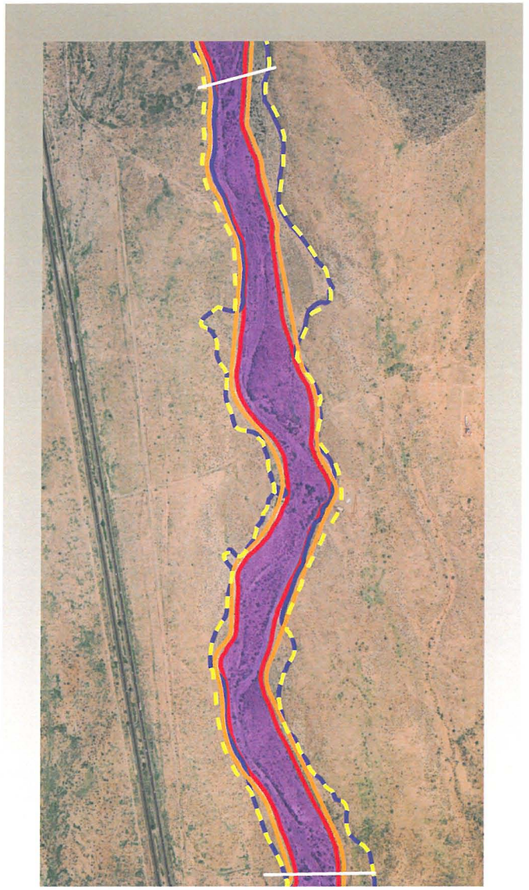
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase I Key Map:

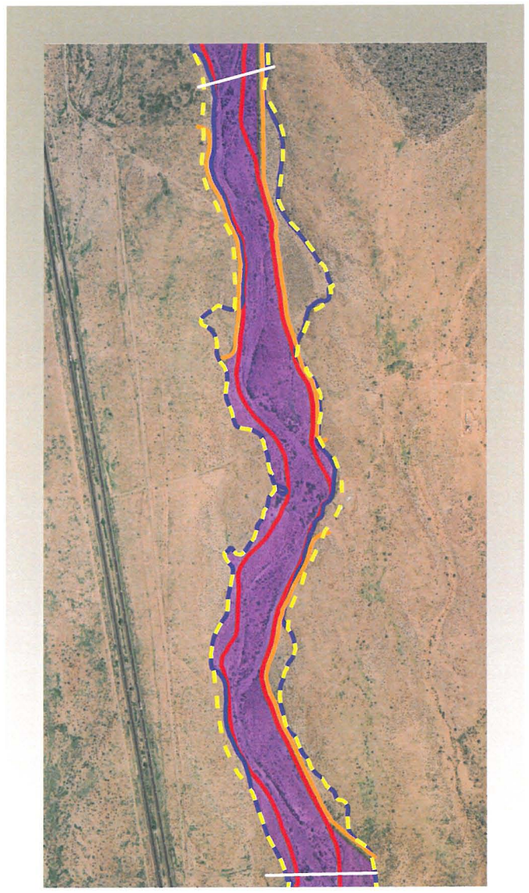


Note: All aerial photographs taken in July 1999

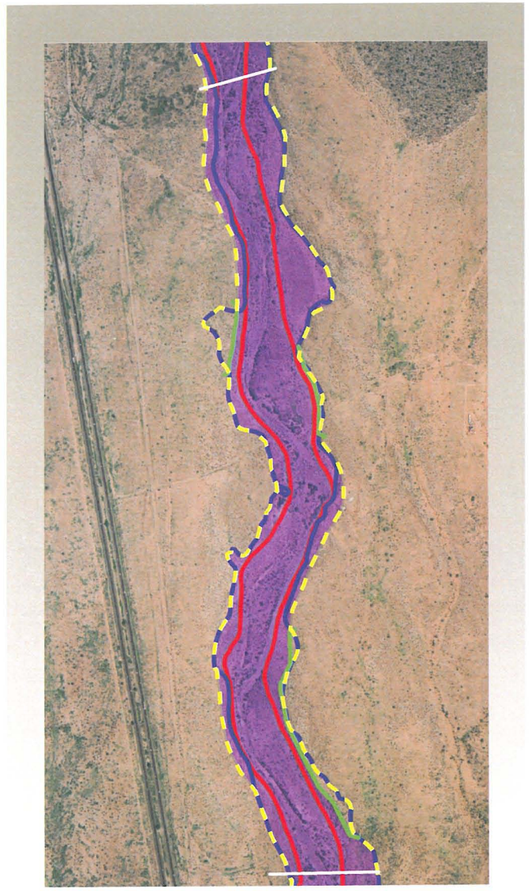
Figure 52. Skunk Creek - Greasewood Reach Alternatives (Phase 1)



Full-Structural Alternative



Stakeholders Alternative



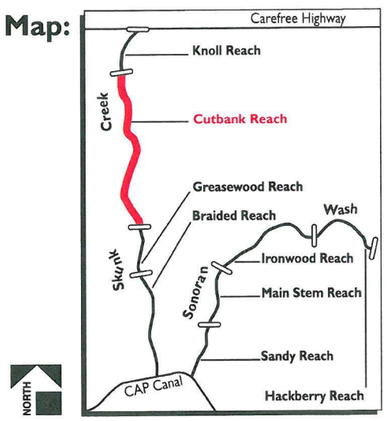
Team Alternative

Nonstructural Alternative

Key

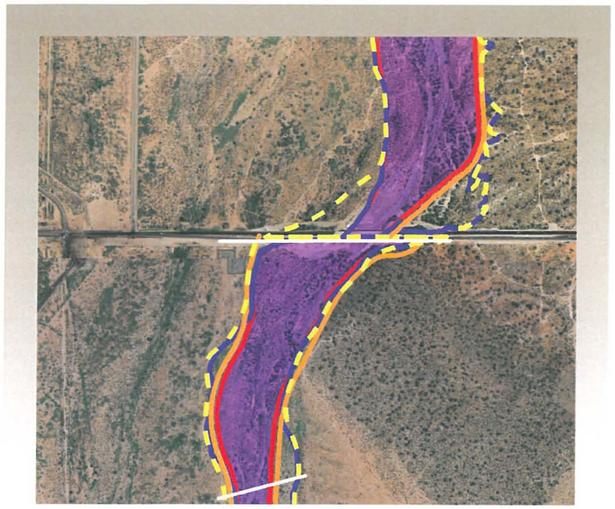
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 1 Key Map:

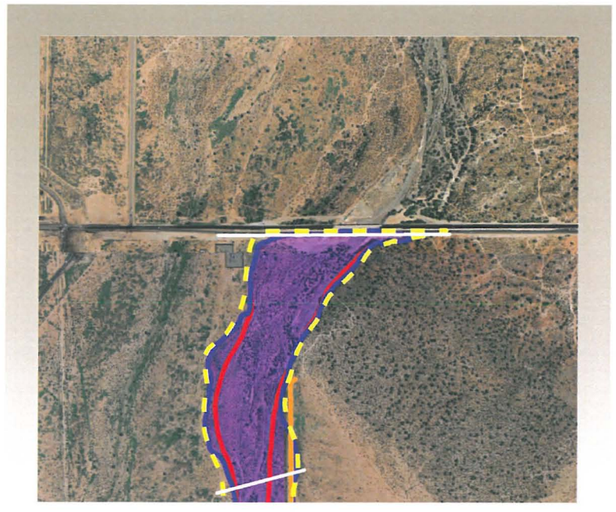


Note: All aerial photographs taken in July 1999

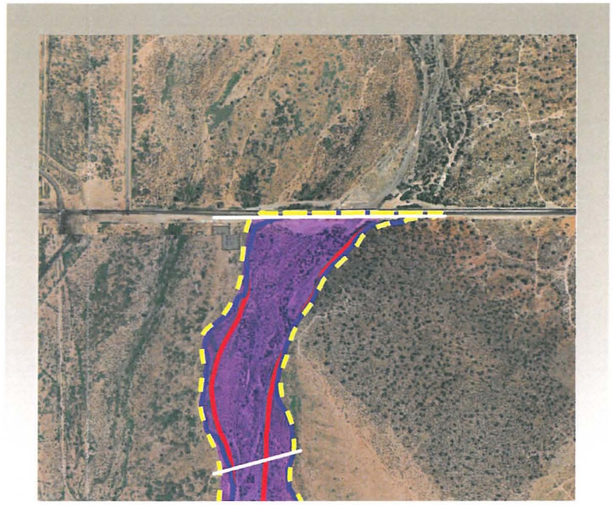
Figure 53. Skunk Creek - Cutbank Reach Alternatives (Phase 1)



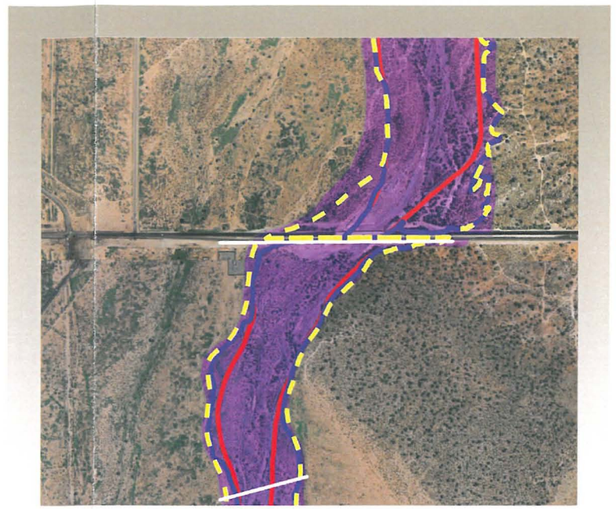
Full-Structural Alternative



Stakeholders Alternative



Team Alternative

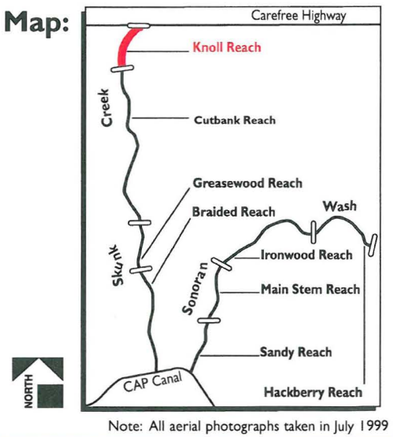


Nonstructural Alternative

Key

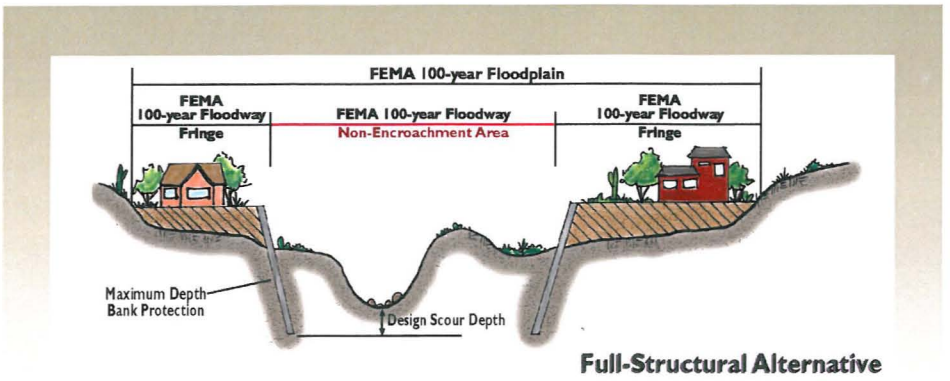
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

Phase 1 Key Map:

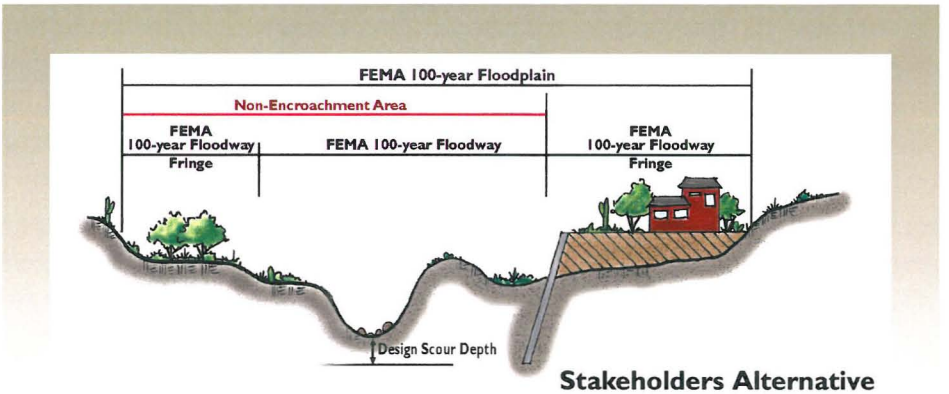


Note: All aerial photographs taken in July 1999

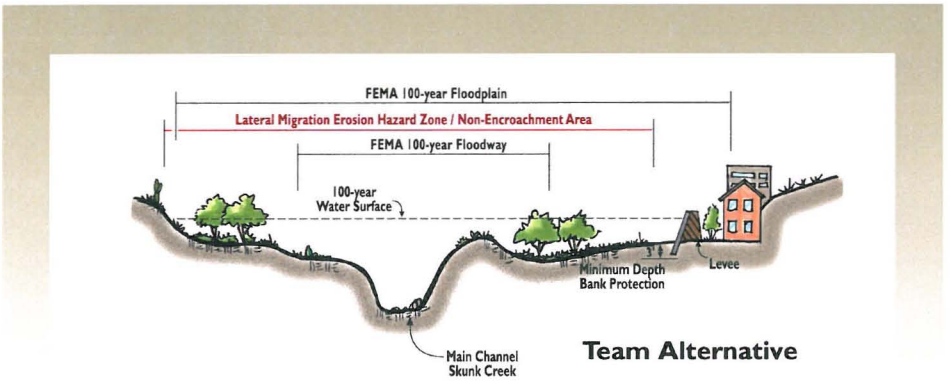
Figure 54. Skunk Creek - Knoll Reach Alternatives (Phase 1)



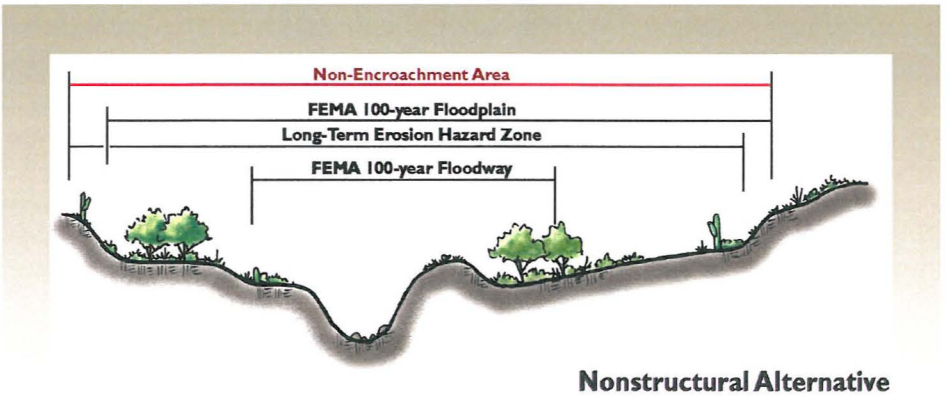
Full-Structural Alternative



Stakeholders Alternative



Team Alternative



Nonstructural Alternative

Figure 55. Typical Cross-Sections for Phase 1 Alternatives

development plans included adjustments to the *FEMA 100-year floodway* boundaries, conditional approval would have to be received from FEMA before the developments plans are implemented.

The Stakeholders Alternative contains encroachments into the *FEMA 100-year floodway fringe*, encroachment into the *FEMA 100-year floodway* of Sonoran Wash (requiring channelization), and areas that are left in their natural state. Where encroachments into the *FEMA 100-year floodway fringe* are proposed, levees, similar to those described in the Full-Structural Alternative, are used. On private lands, the encroachments in the *FEMA 100-year floodplain* are limited to the *FEMA 100-year floodway* boundary or the property line, except for the Main Stem Reach of Sonoran Wash. On public lands, no encroachment is allowed into the *FEMA 100-year floodplains* because it is assumed that this property will be purchased through the API and remain open space. The proposed setback distance is defined by the *non-encroachment area* limits by *reach* for this alternative as shown on Figures 47 through 54. Refer to Figure 62 for a typical section for the Phase 1 Stakeholders Alternative.

The advantages of the Stakeholder Alternative are:

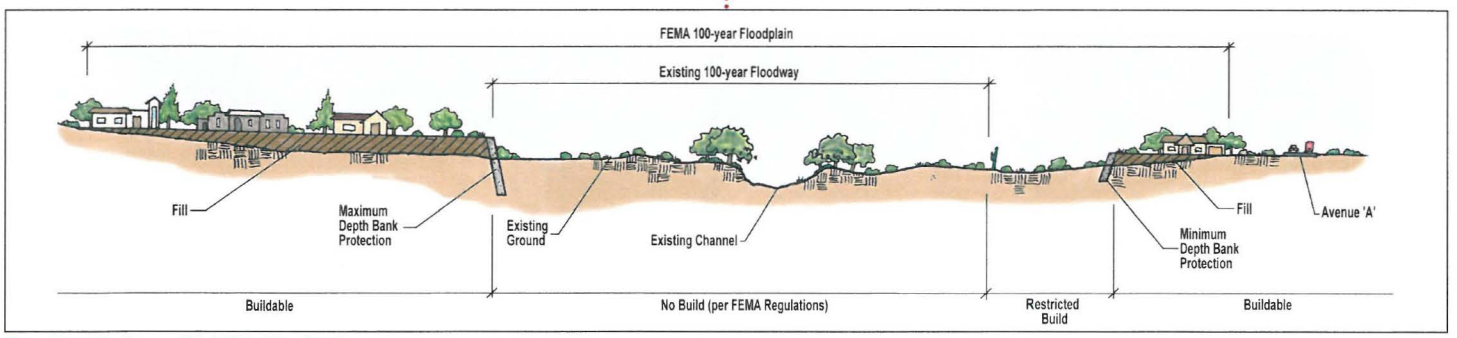
- ★ It accounts for the current development plans of the local landowners.
- ★ Allows the impacts of those plans to be quantified and compared to the other alternatives in the study.
- ★ Provides a vehicle for informing the local landowners about the study and future development restrictions.

The primary disadvantages are that it does so at a high construction cost and with risk to the public because of higher velocity and potential structural failure. The finished product typically has an unnatural appearance and function, particularly in the channelized *reach* of Sonoran Wash, and results in significant disturbance of riparian habitat and cultural features.

3. Phase 1 Team Alternative

The Team Alternative contains both encroachments into the *FEMA 100-year floodway fringe* and areas that are left in their natural state. Where encroachments into the *FEMA 100-year floodway fringe* are proposed, levees, similar to those described in the Full-Structural Alternative, are used. For this alternative, the extent of encroachment is also controlled through the implementation of a regulatory setback distance. The setback distance is generally based on engineering and geomorphic estimates of the lateral migration potential, as defined by the limits of the Lateral Migration Erosion Hazard Zone. The proposed setback distance is defined by the *non-encroachment area* limits by *reach* for this alternative as shown in Figures 47 through 54.

When the Lateral Migration Erosion Hazard Zone boundary is within the shallower, lower velocity areas of the *FEMA 100-year floodway fringe*, a levee embankment, with three feet of bank protection armor below grade (toe-down), is assumed. If the Lateral Migration Erosion Hazard Zone boundary is close to the *FEMA 100-year floodway* boundary, the same full-depth bank protection as for the Full-Structural Alternative is proposed. The three-foot toe-down is referred to as *Minimum Depth Bank*



Team Alternative Sonoran Wash Main Stem Reach

Protection, while the full-depth toe-down is referred to as *Maximum Depth Bank Protection*. Refer to Figure 62 for a typical section of the proposed *Minimum* and *Maximum Depth Bank Protection*. The magnitude of the full-depth toe-down is defined by the total design *scour* described earlier in this report.

The advantages and disadvantages of this alternative lie in the fact that it is a compromise solution that neither maximizes the amount of developable land, nor the amount of undisturbed, natural area along the *watercourse*. The alternative defines the minimum area the *watercourses* need to function naturally over a 60-year period. A significant advantage is that this alternative does not produce significant *cumulative impacts* within a *reach* or upstream or downstream of the study limits.

4. Phase 1 Nonstructural Alternative

As the name implies, the Nonstructural Alternative contains no structural features in the *FEMA 100-year floodplain*. This alternative effectively leaves the study *watercourses* in their natural (albeit existing) state and controls the allowable encroachment for development through the implementation of a regulatory setback distance. The setback distance is based on engineering and geomorphic estimates of the long-term lateral migration potential, as defined by the limits of the Long-Term Erosion Hazard Zone. The proposed setback distance is defined by the *non-encroachment area* limits by *reach* for this alternative as shown in Figures 47 through 54.

The primary advantage of the Nonstructural Alternative when compared to the other alternatives is that it provided the highest level of public safety, the maintenance costs are minimum, and it effectively leaves the *watercourse* corridors in their natural state. The primary disadvantage is that it minimizes the amount of land available for development and is expensive to implement.

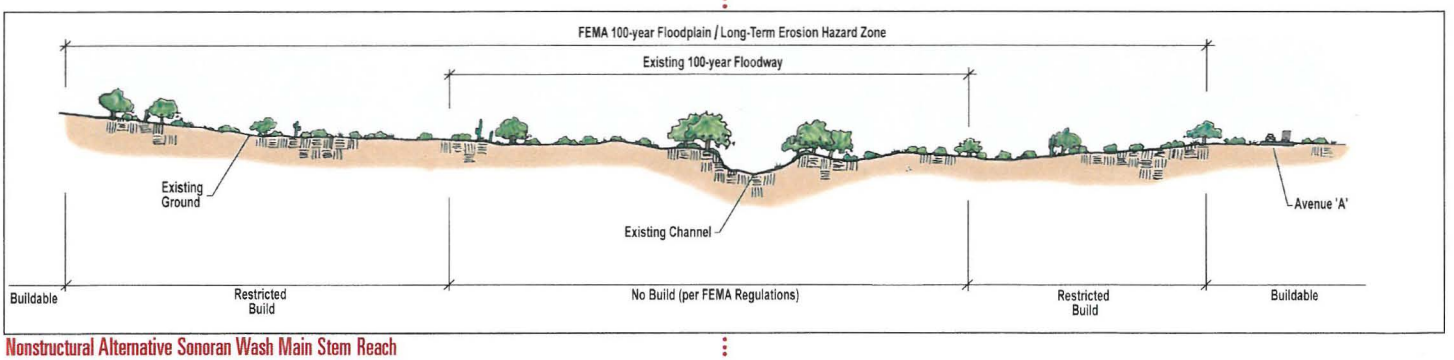
C. Phase 2 Formulation of Alternatives

The Phase 2 alternatives are formulated through a combination of consultation and meetings with the District, a Study Team planning retreat, and input from the public through a public involvement process. As in Phase 1, the alternatives considered range from a totally natural, undisturbed *watercourse*, to a full-structural traditional approach with encroachment to the *FEMA 100-year floodway* limit. Reclamation and re-vegetation of the areas disturbed by human activities are considered for all alternatives. The selection criteria developed for the alternatives is the same as Phase 1, except there is no Stakeholders Alternative.

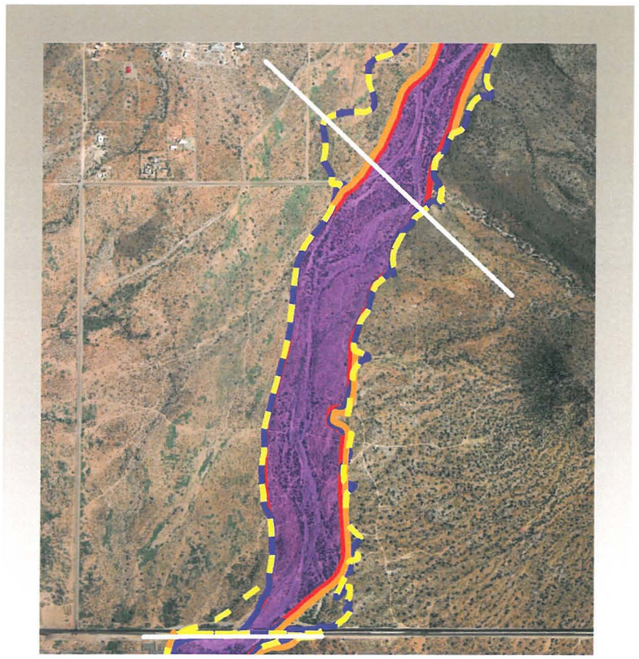
After receiving input from the District and the affected public, a Full-Structural Alternative, a Low-Impact Structural Alternative, and a Nonstructural Alternative, similar to Phase 1, are selected for more detailed study. An overview of each selected alternative is described in the following subsections.

1. Phase 2 Full-Structural Alternative

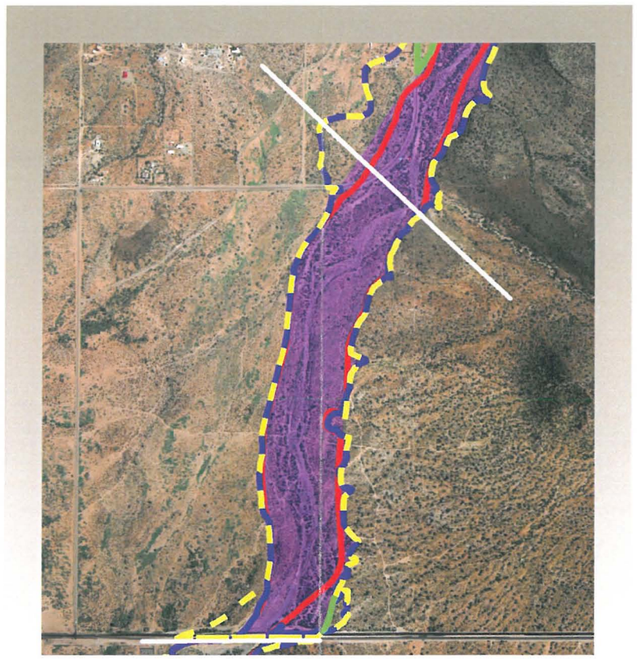
The Full-Structural Alternative for Phase 2 is the same as described previously for Phase 1. The proposed encroachment limits are shown by *reach* on Figures 56 through 62 for this alternative. Refer to Figure 63 for a typical section of the proposed levee.



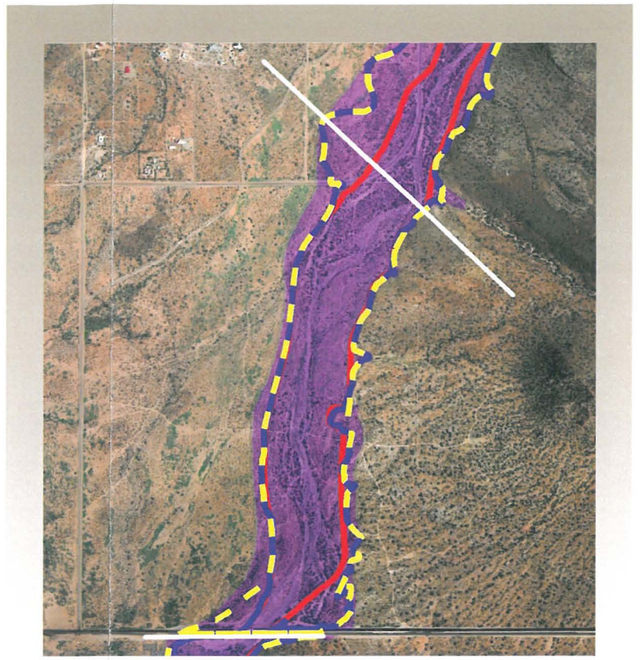
Nonstructural Alternative Sonoran Wash Main Stem Reach



Full-Structural Alternative



Low-Impact Structural Alternative

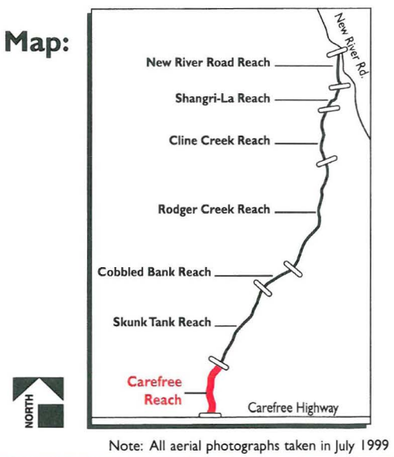


Nonstructural Alternative

Key

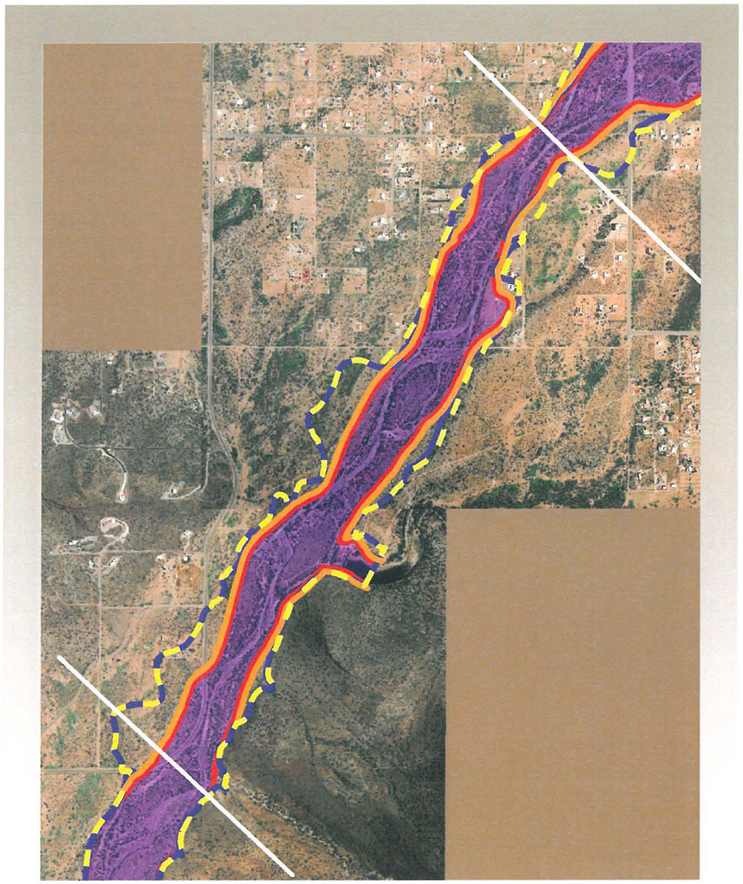
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

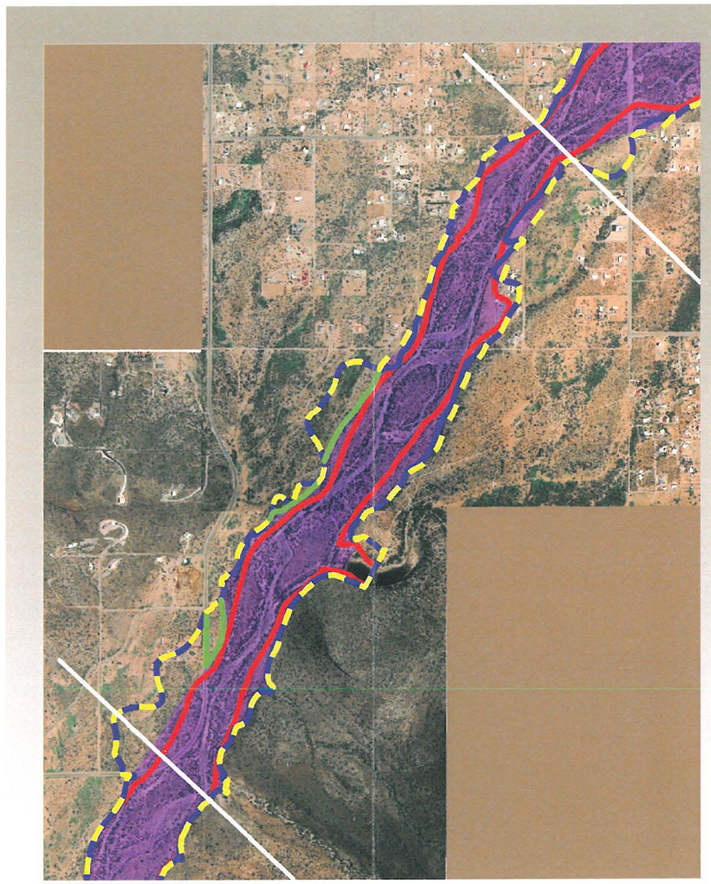


Note: All aerial photographs taken in July 1999

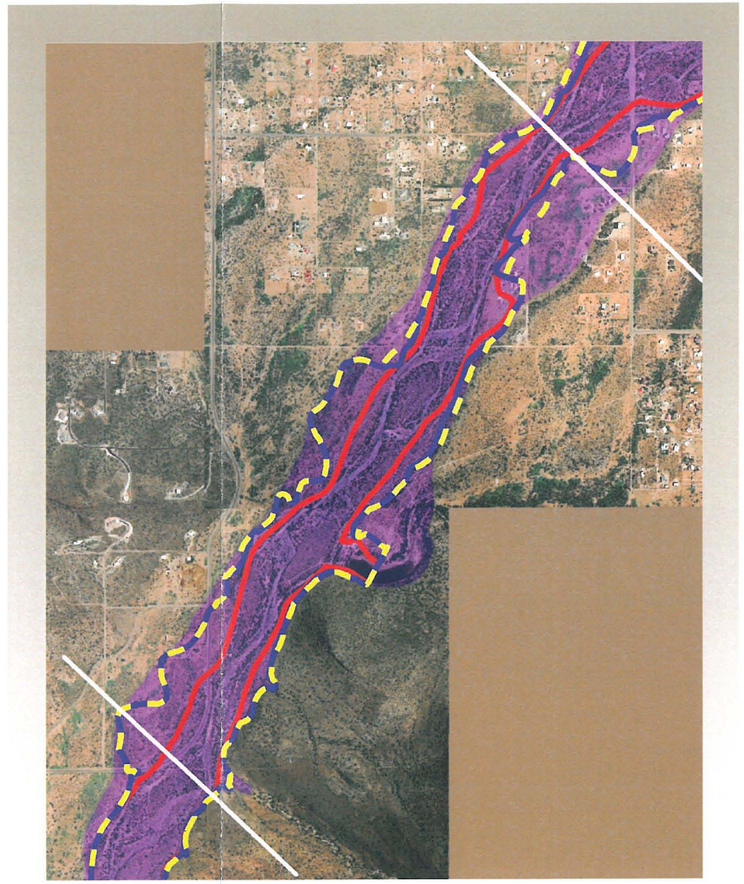
Figure 56. Skunk Creek - Carefree Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

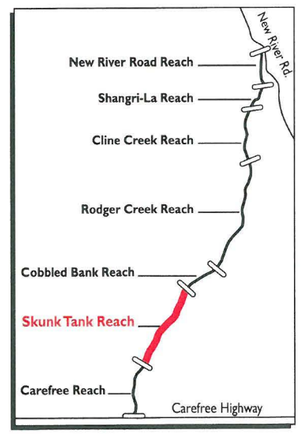


Nonstructural Alternative

Key

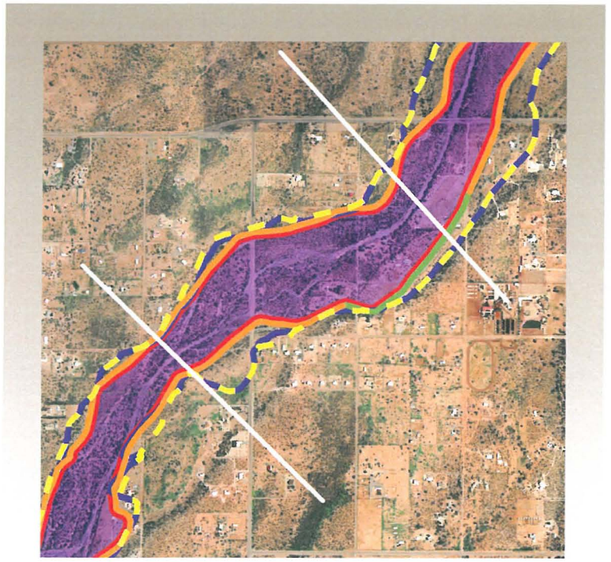
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

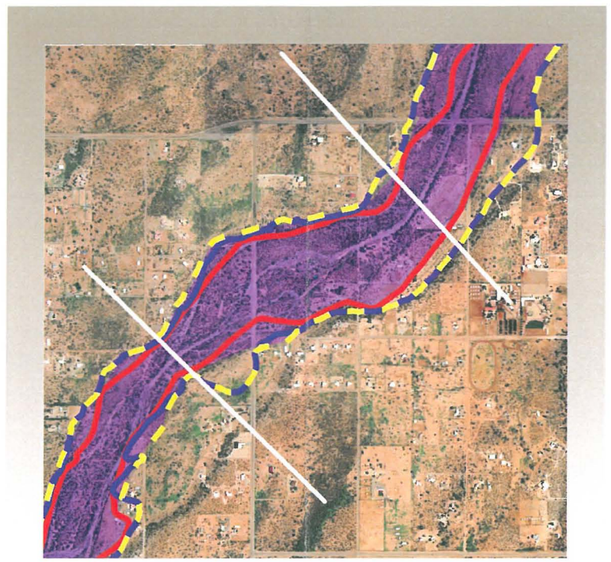


Note: All aerial photographs taken in July 1999

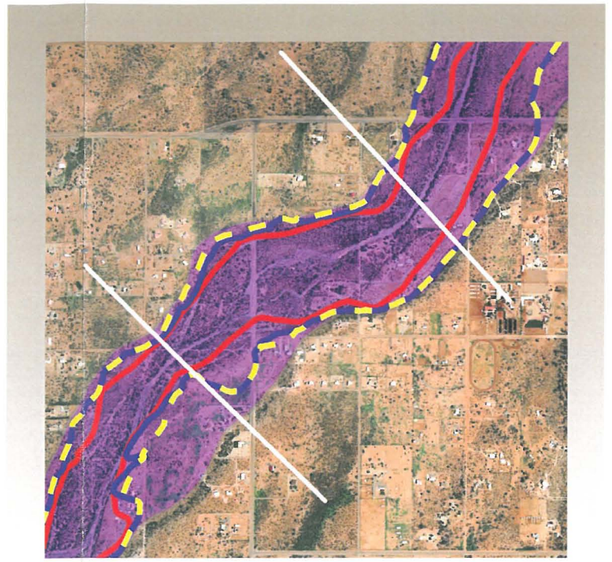
Figure 57. Skunk Creek - Skunk Tank Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

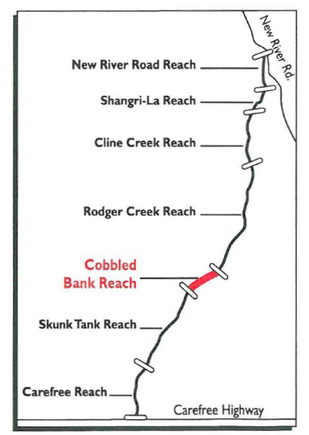


Nonstructural Alternative

Key

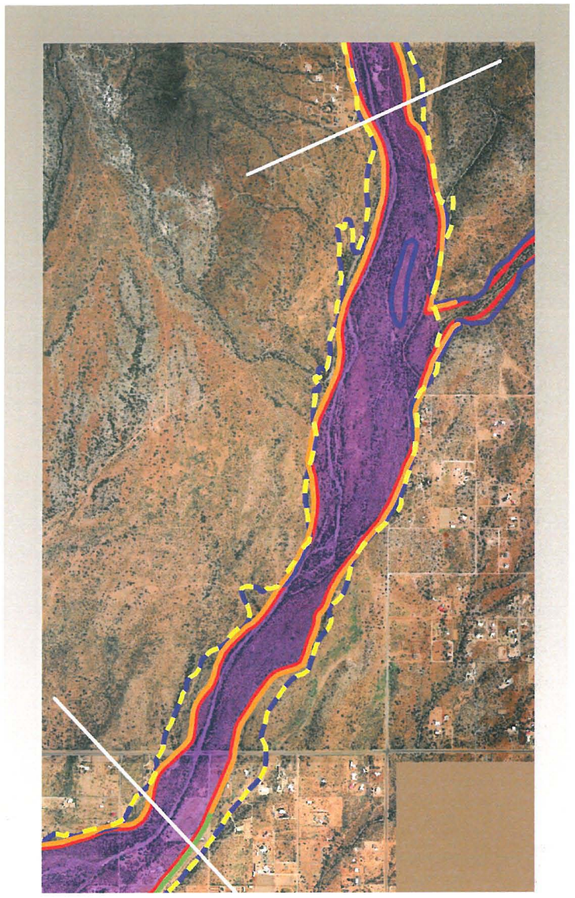
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

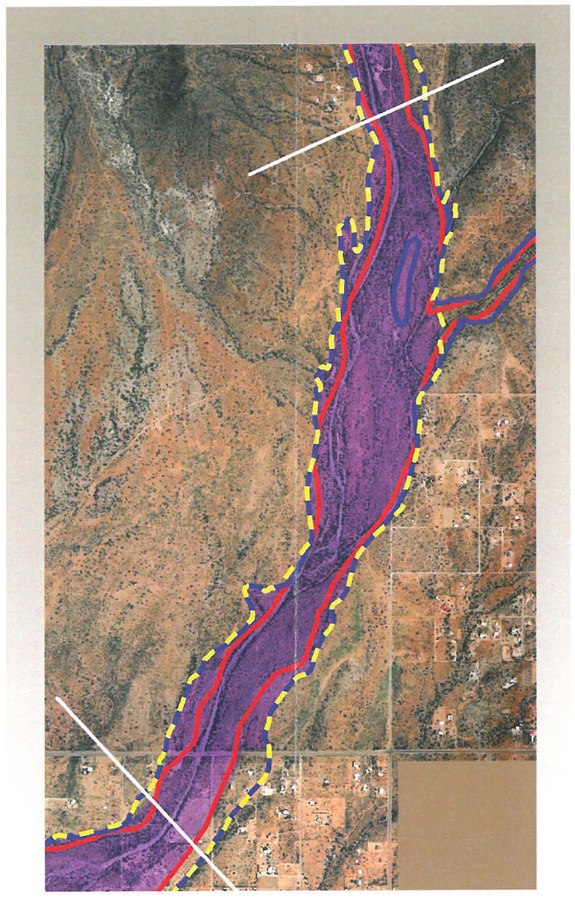


Note: All aerial photographs taken in July 1999

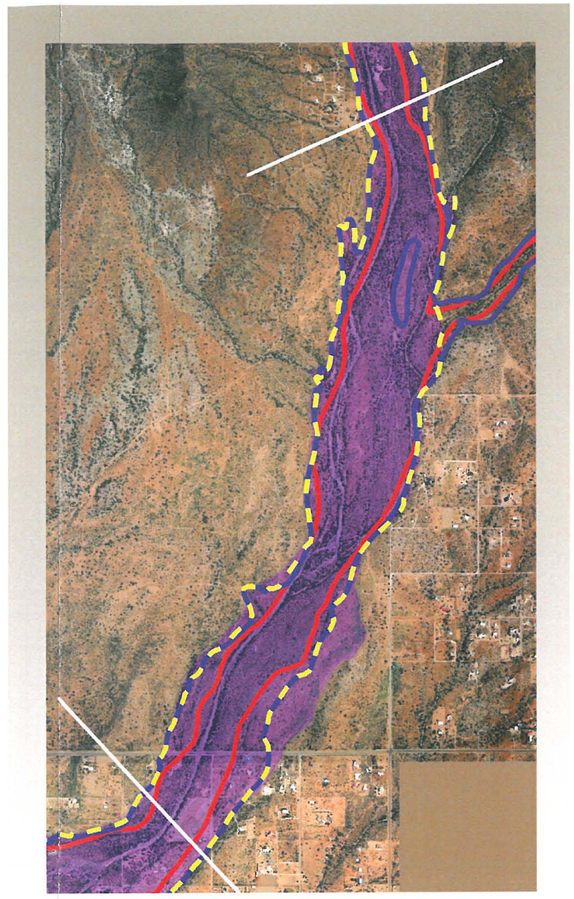
Figure 58. Skunk Creek - Cobbled Bank Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

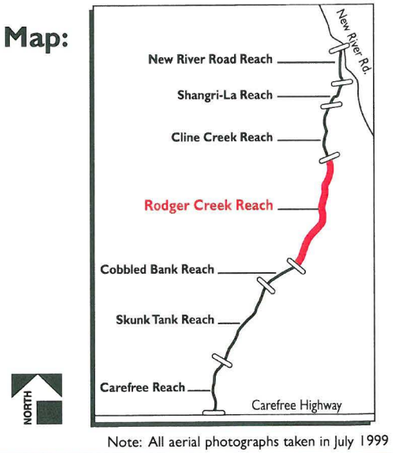


Nonstructural Alternative

Key

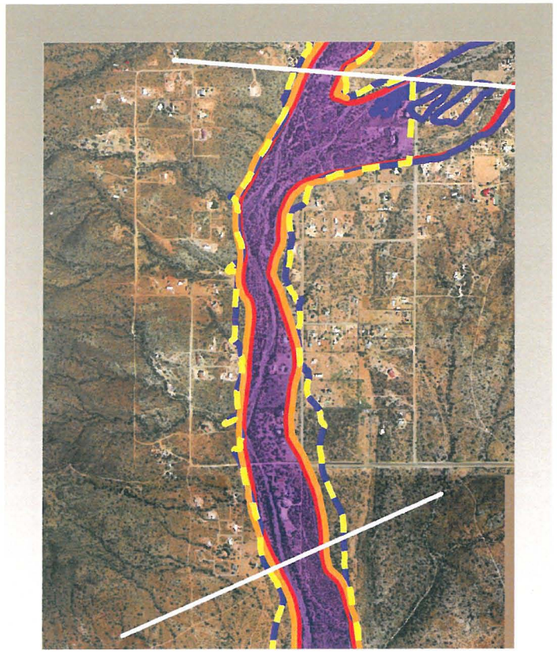
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Minimum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

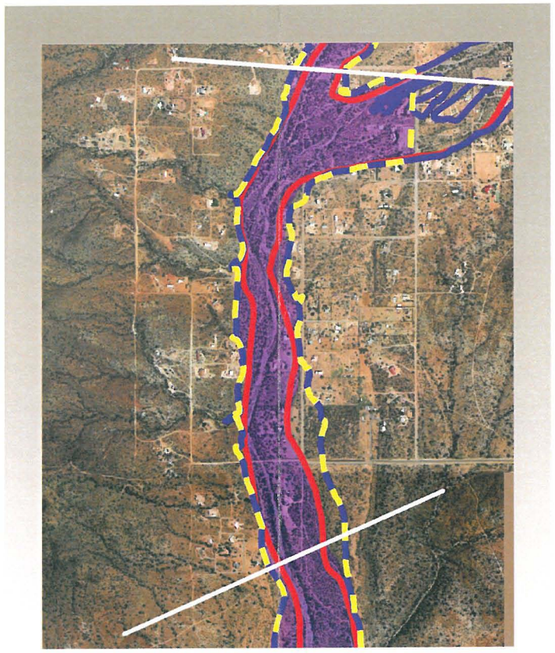


Note: All aerial photographs taken in July 1999

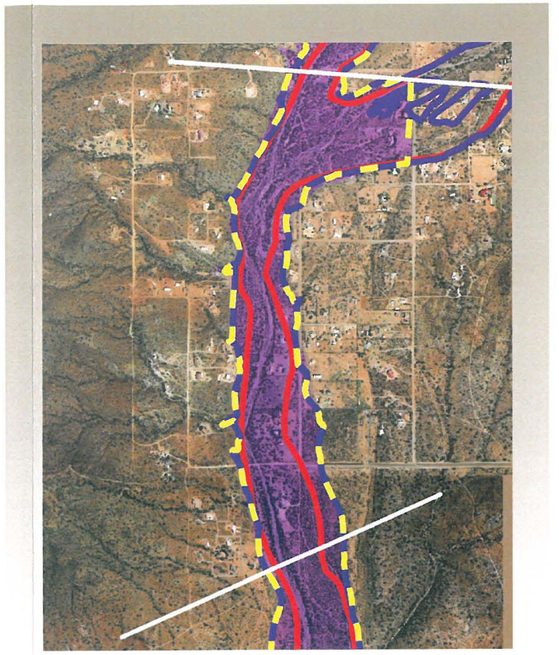
Figure 59. Skunk Creek - Rodger Creek Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

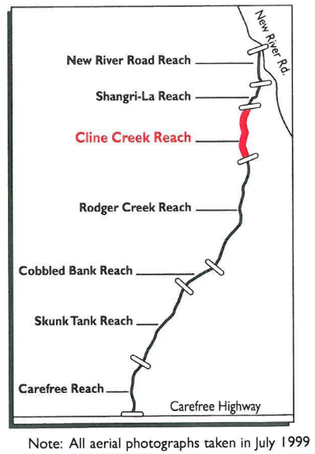


Nonstructural Alternative

Key

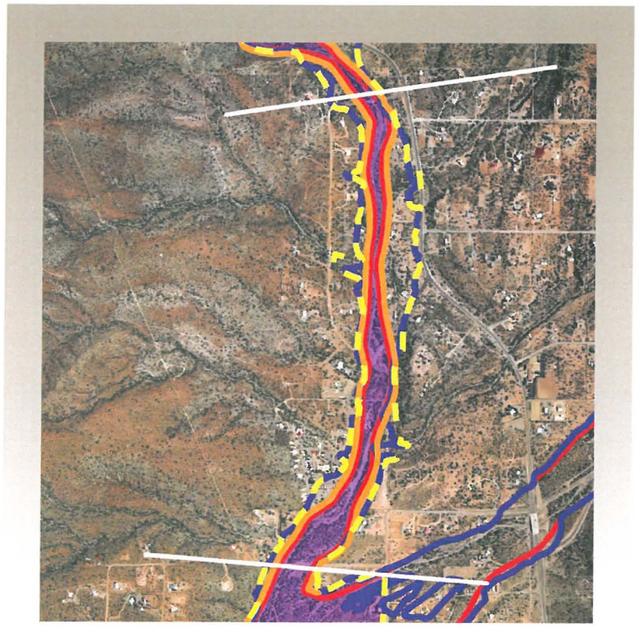
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

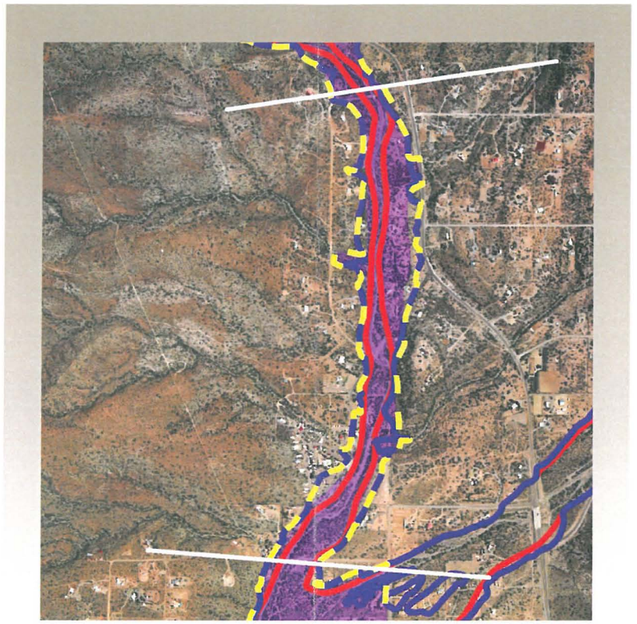


Note: All aerial photographs taken in July 1999

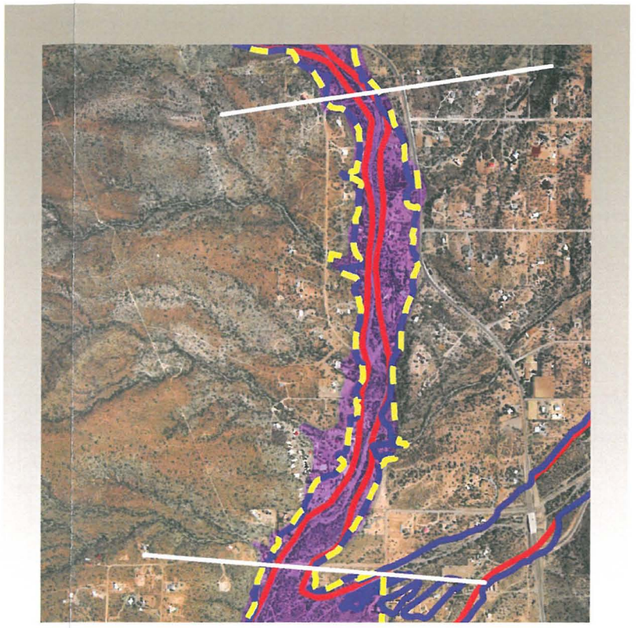
Figure 60. Skunk Creek - Cline Creek Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

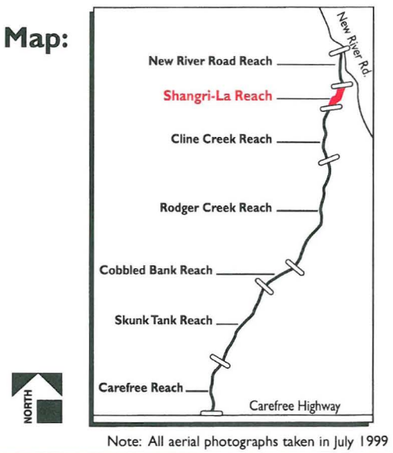


Nonstructural Alternative

Key

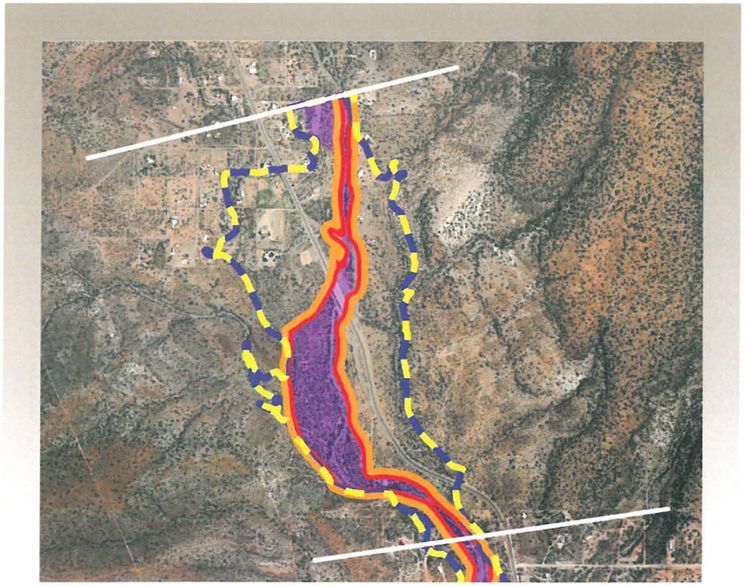
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

Phase 2 Key Map:

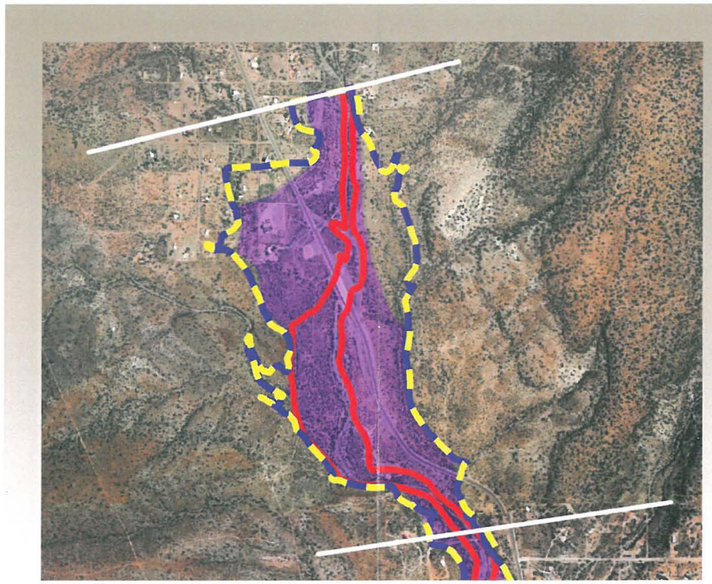


Note: All aerial photographs taken in July 1999

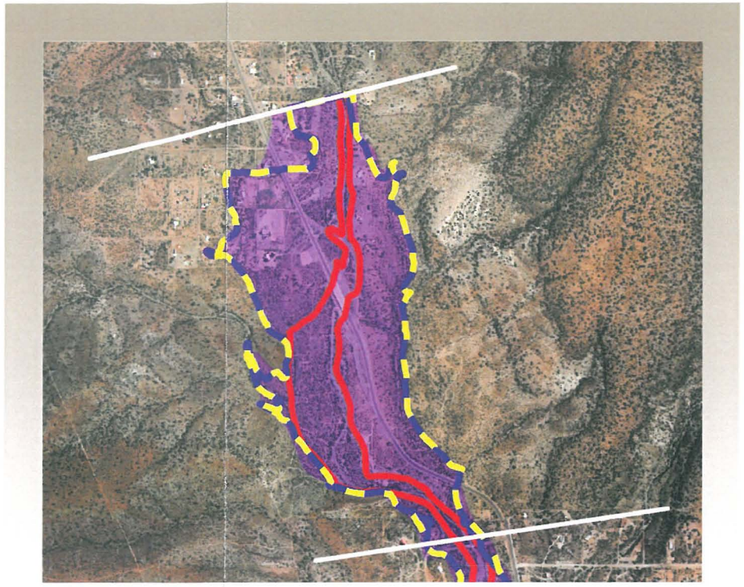
Figure 61. Skunk Creek - Shangri La Reach Alternatives (Phase 2)



Full-Structural Alternative



Low-Impact Structural Alternative

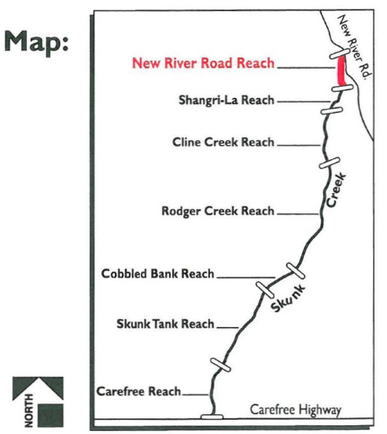


Nonstructural Alternative

Key

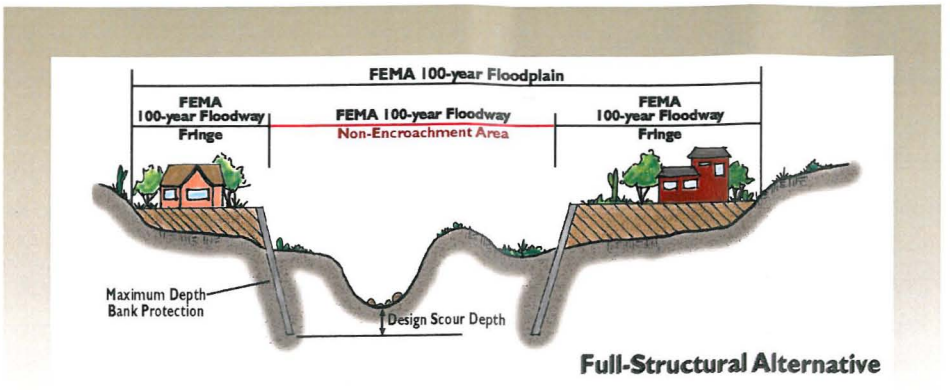
- Non-encroachment Area
- FEMA 100-year Floodplain
- FEMA 100-year Floodway
- Regulatory Line
- Maximum Depth Bank Protection
- Reach Boundary

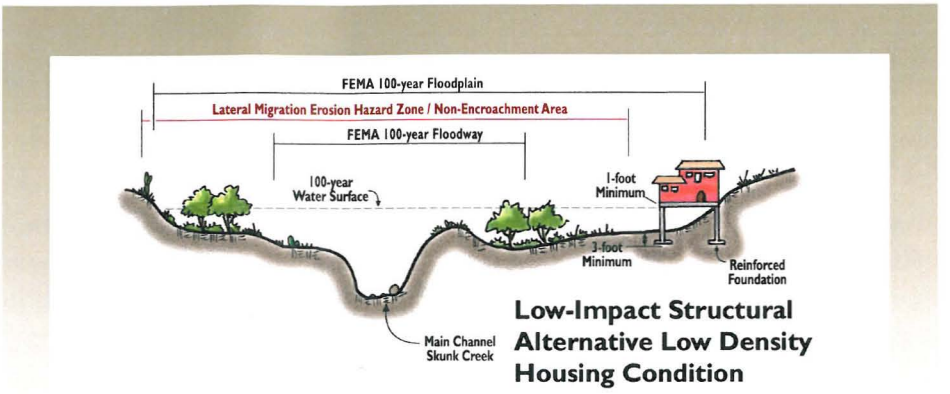
Phase 2 Key Map:

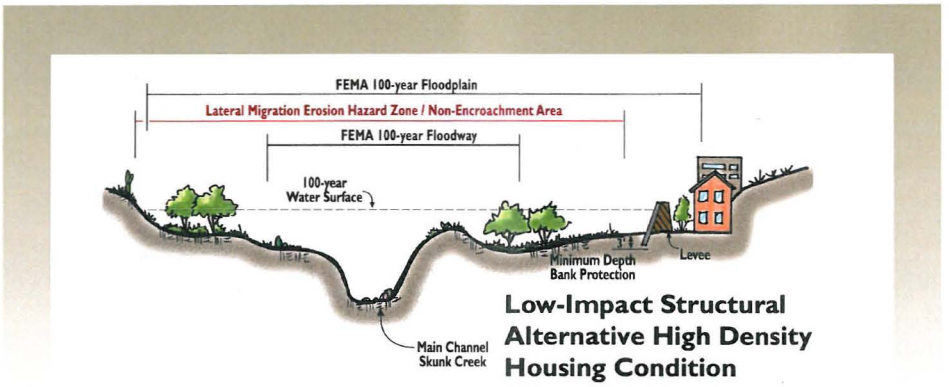


Note: All aerial photographs taken in July 1999

Figure 62. Skunk Creek - New River Road Reach Alternatives (Phase 2)







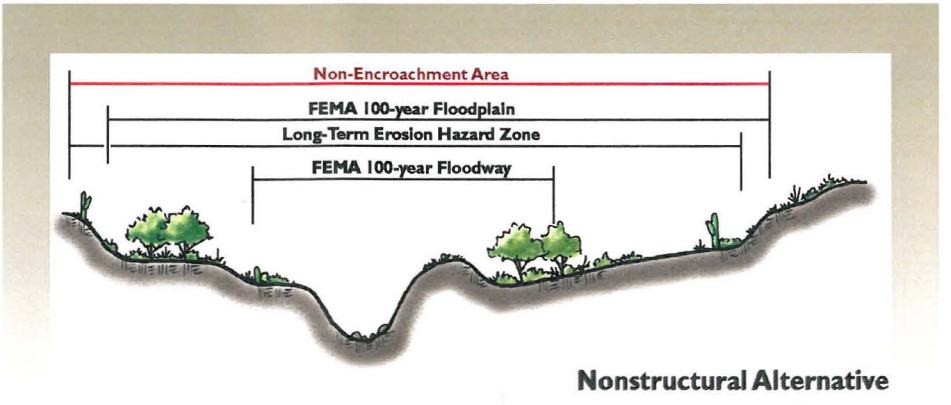


Figure 63. Typical Cross-Sections for Phase 2 Alternatives

The primary advantage of the Full-Structural Alternative is that it maximizes the amount of land available for development in the current *FEMA 100-year floodway fringe* area. The primary disadvantages are that it does so at a high construction cost, and risk to the public because of the resulting higher velocity of water moving through the *watercourse*, excessive *cumulative impacts*, and the potential for structural failure. The finished product typically has an unnatural appearance and function, and results in significant disturbance of riparian habitat.

2. Phase 2 Low-Impact Structural Alternative

The Low-Impact Structural Alternative for Phase 2 is the same as described previously for the Phase 1 Team Alternative. The proposed setback distance is defined by the *non-encroachment area* limits shown by *reach* on Figures 56 through 62 for this alternative. Refer to Figure 63 for a typical section of the proposed *Minimum* and *Maximum Depth Bank Protection*.

The advantages and disadvantages of this alternative lie in the fact that it is a compromise solution that neither maximizes the amount of developable land, nor the amount of undisturbed, natural area along the *watercourse*. The alternative defines the minimum area the study *watercourses* need to function naturally over a 60-year period. In addition, the alternative does not produce significant *cumulative impacts* within a *reach* or upstream or downstream of the study limits.

3. Phase 2 Nonstructural Alternative

The Nonstructural Alternative for Phase 2 is the same as described previously for Phase 1. The primary advantage of the Nonstructural Alternative is that the maintenance costs are minimum, and it effectively leaves the study *watercourse* corridors in their natural state. The primary disadvantage is that it minimizes the amount of land available for development and is expensive to implement. Refer to Figures 55 through 61 for the proposed *non-encroachment area* limits for this alternative.

D. Evaluation of Alternatives

The evaluation of the proposed *watercourse* management alternatives was accomplished by measuring how successful each alternative is at achieving the goals of the WCMP by applying criteria that are indicators that the goals are met. The evaluation of the management alternatives is based on three, weighted criterion - Public Safety weighted a two (2), Social/Environmental Impacts, weighted a one (1), and Economic Impacts, weighted a two (2). The weighting factor represents the "relative importance" of each criterion in the evaluation process. The criteria and weighting factors were developed through application of a value engineering process, with consensus reached among the Study Team members. The evaluation criteria and weights of importance are listed in Table 9.

Table 9
Criteria and Weighting Factors for Evaluation of Watercourse Management Alternatives

Evaluation Criteria (1)	Weighting Factor (0-10) (2)	Maximum Possible Score[1] (3)
Public safety	2	10
Economic	2	10
Social and environmental	1	5
Maximum Possible Score for an Alternative:		**25**

[1] Maximum Possible Score = Weighting Factor x Rating Factor of 5

Each of the three evaluation criterion are made up of several elements. The elements provide a means of measuring the effectiveness of the alternative being evaluated, relative to the WCMP goals. For each alternative, the effectiveness is quantified by assigning a rating factor of one (1) to five (5) to each element, with five being the most effective. Because traditional floodplain management policy allows encroachment to the *FEMA 100-year floodway* limit, the Full-Structural Alternative is selected as a standard to which all other alternatives are compared.

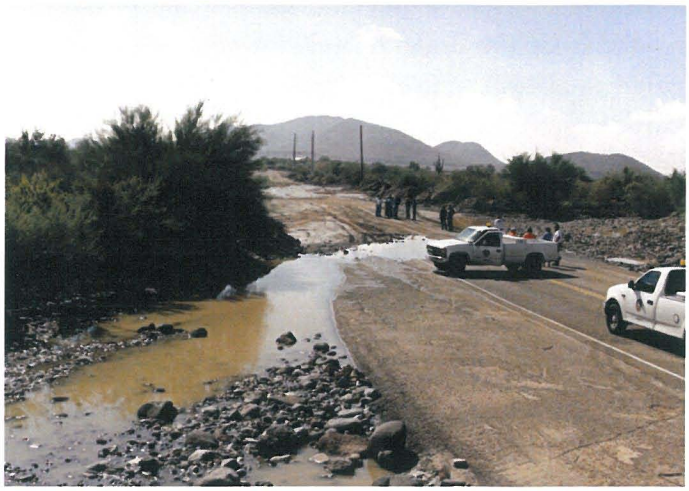
A benchmark rating is then assigned to the Full-Structural Alternative, and the other alternatives are typically measured against the Full-Structural Alternative and rated accordingly. The scores are averaged then multiplied by the criterion weight to determine the criterion score. Finally, the three criterion scores are added to provide the total alternative score. The highest total score possible for an alternative is 25. Each criterion and its element is defined in the following sections.

1. Criterion Elements and Ratings

The elements and the basis for rating the elements for each of the three criterions is described in the following sections.

a) Public Safety

The public safety criterion is based on evaluating the threat for loss of human life and possible damage to residences and property resulting from implementation of a given alternative. This criterion is an indicator of how well the proposed management alternative will succeed in reducing or eliminating life threatening, or potentially life threatening, flood and *erosion* related hazards, as well as reducing the potential for flood and *erosion* related damage to public and private properties. This criterion is also an indicator of how well the proposed management alternative will succeed in achieving overall public safety.



19th Avenue Road Closure at Skunk Creek

The evaluation of the public safety criterion is based on the effectiveness of each alternative in satisfying the ten (10) elements listed below. The elements account for various types of risk, hazards, and impacts associated with development encroaching into natural *watercourses*. All the elements under the public safety criterion are assumed to have equal importance. Refer to Attachment 12 for full descriptions of each element and discussions of the rating applied for each alternative. The ratings for the public safety criterion are summarized in Tables 10 and 11. A rating of 5 means the alternative is found very effective at meeting public safety concerns. A rating of 1 means the alternative is found least effective at meeting public safety concerns.

Cumulative Encroachment Impacts. Removing the storage capacity in *channel* over-bank areas by placing earthen fill or levees can effectively increase peak discharges in a natural *watercourse*. This element is included in the evaluation process to rate the three alternatives in this regard. The HEC-1 hydrologic models used to estimate the runoff rates and volumes from the Skunk Creek watershed are modified to reflect the loss of over-bank storage and rerun for the structural alternatives to quantify the increase in peak 100-year discharges. The greater the encroachment, the greater the increase in peak discharge, and the less effective the alternative will be at meeting the WCMP goals. Using the modified HEC-1 results, a relative scale was developed to rate the alternatives. An alternative with no increase in the 100-year peak discharge is rated a five (5) and an increase of 10 percent or greater is rated a one (1).

Localized Erosion Impacts. Because the proposed levee encroachments into the *FEMA 100-year floodplain* may begin and/or end between the cross-sections used to define hydraulic design parameters, the actual *hydraulics* at these locations may be more severe than those predicted. Consequently, the potential exists for localized *erosion* to occur in excess of that used to design the bank protection at these begin/end levee locations, referred to as terminals. The additional *erosion* could potentially undermine the proposed bank protection and cause it to fail. The risk of this occurring is assumed to be proportional to the number of levee terminals associated with a given alternative. The more terminals there are, the greater the risk for this type of failure to occur, and the less effective the alternative. Alternatives that include frequent bank protection terminals are rated a one (1), while alternatives with no bank protection terminals are rated a five (5).

Hydrologic Modeling Uncertainty. This element accounts for the possibility that the rate of runoff was underestimated for the design event, due to an underestimation of the rainfall intensity, the degree of imperviousness in the watershed, travel time, and other modeling uncertainties. The net effect would be an underestimation of flood levels. Because the conveyance area is reduced, the magnitude of the underestimated flood levels is greater for alternatives that include encroachments into the 100-year floodplain. Therefore, the measure of the effectiveness of a given alternative is based on the degree of encroachment. The greater the encroachment, the greater the threat to public safety. Alternatives that include full, continuous channelization and high levees to maximize the degree of encroachment are rated a one (1), while alternatives with no encroachment into the 100-year floodplain are rated a five (5).

Hydraulic Modeling Uncertainty. This element accounts for the potential of underestimating or overestimating intractable factors, such as the roughness of the *channel* and over-bank areas, for the *watercourses* within the study area. The primary consequence of underestimating roughness is actual flood levels that are higher than predicted. The primary consequence of overestimating roughness is actual velocities higher than predicted, which would, in turn, result in greater *scour* depths than predicted. Since greater *scour* depths could affect the stability of structural features, the threat to the general public is assumed to be proportional to the amount and extent of structural features and the degree of encroachment associated with a given alternative. Therefore, the measure of effectiveness is based on the amount and extent of structural features and the degree of encroachment. Alternatives that include continuous levees and a maximum degree of encroachment would be rated a one (1), while alternatives with no encroachment into the *FEMA 100-year floodplain* are rated a five (5).

Development Opportunity. This element represents the amount of land reclaimed from the *FEMA 100-year floodplain* by a given alternative and, thereby, made available for potential development. The effectiveness of a given alternative, relative to the public safety criteria, is based on the degree of encroachment into the floodplain. The greater the degree of encroachment, the greater the development opportunity, and the greater the risk of damage during a 100-year flood event. To measure effectiveness for this element, the amount of land reclaimed from the floodplain was computed as a percentage of the total floodplain area for each alternative for both Skunk Creek and the Sonoran Wash system. The higher the percentage, the lower the rating will be for a given alternative.

Risk of Failure. This element accounts for the risk that a structural feature may fail during a flood event. The measure of risk is assumed to be proportional to the length of levees included in the alternative being evaluated, i.e., the more levees the higher the inherent risk of a failure. An alternative that needs continuous levees to provide the desired encroachment would be rated a one (1), while an alternative with no levees would receive a rating of five (5). The length of levees was measured for each alternative and a relative rating was selected, as described below.

Flood Events Greater Than Design. This element accounts for the fact that flood magnitudes greater

than those used for analysis or design are expected in the long term. When such floods occur, some degree of failure or damage can be expected for any alternative. The measure of the threat to public safety is assumed to be proportional to the degree of encroachment into the *FEMA 100-year floodplain*, i.e., the greater the encroachment, the greater the threat. Since the occurrence of such an event represents a threat to public safety for all alternatives, the highest rating given for this element is a four (4). An alternative that includes the maximum possible encroachment into the *FEMA 100-year floodplain* would be rated a one (1). An alternative with a *non-encroachment area* that extends beyond the *FEMA 100-year floodplain* at all locations would receive a rating of five (5).

Flood Events Less Than Design. This element accounts for the level of protection provided to the public for flood magnitudes less than those used for analysis and design. The 10-year flood event was used to evaluate the alternatives in this regard. The results of the evaluation indicate that all alternatives have been designed to provide sufficient protection against flood events less than design through a combination of bank protection and setback distances. Consequently, all alternatives are rated a five (5) for both Skunk Creek and the Sonoran Wash systems.

Emergency Response. This element accounts for the ease of access to the *main channel* at any point along the *watercourses* in the study area should an emergency response be necessary. Barriers to such access can be man-made, such as levees, or natural topography. For this element, it is assumed that the street infrastructure, or other available access to the study area, is the same for all alternatives. The effectiveness of this element was measured according to the percent of *channel* (both banks) occupied by levees for each alternative. An alternative with no obstruction to access would be rated a five (5), while an alternative with continuous levees and no access ramps to the *channel* areas would be rated a one (1).

Incidental Use. This element accounts for the potential threat to public safety due to incidental uses of the *watercourse* areas. Examples of such uses might

Emergency Response Unit

be walking, hiking, camping, or horseback riding. Since it is anticipated that incidental uses will be encouraged as a result of the WCMP, the potential for injury exists for all alternatives. Therefore the maximum rating possible is limited to a four (4). The potential for injury is greater for alternatives containing structural features. For example, a person is more prone to injury on steep bank protection than a mild natural slope. Accordingly, the measure of the threat, due to structural features, is assumed to be proportional to the length of bank protection associated with a given alternative. The more bank protection, the lower the rating assigned to the alternative. An alternative with full channelization and bank protection is considered worst-case and would receive a rating of one (1).

b) Social/Environmental

The evaluation of the Social/Environmental criterion is based on the effectiveness of each alternative in satisfying the six (6) elements described below. By consensus of the consultant team and representatives of the District, each element is of equal importance. The ratings for the social/environmental criterion for Phases 1 and 2 are summarized in Tables 12 and 13, respectively.

Community Acceptance. This element accounts for the input received from the public involvement process. Consideration was also given to the fact that a significant portion of the Phase 1 study area is located within the COP's Sonoran Preserve, and that the citizens of Phoenix had voted to preserve desert

Table 10 Phase 1 Ratings for the Public Safety Criterion				
Evaluation Criteria (1)	Watercourse Management Alternative Full-Structural (2)	Stakeholders (3)	Team (4)	Nonstructural (5)
Skunk Creek Phase 1				
Cumulative encroachment impacts	1	2	4	5
Localized erosion impacts	4	3	3	5
Hydrologic modeling uncertainty	2	3	4	5
Hydraulic modeling uncertainty	2	3	4	5
Development opportunity	2	3	4	5
Risk of failure	2	4	4	5
Flood events greater than design storm	2	3	4	4
Flood events less than design storm	5	5	5	5
Emergency response	3	4	4	5
Incidental use	2	4	4	4
Average Rating for Skunk Creek Phase 1:	**2.5**	**3.4**	**4.0**	**4.8**
Sonoran Wash				
Cumulative encroachment impacts	1	1	4	5
Localized erosion impacts	1	2	3	5
Hydrologic modeling uncertainty	2	3	4	5
Hydraulic modeling uncertainty	2	3	4	5
Development opportunity	2	3	4	5
Risk of failure	2	3	3	5
Flood events greater than design storm	2	3	4	4
Flood events less than design storm	5	5	5	5
Emergency response	2	3	4	5
Incidental use	2	3	4	4
Average Rating for Sonoran Wash:	**2.1**	**2.9**	**3.9**	**4.8**

washes for the natural and biological resource values. The specific input from the public involvement process for both phases range from a strong desire to preserve the study *watercourses* and their associated habitat to a equally strong desire to maximize the area that can be reclaimed from the *FEMA 100-year floodplain* for development. This range of attitudes is understandable given the mix of private and public lands in Phase 1 and Phase 2. Approximately 62 percent of the land in Phase 1 is publicly owned, compared with 26 percent for Phase 2.

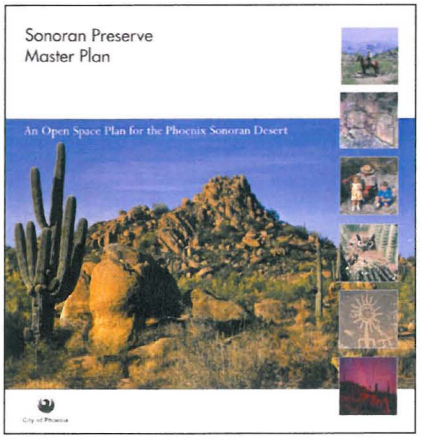
The effectiveness of the alternatives in meeting community acceptance is measured by evaluating each alternative against the following four criteria:

- ★ Honors the Phoenix Sonoran Preserve Master Plan on public lands.
- ★ Allows encroachment into the *FEMA 100-year floodplain* on private land.
- ★ Minimizes the threat to public safety.
- ★ Minimizes adverse environmental impacts (i.e., loss of open space and wildlife habitat).

An alternative that violates either of the first two criteria is rated a one (1), and since no alternative can fully satisfy all the criteria, the highest rating given for this element is a four (4). The threat to public safety is measured by the cumulative encroachment element of the public safety criterion, while the adverse environmental impact is measured by the amount of land preserved in its natural state as a percentage of the total study area. The *non-encroachment area* represents the total study area for the Nonstructural Alternative. As the degree of

Table 11 Phase 2 Ratings for the Public Safety Criterion			
Evaluation Criteria (1)	**Full-Structural (2)**	**Low-Impact (3)**	**Nonstructural (4)**
Skunk Creek Phase 2			
Cumulative encroachment impacts	1	3	5
Localized erosion impacts	2	3	5
Hydrologic modeling uncertainty	3	4	5
Hydraulic modeling uncertainty	3	4	5
Development opportunity	2	4	5
Risk of failure	2	4	5
Flood events greater than design storm	2	3	4
Flood events less than design storm	5	5	5
Emergency response	2	4	5
Incidental use	2	4	4
Average Rating for Skunk Creek Phase 2:	**2.4**	**3.8**	**4.8**

encroachment increases, so does the potential adverse impact on the environment and the threat to public safety. Consequently, a alternative with a relatively high degree of encroachment over a long *reach* of *channel* is rated a two (2), while an alternative with a relatively low degree of encroachment over a short *reach* of *channel* is rated a four (4).



Sonoran Preserve Master Plan

Complexity of Environmental Permitting. This element focuses on the acquisition of US Army Corps of Engineers 404 Permits and 401 Water Quality Certifications. The alternatives are measured based on the potential for needing a 404 Permit, the level of 404 Permit required (Nationwide vs. Individual), and the level of mitigation necessary to gain federal approval to construct the alternative. To evaluate this element, it is assumed that alternatives with structural features will cause disturbance to the land within the waters of the United States. The more extensive the structural features, the lower the rating. As an example, constructing a wide, rectangular, concrete *channel* would place fill within the waters of the United States, require an Individual 404 Permit and 401 Water Quality Certification, and require extensive mitigation measures to replace the relatively high-value habitat and vegetation associated with the undisturbed desert riparian wash. On a scale of one to five, an alternative based on this type of structure would be rated as a one (1). Alternatives that do not include structural features would be rated a five (5).

Impact on Wildlife Habitat. This element accounts for the potential impact on wildlife habitat by the proposed alternatives and how well the proposed management alternative will succeed in preserving or restoring the natural riparian environment found


Great Horned Owl at Skunk Creek

along the study *watercourses*. The most important indicator of this is the ability of a given alternative to preserve wildlife habitat or minimize disruption to existing habitat.

The measure of the impact is quantitative and based on the quality and acreage of wildlife habitat involved. The rating selected for a given alternative is based on the percent of combined high- and medium-value habitat potentially lost to development, relative to the total acreage of such habitat within the Skunk Creek and Sonoran Wash corridors. The total acreage is that within the *non-encroachment area* of the Nonstructural Alternative. Alternatives that include full channelization would receive a rating of one (1) because they would potentially impact all wildlife habitat within the study area. Alternatives that do not impact any wildlife habitat within the study area would be rated a five (5).

Visual Resource and Aesthetic Compatibility. This element is an indicator of the overall appearance projected by the alternatives. The visual resource and aesthetic compatibility criterion is based on the goals of the Sonoran Preserve Master Plan. The key goal is maintaining the visual qualities and character identified in the Sonoran Preserve Master Plan.

Skunk Creek

This element evaluates the relative degree of contrast between the various components of the alternatives and their setting in the landscape. Visual contrast is based on spatial dominance, visual compatibility, color, line, and form. The standard used to measure the compatibility of a given alternative is the construction of a wide, rectangular, concrete *channel*. Such a *channel* would spatially dominate the setting, have a high degree of contrast in terms of color, line, and form, and would not be visually compatible with the surrounding natural desert vegetation and landforms. A structure of this type would be rated as a one (1). Alternatives that do not include structural features would be rated a five (5).

Multi-use Opportunities. This element is an indicator of the potential for using the *non-encroachment area* for uses other than flood and *erosion* control. Examples of such uses included passive and active recreation, trails, and open space. The effectiveness of the criterion is based on the extent of multi-use opportunities that result from implementing a given alternative.

The alternatives were assessed based on their ability to accommodate multi-use trails/pathways, their compatibility with other potential recreation facilities in terms of access, and user's experience on the trail/pathway. The standard used to evaluate the alternatives is a combination of *channel* type and available access. Multi-use opportunities associated with a wide, rectangular, concrete *channel* with limited access points would be rated a one (1) due to the limitations in accommodating equestrian use, the restriction on potential connections to other recreation facilities, and the less than desirable user experience. Alternatives that permit unlimited access to a natural *channel* environment would be rated a five (5).

Impact on Cultural Resources. This element accounts for the potential impact on cultural resources by a given alternative. It is also an indicator of how well the alternatives will succeed in preserving cultural resources. The measurement of the potential impact is based on the acreage of known cultural resources potentially lost due to development, as a percentage of the total acreage of known cultural resources along the Skunk Creek and Sonoran Wash corridors. The total acreage of known cultural resources is that contained within the *non-encroachment area* of the Nonstructural

Table 12 Phase 1 Ratings for the Social/Environmental Criterion				
Evaluation Criteria (1)	**Full-Structural (2)**	**Stakeholders (3)**	**Team (4)**	**Nonstructural (5)**
Skunk Creek Phase 1				
Community acceptance	1	3	4	1
Complexity of environmental permitting	2	3	4	5
Impact on wildlife habitat	3	4	4	5
Visual resource and aesthetic compatibility	2	3	4	5
Multi-use opportunities	3	4	4	5
Average Rating for Skunk Creek Phase 1:	**2.2**	**3.4**	**4.0**	**4.2**
Sonoran Wash				
Community acceptance	1	3	4	1
Complexity of environmental permitting	2	3	4	5
Impact on wildlife habitat	3	4	4	5
Visual resource and aesthetic compatibility	2	3	4	5
Multi-use opportunities	2	3	4	5
Average Rating for Sonoran Wash:	**2.0**	**3.2**	**4.0**	**4.2**

Alternative. An alternative that impacts all of the known cultural resources would be rated a one (1), while an alternative that impacts none of the known cultural resources would be rated a five (5).

c) Economic Criteria

The evaluation of the economic criterion is based on the effectiveness of each alternative in satisfying two (2) elements described below. Again, by consensus of the consultant team and representatives of the District, each element is of equal importance.

Implementation Cost. This element represents the estimated cost of the proposed management alternative to the public, either through increased development costs passed onto future residents of the area who will directly benefit from the improvements (local public) or the costs to the general public. This cost considers the structural improvements necessary to implement the proposed management alternative (a positive cost), the value of land within the *Regulatory Line* reclaimed from the floodplain by the structural improvements (a negative cost, i.e. benefit), and the value of land outside the *Regulatory Line* that must be obtained to implement the alternative (a positive cost). Added together, these costs represent the total net cost of the alternative.

The effectiveness of a given alternative is measured by using the total net cost. The lower the net cost,

Table 13 Phase 2 Ratings for the Social/Environmental Criterion			
Evaluation Criteria (1)	**Full-Structural (2)**	**Low-Impact (3)**	**Nonstructural (4)**
Skunk Creek Phase 2			
Community acceptance	2.0	4.0	1.0
Complexity of environmental permitting	2.0	4.0	5.0
Impact on wildlife habitat	3.0	4.0	5.0
Visual resource and aesthetic compatibility	2.0	4.0	5.0
Multi-use opportunities	2.0	4.0	5.0
Impact on cultural resources	1.0	2.0	5.0
Average Rating for Skunk Creek Phase 2:	**2.0**	**3.7**	**4.3**

Table 14 Phase 1 Ratings for the Economic Criterion				
Evaluation Criteria (1)	Full-Structural (2)	Stakeholders (3)	Team (4)	Nonstructural (5)
Skunk Creek Phase 1				
Implementation cost	5	4	4	1
Maintenance cost	2	4	4	5
Average Rating for Skunk Creek Phase 1:	**3.5**	**4.0**	**4.0**	**3.0**
Sonoran Wash				
Implementation cost	4	4	4	1
Maintenance cost	2	3	4	5
Average Rating for Sonoran Wash:	**3.0**	**3.5**	**4.0**	**3.0**

the higher the rating for the alternative. The alternative with the lowest net cost in either the Skunk Creek or the Sonoran Wash system is rated a five (5), while the alternative with the highest net cost is rated one (1). The costs associated with the levee option were used to establish the ratings.

Maintenance Cost. This element accounts for the potential maintenance costs associated with the structural components of the alternatives. It is assumed that such costs are proportional to the length of bank protection proposed for a given alternative. The greater the bank protection length, the higher the potential maintenance cost and the lower the rating. However, since more severe encroachment is possible, it is also assumed that maintenance costs can be greater than those expected for the Full-Structural Alternative. Therefore, the Full-Structural Alternative is not rated less than a two (2). An alternative with no bank protection would be rated a five (5). The ratings for the economic criterion for Phases 1 and 2 are summarized in Tables 14 and 15.

2. Summary of Results

The scoring results for each Phase 1 alternative are summarized for Skunk Creek and Sonoran Wash in Table 16. The scoring results for each Phase 2 alternative are summarized for Skunk Creek in Table 17.

E. Recommended WCMP Management Alternative for Phase 1

The recommended management plan for Phase 1 of the Skunk Creek WCMP is the Team Alternative. The Team Alternative achieved a total score of 39.8, as compared to scores of 26.6, 34.2, and 39.6 for the Full-Structural, Stakeholders, and Nonstructural Alternatives, respectively. This alternative achieved a total score of 20 and 19.8 out of a possible 25 points for Skunk Creek and Sonoran Wash, respectively. Although the margin is small over the Nonstructural Alternative, the Team Alternative is the most successful at meeting the WCMP goals. Key

Table 15 Phase 2 Ratings for the Economic Criterion			
Evaluation Criteria (1)	Full-Structural (2)	Low-Impact (3)	Nonstructural (4)
Skunk Creek Phase 2			
Implementation cost	3	5	1
Maintenance cost	2	4	5
Average Rating for Skunk Creek Phase 2:	**2.5**	**4.5**	**3.0**

Table 16

Phase 1 Summary of Alternative Scoring for Skunk Creek and Sonoran Wash

Evaluation Criteria (1)	Weighting Factor (2)	Full-Structural		Stakeholders		Team		Nonstructural	
		Rating (3)	Score[1] (4)	Rating (5)	Score[1] (6)	Rating (7)	Score[1] (8)	Rating (9)	Score[1] (10)
Skunk Creek Phase 1									
Public safety	2	2.5	5.0	3.4	6.8	4.0	8.0	4.8	9.6
Economic	2	3.5	7.0	4.0	8.0	4.0	8.0	3.0	6.0
Social and environmental	1	2.2	2.2	3.4	3.4	4.0	4.0	4.2	4.2
Total Scores for Skunk Creek Phase 1:	---	---	**14.2**	---	**18.2**	---	**20.0**	---	**19.8**
Sonoran Wash									
Public safety	2	2.1	4.2	2.9	5.8	3.9	7.8	4.8	9.6
Economic	2	3.0	6.0	3.5	7.0	4.0	8.0	3.0	6.0
Social and environmental	1	2.0	2.0	3.2	3.2	4.0	4.0	4.2	4.2
Total Scores for Sonoran Wash System:	---	---	**12.2**	---	**16.0**	---	**19.8**	---	**19.8**
Watercourse Master Plan, Phase 1									
Public safety	---	---	9.2	---	12.6	---	15.8	---	19.2
Economic	---	---	13.0	---	15.0	---	16.0	---	12.0
Social and environmental	---	---	4.2	---	6.6	---	8.0	---	8.4
Watercourse Master Plan Total Scores :	---	---	**26.4**	---	**34.2**	---	**39.8**	---	**39.6**

[1] Score = Weighting Factor x Rating Factor

Table 17

Phase 2 Summary of Alternative Scoring for Skunk Creek

Evaluation Criteria (1)	Weighting Factor (2)	Full-Structural		Low-Impact		Nonstructural	
		Rating (3)	Score[1] (4)	Rating (5)	Score[1] (6)	Rating (7)	Score[1] (8)
Skunk Creek Phase 2							
Public Safety Criterion	2	2.4	4.8	3.8	7.6	4.8	9.6
Economic Criterion	2	2.5	5.0	4.5	9.0	3.0	6.0
Social and Environmental Criterion	1	2.0	2.0	3.7	3.7	4.3	4.3
Total Scores for Skunk Creek Phase 2:	---	---	**11.8**	---	**20.3**	---	**19.9**

[1] Score = Weighting Factor x Rating Factor

factors supporting the selection of the Team Alternative are that it allows use of private land within the *FEMA 100-year floodplain* without compromising public safety and it also meets the goals of the Sonoran Preserve Master Plan, and the North Black Canyon Corridor Plan. Selection of this alternative is also consistent with the alternatives analysis conducted by the COP (refer to Attachment 12).

Sonoran Wash

A significant amount of State land within the *non-encroachment area* of the Team Alternative is within the land slated for purchase under the API. However, the API designation does not guarantee preservation. The API designation is only good for a maximum of 7 years. After that time frame, the ASLD is free to place the land on the open market for development. If sold, the ASLD must sell the land at market value. It is, therefore, recommended that the State land within the *non-encroachment area* of the Team Alternative be designated a high priority for acquisition under the API. Successful implementation of the Team Alternative is contingent upon the acquisition, or if land acquisition is not feasible, the regulatory control of the *non-encroachment area* through such methods as zoning and density transfers. Regulatory control of the *non-encroachment area* on private land must be accomplished through such methods as zoning and density transfers.

F. Recommended WCMP Management Alternative for Phase 2

The recommended management plan for Phase 2 of the Skunk Creek WCMP is the Low-Impact Structural Alternative. The Low-Impact Structural Alternative achieved a total score of 20.3, as compared to scores of 11.8 and 19.9 for the Full-Structural and Nonstructural Alternatives, respectively. Although the margin is small over the Nonstructural Alternative, the Low-Impact Structural Alternative is the most successful at meeting the WCMP goals. A key factor supporting the selection of the Low-Impact Structural Alternative for Phase 2 of the study is the flexibility afforded to private landowners to reclaim land from the *FEMA 100-year floodplain*, while minimizing adverse impacts on the environment and the threat to public safety. Approximately 74 percent of the land in Phase 2 is privately owned.

Skunk Creek

8 Monitoring and Maintenance Plan

The Monitoring and Maintenance Plan for the WCMP is developed for the purpose of providing a recommendation for a systematic approach for monitoring and maintaining Skunk Creek and Sonoran Wash in a manner that will attempt to preserve *watercourse* stability and design functionality for a minimum 60-year time period. The primary objective for development of the Monitoring and Maintenance Plan is to formulate simple monitoring and maintenance protocols that, if adopted by the District, should be relatively easily accomplished and completed on an ordinary basis as well as an extraordinary basis with minimal, straightforward field application. Refer to Attachment 10 for the complete Monitoring and Maintenance Plan and exhibits on which are depicted the elements and areas recommended for monitoring and maintenance. The monitoring plan is also intended for development of a historical database that can be used by the District for verification and adjustment of the procedures used for the lateral stability analyses. The District may also elect to use the database for future *watercourse* research activities.

The Monitoring and Maintenance Plan for the WCMP consists of the following elements:

- Short-term Monitoring Criteria.
- Long-term Monitoring Criteria.
- Maintenance Criteria.

A. Short-term Monitoring

Short-term monitoring criteria are developed in order to identify significant *watercourse* changes typically developing over very short time periods (e.g., hours or a few days). Such rapid changes will generally be caused by single flood events of significant magnitude occurring on the Skunk Creek system. Accordingly, such changes will be the result of less frequent flows-i.e., those occurring on the order of once every 10 years, or less (i.e., a 10-year flood, or greater)-although smaller flow events with longer duration's might also create significant *watercourse* changes over a relatively short-term time period. Short-term monitoring of Skunk Creek should occur when:

- There is no reported flood damage, yet precipitation of 1.2 inches, or more, falls within the contributing watershed within a time period of one hour or less, or 2.0 inches of precipitation falls within 24 hours or less.
- Flood damage or disruption to transportation systems due to stormwater runoff (e.g., at wash crossings) has been reported.
- Specific hydraulic structures and/or stormwater detention/retention facilities located within the contributing watershed and along system *watercourses* have been reported either to have failed or started to fail.

The following system-wide elements should be monitored for short-term changes:

- Hydraulic structures including the bridges over Skunk Creek at New River Road and the Carefree Highway, the CAP Canal Overchutes, the Cloud Road and 27th Avenue culverts.
- Roadway dip crossings including 19th Avenue, Desert Hills Road, Honda Bow Road, Circle Mountain Road, and Zorrillo Road.

Carefree Highway Bridge at Skunk Creek

- ★ Bank protection improvements.
- ★ Locations where structurally improved *reaches*, transition either into or out of nonstructural *channel reaches*.

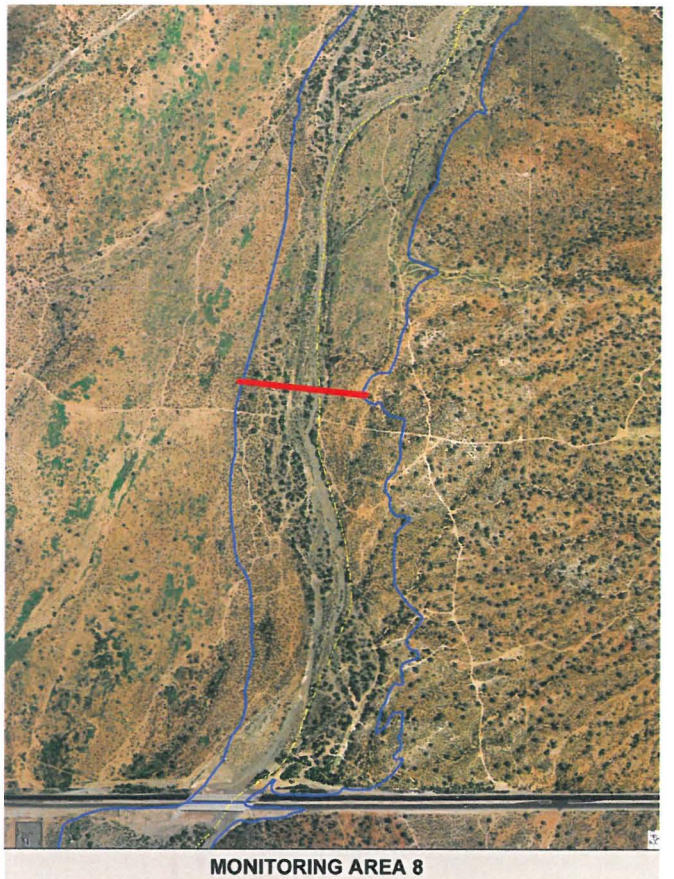
B. Long-term Monitoring

Long-term monitoring criteria are developed and recommended in order to identify significant *watercourse* changes typically occurring over much longer time periods (e.g., years to decades). Such gradual changes will generally be caused by a series of smaller flood events, which may occur over a period of as little as a few years to a period as long as several decades, in combination with system-wide changes in watershed sediment continuity, initiated primarily by watershed urbanization and by man-made *channel* changes. Changes will likely occur in the form of gradual *channel* widening, *channel degradation* (i.e., a gradual lowering of the level of the streambed), or *aggradation* (i.e., a gradual raising of the level of the streambed, a condition that can potentially lead to system-wide *channel* widening).

Long-term monitoring of Skunk Creek should occur on a routine, programmatic basis, as follows, if the District chooses to adopt the program:

- ★ Field monitoring should occur on a biennial (i.e., once every two years) basis. The monitoring should occur preferably at the end of the summer monsoon season, around the beginning of October of each year.
- ★ Aerial photography of the system *watercourses* should be performed on a biennial basis, and the *watercourse main channels* examined for long-term movement.
- ★ Field surveying of streambed profiles should occur every six years and compared with historical profiles for the purpose of monitoring *aggradation* and *degradation*.
- ★ Field surveying of stream cross-sections should occur every six years at appropriate intervals along the *watercourses* within the Skunk Creek system and compared with historical cross sections for monitoring long-term *main channel* migration and bank widening.

The same system-wide elements should be monitored for long-term changes as defined for short-term changes.



Typical Monitoring Cross Section Location

C. Maintenance Criteria

The monitoring criteria described within the preceding sections establish the guidelines regarding system elements to be monitored, and the recommended frequency. The purpose of maintenance criteria is to provide easy-to-apply guidelines, which if adopted by the District, aid in ascertaining when maintenance of system elements is warranted. Accordingly, such criteria should be based upon visual inspections

and assessment of changes in geometric parameters, such as *channel* top width, *channel* bank height, horizontal location, and thalweg elevation and location. When changes are significant, maintenance should be considered to prevent or arrest the potential for localized or system-wide instabilities.

The need for maintenance, whether localized or system-wide, should be given serious consideration when the following criteria are met. These criteria have been written assuming that all recommended structural and nonstructural elements have been put in place.

- *Channel* top-width along a *channel* segment has unexpectedly increased or decreased by 15%, or more, from its original, baseline configuration.
- Streambed elevation along a *channel* segment has unexpectedly lowered or has risen by 1.0 foot, or more, from its original, baseline configuration.
- Cracks or separations in joints are observed along *channel* linings.
- A low-flow thalweg has unexpectedly formed within or along a streambed that previously did not contain this hydraulic element.
- Loss of supporting soils is observed to occur immediately behind engineered embankments.
- Significant amounts of debris are observed with in a *channel* system to the degree that hydraulic capacity might be unduly restricted.
- Unexpected sand and gravel bars are observed to form in locations that might unduly restrict hydraulic capacity or change the flow pattern.
- Sediment buildup is observed within hydraulic structures to the degree that 15%, or more, of the flow area is blocked.
- An unexpectedly large *scour* hole has formed in the immediate vicinity of a hydraulic structure (e.g., a bridge or culvert), which if left unchecked, might undermine the structure.

Since potential *watercourse* instabilities can manifest themselves in a variety of ways, the above criteria should not be considered a complete list.

D. Maintenance Measures

Maintenance measures that should be considered in order to preclude or arrest localized changes on a short- or long-term basis include, but are not limited to:

- Removing sediment deposition from hydraulic structures, and at-grade stream crossings of roadways in order to restore hydraulic capacity.
- Filling in areas where supporting soils have been lost immediately behind engineered embankments.
- Repairing cracks or separations in joints along *channel* linings.
- Where warranted, removing localized debris buildup from a *channel* system to preclude undue restriction of hydraulic capacity.
- Removing sediment buildup within hydraulic structures where 15%, or more, of the flow area is blocked to remove undue restriction of hydraulic capacity.
- Filling in of large *scour* holes formed in the immediate vicinity of hydraulic structures (e.g., a bridge or culvert) to preclude or arrest the potential for their being undermined.
- Horizontal extension of bank protection endpoints to preclude outflanking of engineered embankments.
- Vertical extension of toe protection to preclude undermining of engineered embankments.

Additional maintenance measures that could be considered in order to preclude or arrest system-wide changes on a long-term basis include, but are not limited to:

- Construction of sediment and debris entrapment facilities to either reduce or eliminate down stream *sedimentation* problems.
- Construction of larger hydraulic structures to safely pass both sediment and water.
- Construction of grade control structures and ancillary guide-bank measures to reduce or eliminate long-term *channel degradation*.
- Construction of bank protection to reduce or eliminate long-term *lateral channel migration*. Horizontal extension of bank protection end-points to preclude outflanking of engineered embankments.

19th Avenue at Skunk Creek Closed for Sediment Removal

9 Implementation Plan

The recommended Implementation Plan for the WCMP is developed to provide guidance for the District to implement the proposed management plan.

The Implementation Plan for the WCMP includes the following recommended elements:

- Regulation of Recommended Non-Encroachment Area.
- Interim Flood Warning System.
- Acquisition Program for Residences in High-Hazard Areas.
- Recommendations for the Adobe Dam Area Drainage Master Plan or other future studies.
- Establishment of monitoring and maintenance program.

Refer to Attachment 11 for the complete Implementation Plan.

Skunk Creek

A. Regulation of Recommended Non-Encroachment Area

The implementation of the recommended *non-encroachment area* for both phases of the WCMP is critical to the successful management of the study watercourses. Implementation strategies for each phase are discussed separately in the following sections.

1. Phase 1.

Implementation of the Phase 1 *non-encroachment area* is underway by the COP. The method chosen by the COP for enforcement of the recommended *non-encroachment area* is establishment of a Flood Hazard and Erosion Management Zoning District. The Flood Hazard and Erosion Management District (FH) is intended to provide a new zoning category that will address the permitted use of land within areas that are prone to flooding or *erosion* hazards. It is further intended that watercourses be retained and maintained in a natural desert state to the greatest extent possible with flood control structures limited to the minimum necessary and designed to reflect a natural condition. In addition to the uses allowed within the FH district, a proposal for the transfer of limited residential density and non-residential building area to locations outside the boundary of the FH district will also be permitted when the property is combined with adjacent land for development purposes. The permitted uses are as follows:

- Drainage and storm water conveyance, natural or limited structural (when deemed necessary and designed to reflect a natural condition).
- Open space, natural or unimproved (native landscape enhancements/restoration are permitted).
- Open space, improved - shall be limited to passive and active recreational activities including hiking/riding trails, exercise par courses, picnic areas and similar activities within a natural desert landscape. There shall be

no game/sports courts or grassed areas. Structures shall be limited to security lighting, open fencing, shade structures, tables, seating, and exercise equipment which shall not impede storm water conveyance.

Acceptable Improved Open Space Use

- Residential use - when the area covered by this zoning district is combined with an adjacent zoning district(s) outside the floodway for the purpose of residential development then residential use at a density not to exceed one dwelling unit per acre shall be permitted. The permitted density together with all structures, parking, and accessory uses, except as otherwise permitted by this district shall be transferred to the adjoining zoning district(s).

- Non-residential development - when the area covered by this zoning district is combined with an adjacent zoning district(s) outside the floodway for the purpose of non-residential development (including but not limited to commercial, office, industrial, public or quasi public uses) then non-residential intensity at a floor area ratio (F.A.R. = gross building area to gross lot area) of 0.1 is permitted. The permitted F.A.R. together with all structures, parking, and accessory uses, except as otherwise permitted by this district shall be transferred to the adjoining zoning district(s).

- Accessory uses:

  1. Utilities - which shall be limited to wash crossings only; all installations shall be protected against scouring.

  2. Roadway/bridge crossings.

2. Phase 2.

The recommended *non-encroachment area* for Phase 2 can be enforced through the following methods:

- Establish a Flood Hazard and Erosion Management Zoning District, similar to that being implemented by the COP for Phase 1.

- Regulate the *non-encroachment area* outside the *FEMA 100-year floodway* as an Erosion Control Zone in conformance with the Floodplain Regulations for Maricopa County.

- Re-map the *non-encroachment area* within the *FEMA 100-year floodplain* as FEMA 100-year Floodway and regulate accordingly.

Two of the three possible enforcement methods to be described are not desired by the District. The establishment of a Flood Hazard and Erosion Management Zoning District is possible, but is not the method preferred by the District staff. The entire Phase 1 area is undeveloped, and slated for subdivision-type land uses. Phase 2 is for the most part already broken up into privately owned parcels with a maximum land use density of predominately 1 unit per acre. Large subdivision-type developments are not expected to occur in the study area. Therefore, an implementation option that respects personal property rights as much as possible without sacrificing public safety is preferred. The regulation of the entire *non-encroachment area* as if it were a *FEMA 100-year floodway*, while maximizing public safety, minimizes use of the land by private property owners, and is therefore not preferred. The option to regulate the *non-encroachment area* outside the

FEMA 100-year floodway as an *Erosion Control Zone* is the preferred implementation method by the District, and also recommended herein.

The District added the *Erosion Control Zone* designation to the Floodplain Regulations for Maricopa County in the 2000 revision. There are no formal policy statements written for regulation of this zone as of the writing of this WCMP. Therefore, the following are the recommended regulation policies for allowable uses specific to the WCMP for administration of the *Erosion Control Zone*, and correspondingly, the recommended *watercourse* management *non-encroachment area* (It is understood that the area inside the *FEMA 100-year floodway* shall be regulated in accordance with the existing Floodplain Regulations for Maricopa County):

- Drainage and storm water conveyance, natural or limited structural (when deemed necessary and designed to reflect a natural condition).

- Open space, natural or unimproved (native landscape enhancements/restoration are permitted).

- Open space, improved - shall be limited to passive and active recreational activities including hiking/riding trails, exercise par courses, picnic areas and similar activities with in a natural desert landscape. Game/sports courts or grassed areas are allowed, including equestrian arenas. Structures shall be limited to security lighting, open fencing, pole barns, shade structures, tables, seating, and exercise equipment which shall not impede storm water conveyance.

- Residential use - Residences are not encouraged in this area, but may be permitted if the following conditions are met:

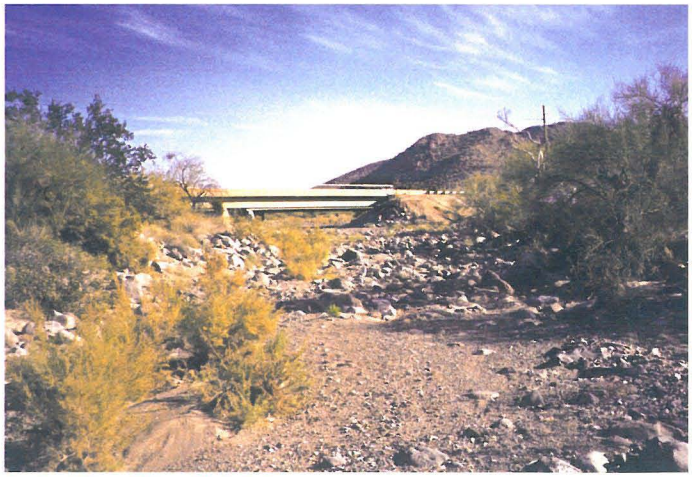
  1. The structure does not impede stormwater conveyance or result in *cumulative impacts*. *Cumulative impacts* are to be measured in terms of the percent increase in peak discharge resulting from *floodplain encroachment* and may not exceed the values listed in Table 6 for the Low-Impact Structural Alternative. Consideration shall be given to conveyance exchange with allowable floodplain encroachments outside the Erosion Control Zone on the same property.

  2. The foundation of the structure is designed by a structural engineer licensed to practice in the State of Arizona to withstand the effects of floodwaters and *erosion* assuming the main *channel* migrates to the residence. The foundation shall extend below the adjacent main *channel* thalweg elevation to a depth equal to the maximum design *scour* depth listed in Table 8 for the *reach* in question.

- Accessory uses:

  1. Utilities - which shall be limited to wash crossings only or to service a permitted residence or outbuilding; all installations shall be protected against *scour* and *erosion*.

  2. Roadway/bridge crossings.



Carefree Highway Bridge at Skunk Creek

Residences constructed within the *FEMA 100-year floodplain*, but outside the *Erosion Control Zone*, shall be constructed with either:

1. The foundation extended to a 3-foot depth below existing ground and constructed of rein forced masonry or concrete materials.

2. The foundation constructed on fill materials compacted to 95% of maximum dry density and the entire fill area protected with bank protection extending a minimum of 3-feet below existing ground.

B. Interim Flood Warning System

Now that the floodway limits have been mapped, District staff may propose as one component of the implementation strategy for the WCMP, the establishment of a flood warning system for Skunk Creek between Cloud Road and the upper limit of the Phase 2 study area located about 2,200 feet upstream of the New River Road bridge. The purpose of the system is early detection of flooding events that could damage the existing residences within the *FEMA 100-year floodway* and Severe Erosion Hazard Zone. This information could be used to warn residents of the impending flood and trigger evacuation notices. This flood warning plan and system would be considered only an interim measure because it is to be phased-out by the acquisition/relocation program described below. Any proposed acquisition program will be voluntary. If acquisition offers are made, the flood warning system for individual residences would be terminated:

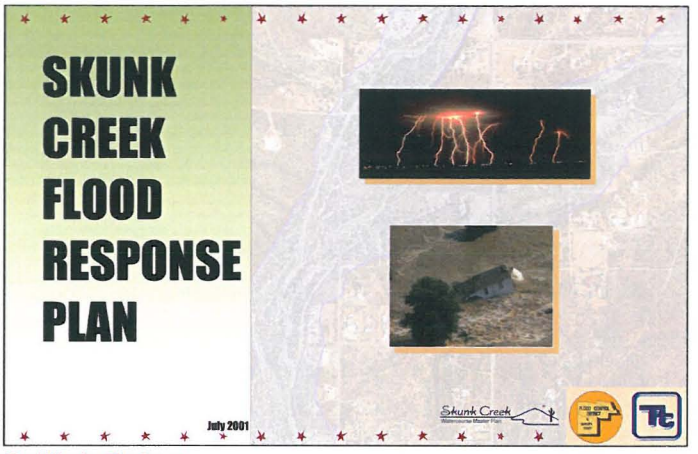
1) after the property owner accepts the offer and is moved out, or
2) after the property owner declines the offer.

The District has maintained and operated a rain gage and a streamflow gage in the Phase 2 study *reach* of upper Skunk Creek since 1981 and 1995, respectively. Those gage data, in combination with rainfall and streamflow data from gages located downstream at the I-17 crossing of Skunk Creek, are used by the District to support the following functions:

★ Flood Warning. The primary flood warning use of the Skunk Creek gages has been to provide data for evaluating the performance and safety of Adobe Dam, located downstream. Additionally, the collected data provide advisory information in support of road closure decisions during flood events.

★ Data Collection/ Archive. The data continue to be incorporated into rainfall and streamflow databases maintained by the District. These databases provide critical data for the design and evaluation of engineered structures in the Skunk Creek watershed as well as elsewhere around Maricopa County and the State of Arizona.

District staff report that the existing flood warning system has been adequate, thus far, in meeting the flood warning needs in the Skunk Creek watershed as described above. However, since June 1995 when the "Skunk Creek near New River" streamflow gage was installed, no extreme flood events have occurred. However, in consideration of the potential impacts to structures and roadway crossings in the Phase 2 study area, and the flood warning needs for larger floods occurring in this area, a more comprehensive investigation is recommended.



Flood Warning Plan Report

1. Flood Warning System (FWS) Needs Assessment

The necessary elements of the Skunk Creek FWS are assessed by:

★ Considering the information provided by the Districts' existing Automated Local Evaluation in Real Time (ALERT) sensor detection network in the watershed.

- Comparing the flow rate at which overbank flooding occurs with the precipitation necessary to produce that flow rate.

- Determining the locations of structures and road crossings in the floodway, floodplain and Severe Erosion Hazard Zone.

- Examining the travel time to these locations from existing streamflow gages as well as the approximate frequency of the beginning of inundation at these locations.

The results of the assessment indicate that the primary need for flood warning in the Skunk Creek watershed is for closure of at-grade road crossings. A secondary need for larger floods is the warning and evacuation of structures that are located within the Skunk Creek floodway and those structures located outside the floodway, but within the Severe Erosion Hazard Zone. The relatively quick basin response time of streams in the Skunk Creek watershed and the somewhat remote location of the area limit the nature of, and means for, flood warning. Finally, development within the downstream portions of the study area may change the flood warning needs as future development proceeds. Flood warning needs should be reevaluated as development occurs.

2. FWS Components

An effective flood warning system is the combination of several vital elements. The first element is the ability to detect and evaluate a flood threat in its early stages and make a decision to warn people before flood damages or personal injuries occur. The second element is the dissemination of the warning to the public at risk. The third element is the public response to the warning. The following is a brief description of the each of these components relative to the Skunk Creek FWS.

a) Flood Detection

The earliest recognition of a potential flood threat for the Skunk Creek basin will be the forecast products available from the District and the National Weather Service (NWS). The Precipitation Outlook (PO) forecast provided by the Flood Control District of Maricopa County Meteorological Services Program (MSP) provides a daily assessment of the flooding potential of the atmosphere and a basin-specific Quantitative Precipitation Forecast (QPF). The MSP also provides a series of flood alert messages of increasing severity and urgency. The MSP service supplements standard NWS forecast products, and the flash flood watch and flash flood warning messages issued by the NWS. MSP forecasts and messages are comparatively more site-specific to the Skunk Creek watershed. District MSP messages are coordinated with the NWS Weather Forecast Office in Phoenix. Depending on staffing and personnel assigned by the District. District flood alert messages and NWS flash flood watches and flash flood warnings could be issued in an agreed upon sequence for areas impacted by flooding along Skunk Creek.

Precipitation and Stream Flow Gauge

The automated rain gages and stream gages in the Skunk Creek basin and adjacent watersheds transmit rainfall data and real-time streamflow measurements to ALERT base stations located at the District and NWS. The effectiveness of the Skunk Creek FWS is highly dependent upon adequate rainfall and

streamflow data collected and transmitted by the sensors comprising the flood detection network for the Skunk Creek watershed. Therefore, one new streamflow gage and three new rainfall gages are scheduled to be installed to supplement the existing rainfall and streamflow gages on Skunk Creek near New River (#5580 and #5583, respectively). The new streamflow gage is planned for Cline Creek, a major tributary that joins Skunk Creek downstream of the existing streamflow gage. In addition, a new rainfall gage will be co-located at this site. One new rain gage is planned for each of the upper watersheds of Skunk, Cline, and Rodger Creeks. These new gages should substantially improve the hydrologic data available for the District to support decisions concerning road closures and can trigger the flood response plan action protocols that are based upon pre-determined flood detection criteria and sensor threshold alarms.

A new stream gage was proposed for Rodger Creek. There is only one viable site that meets the requirements of access and accurate flow measurements. The site is on privately owned property, and the property owners declined to allow the District to construct a gage on their property.

b) Information Dissemination

An interim program to disseminate flood warning messages to the public and to emergency response agencies is recommended to the District, and could be accomplished using NOAA weather radios and pagers. Notification via multiple paths is provided for redundancy and robustness of the FWS. The NWS will issue warning messages to the public via:

- Emergency Alert System (EAS). The system consists of radio and television broadcast stations in the Phoenix operational area that are responsible for disseminating emergency information and warnings to the public (voluntary).

- NOAA Weather Radio (NWR). NWS issues flash flood watch and flash flood warning messages via NOAA Weather Radio according to a standard protocol using tone alarms followed by voice messages.

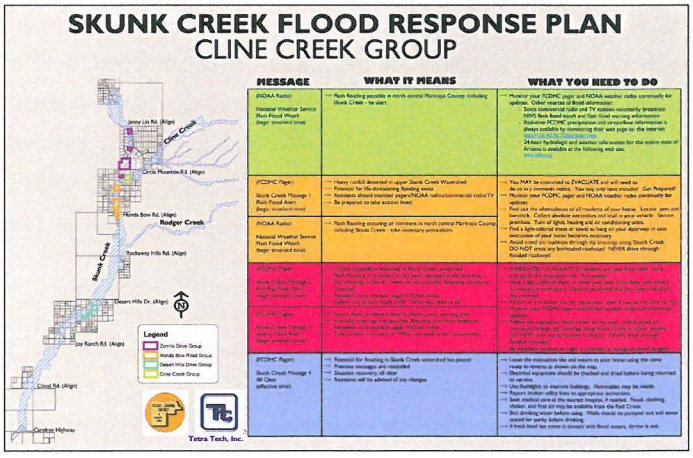
The District's program could then send flood alert messages via text pager to residents in the Skunk Creek floodway and Severe Erosion Hazard Zone, as appropriate. The message would be sequenced into the NWS flash flood watch and flash flood warning message suite.

c) Flood Response Plan (FRP)

The recommended response component of the FWS consists of three primary elements:

- Technical Memorandum. The Technical Memorandum includes documentation of the meteorological analysis, and the hydrologic and hydraulic modeling results as they relate to the estimation of hydrologic lead-times for the *watercourse*. It also includes assumptions regarding decision times and action times used in preparation of the FRP.

- Flood Response Plan Field Book. The FRP Field Book includes information relative to flood vulnerability, flood detection, information dissemination, emergency response agency actions, post-flood actions, and training exercises. The Field Book is to be used by the District and other emergency response agency personnel.



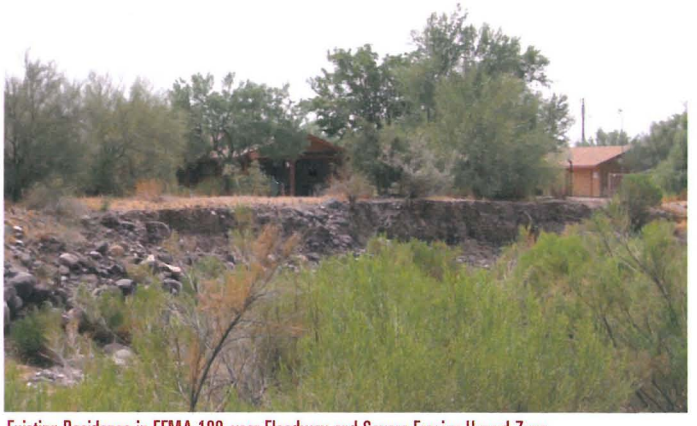
Example of Flood Response Plan Menu

★ Flood Response Plan Menu. The FRP Menu is for use by the individual residents in the Skunk Creek floodway and Severe Erosion Hazard Zone. The FRP Menu includes a list of flood detection/prediction messages that will be received by the residents via NWR or pager. These messages trigger actions required by the affected individuals. The menu also includes maps showing evacuation routes and destination sites.

C. Recommended Alternative Project Addressing Residences in High-Hazard Areas

A very important component of the implementation plan is addressing the possible public safety issues identified during the study. The most important of these is the residences that exist within the *FEMA 100-year floodway* and the Severe Erosion Hazard Zone. There are a total of 9 site-built residences and 8 mobile residences within the *FEMA 100-year floodway* of Phase 2, located on a total of 12 parcels of land. There is also 1 site-built residence and 2 mobile residences within the Severe Erosion Hazard Zone, but outside the *FEMA 100-year floodway* of Phase 2, on 3 parcels of land. In addition, the Shangri La Resort has several temporary travel trailers and mobile homes that are outside the *FEMA 100-year floodway* but within the Severe Erosion Hazard Zone. These 20 residences and the Shangri La Resort trailers are located in a very dangerous setting where lives could be lost and property severely damaged during flood events. Many residences are within *erosion* hazard areas where structures are in danger of foundations being damaged and/or washed away, and all are subject to flow depths and velocities that are capable of sweeping a person off their feet and carrying them downstream.

Research shows these residences were permitted for construction prior to the original delineation and subsequent re-delineation of the existing *FEMA 100-year floodplain* and floodway in 1987 and 1997, respectively. The owners of these parcels of land now find themselves living in what is now identified as a very dangerous location, and they will probably be unable to sell their property without disclosing that new building permits cannot be obtained. Pursuant to Flood Control District regulations, they cannot rebuild if their residence burns down, or suffers damage greater than 50% of the appraised value. One way to address the problem is to include these 16 parcels of land in a voluntary acquisition or on-site relocation program by Maricopa County. The purchased structures would be demolished and the land returned to as natural a condition as possible. This alternative to any structural project would benefit the owners and also the County by providing a high degree of public safety because residents would be removed from the high-hazard area. Consideration should be given to relocation of the existing homes to safer locations on the same parcel wherever possible. This is possible for Assessors Parcels 202-21-024B, 202-21-013M, 202-21-145, and 202-21-031Q. The owner of Assessors Parcel 202-21-024B has expressed an interest in taking that approach. None of the other three property owners have been contacted in this regard, so a acquisition option is used to define the estimated costs for those parcels. The remaining parcels are recommended for inclusion in a acquisition program because there is insufficient land in a safe area to accommodate relocation. The trailers on the 36-acre Shangri La Resort are present under a conditional floodplain use permit. It is recommended that all habitable structures on that parcel within the Severe Erosion Hazard Zone be relocated to a safer area on the parcel.



Existing Residence in FEMA 100-year Floodway and Severe Erosion Hazard Zone

Should the alternative acquisition project be approved by the Districts Board of Directors, the locations of the properties proposed for purchase are shown on Figure 64. The recommended priority for purchase/relocation of each of the 16 parcels of land is shown in Table 18. The priority is based on the relative hazards between parcels using the residence in the most hazardous situation on each parcel. The hazard assessment for ranking priorities is based on the information in columns 10 through 13. In column 10, the relative hazards associated with the three *erosion* hazard zones are accounted for by assigning a multiplier, as follows:

- "3" multiplier: assigned for residences located within the Severe Erosion Hazard Zone.
- "2" multiplier: assigned for residences located within the Lateral Migration Erosion Hazard Zone.
- "1" multiplier: assigned for residences located within the long-term *erosion* hazard zone.

The estimated percent chance within any given year associated with floodwaters entering the residence, or flowing under a mobile residence, is listed in column 11. Column 12 lists a personal hazard factor that represents a relationship between depth of flow and velocity at the residence during the 100-year flood peak. A value greater than 18 in column 12 means there is sufficient depth and velocity of flow to sweep a person (child or elderly) their feet. This is based on relationships between depth and velocity developed by the US Bureau of Reclamation (USBR, 1988) and refined by Pima County, AZ (Pima County, 1999). Column 13 lists a multiplier used to account for personal safety hazards associated with flood warning/emergency response time. The multiplier is directly related to the amount of time between: 1) the most intense precipitation occurring on the watershed, and 2) when the flow in the area of the residence reaches a hazardous level (finished floor elevation or ground elevation under mobile residences). Item 1 represents the first opportunity for the flood warning system administrator or other designated individual to "see" sufficient precipitation occurring on the watershed to warrant issuing an evacuation notice (various increasing levels of flood warning notices would probably already have been sent). The difference between items 1 and 2 is the time available to issue the evacuation notice, and for residents to receive the notice, react and leave the area. The multipliers are assigned as follows:

- "5" multiplier: time differential is 1 hour or less.
- "4" multiplier: time differential is between 1 and 3 hours.
- "3" multiplier: time differential is between 3 and 6 hours.
- "2" multiplier: time differential is between 6 and 12 hours.
- "1" multiplier: time differential is greater than 12 hours.

All the residences listed in Table 18 have flood warning response times of less than 1 hour, and in fact are less than 35 minutes. The personal safety hazard is extremely high for flood warning response times of less than 35 minutes. This is one of the prime reasons why an alternative project acquisition program is recommended for these properties.

The hazard ranking values listed in column 14 are the product of the factors in columns 10 through 13. The higher the value in column 14, the higher the relative hazard for the parcel. The acquisition/relocation priorities are assigned by sorting the parcels from highest relative hazard to lowest using column 14.

D. Recommendations for the Adobe Dam Area Drainage Master Plan

There are a number of areas of concern for Skunk Creek and Sonoran Wash identified as a part of the

July 1999 Aerial Photograph

Figure 64. Location of Parcels Recommended for Inclusion in the Acquisition Program

Table 18

Prioritization for Residence Acquisition in High-Hazard Areas

Tag ID (1)	Assessors Parcel Number (2)	Rec. Buy-Out Priority (3)	Parcel Area acres (4)	Year Built (5)	Hazard Assess. Done On (6)	In F/W (7)	In Sev EHZ (8)	In LM EHZ (9)	Erosion Hazard Multiplier[1] (10)	Approx. Chance of Flooding[2] (11)	Personal Hazard Factor[3] (12)	Response Time Factor[4] (13)	Hazard Ranking Value (10)*(11)*(12)*(13) (14)
5	211-22-002B	1	2.5	1985	House	Y	Y		3	20.0%[5]	76	5	22800.0
847	202-21-169	2	4.5	1988	House	Y	Y		3	20.0%	52	5	15600.0
62	211-50-022	3	9.6	n/a	Mobile 3	Y			1	20.0%	59	5	5900.0
579	202-21-008T	4	36.4	n/a	Mobile	N	Y		3	16.7%	22	5	5511.0
6	211-22-002J	5	3	1981	Mobile	Y	Y		3	6.3%	35	5	3281.3
104	211-50-037C	6	5.2	1980[6]	Mobile	Y		Y	2	8.3%	36	5	3000.0
84	211-50-016J	7	6.5	n/a	Mobile 1	Y			1	9.1%	54	5	2454.5
616	202-21-024B	8	4.5	1976	House	Y		Y	2	7.7%	31	5	2384.6
826	202-21-150	9	3.9	1996	Mobile	N	Y		3	7.7%	13	5	1501.5
584	202-21-013M	10	9.4	1970	House	N	Y		3	2.4%	21	5	750.0
585	202-21-013R	11	9.2	1976	House	Y		Y	2	2.9%	15	5	441.2
634	202-21-031C	12	8.7	n/a	House	Y			1	2.5%	34	5	425.0
929	211-50-016H	13	2.5	n/a	Mobile	Y	Y		3	1.4%	5	5	105.6
647	202-21-032A	14	4.7	1976	House	Y			1	1.1%	5	5	27.5
639	202-21-031Q	15	2.7	1960	House	Y	Y		3	1.0%	0	5	0.0
148	203-32-006	16	10.2	n/a	Mobile	N	Y		3	<1.0%	0	5	0.0

[1] "1" for outside Severe and Lateral Migration EHZ's, "2" for within Lateral Migration EHZ, and "3" for within Severe EHZ.

[2] Represents the percent chance of flood water entering a house, or flowing under a mobile, in any given year.

[3] Represents flow depth times velocity squared at the residence during the 100-year flood.

[4] Accounts for personal safety related to time between the most intense precipitation and the time for flood peaks to reach the residence. "1" for > than 12 hours, "2" for > 6 to 12 hours, "3" for 3 to 6 hours, "4" for 1 to 3 hours, "5" for <1 hour.

[5] 20.0% Estimates are based on a field survey of actual finished floor elevations.

[6] 1980 is the year the house was constructed. The year the mobile was set is unknown.

WCMP that warrant more detailed analysis that is beyond the scope of this study. It is recommended that these items be added to the scope of work for the upcoming Adobe Dam Area Drainage Master Plan. The areas of concern are identified below, and discussed in the following sections.

- New River Road Bridge Area.
- Skunk Creek between the WCMP north study limits and the Tonto National Forest Boundary.
- CAP Canal and I-17 Flow Breakout.
- Watershed Issues.

1. New River Road Bridge Area.

A unique problem was identified while conducting the Phase 2 hydraulic, sediment transport, and *scour* analyses on Skunk Creek in the vicinity of the New River Road Bridge. This bridge, which is located in the middle of the New River Road Reach, at the upstream end of the Phase 2 study area is a 367-foot, 5-span, continuous concrete slab, built in 1995. The bridge was built on an extreme skew to the Skunk Creek *channel* (60 degrees) in an area where the 100-year floodplain is shallow and very wide (approximately 1700 feet). Presumably to reduce cost, yet provide sufficient conveyance area to pass the 100-year discharge under the bridge, the Skunk Creek *channel* was abruptly widened from approximately 30 feet to 180 feet in the immediate vicinity of the bridge, with no transition back to the natural *channel* geometry downstream. This dramatically reduced the sediment transport capacity of the *channel* at this location, especially for the more frequent

West Side of New River Road Bridge

storm events, and has resulted in significant sediment deposition at the bridge since its construction. The deposition is so significant that the entire area excavated in-fills with sediment to the level of the original overbank, reducing the conveyance area to the point where the bridge effectively acts like a dam under high flow rates, forcing more flow out of the *channel* than would occur naturally. Constant maintenance to remove the deposited sediment is and will continue to be required to minimize the aggravated flooding problems at the site. The two photographs of New River Road Bridge illustrate this problem. The photograph labeled "New River Road Bridge" was taken during maintenance operations in July 2001 to remove sediment deposition that has occurred in the right-of-way since construction of the bridge. The second photograph labeled "West Side of New River Road Bridge" depicts how low the bridge is in relation to the downstream *channel* area. This downstream constriction creates a backwater condition that limits the hydraulic capacity of the bridge and contributes to the sediment deposition problem.

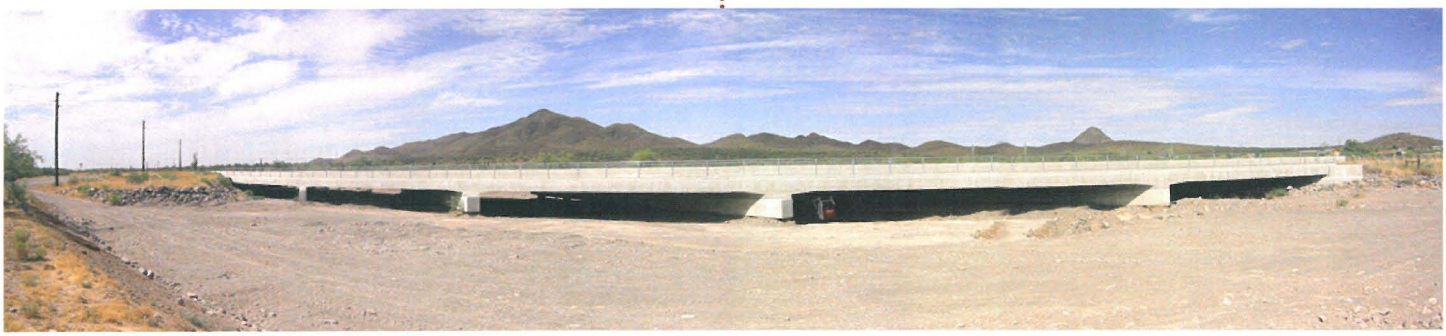
A cursory investigation into potential solutions to this problem was conducted during the WCMP. Among them is the construction of levees to contain the 100-year discharge and force it through the bridge, along with various combinations of *channel* improvements at and downstream of the bridge. Because of natural outcrops of caliche and bedrock downstream of the bridge, acting as grade control, it was concluded that the *channel* would continue to aggrade at the bridge site during frequent storm events even with the levees. The possibility of removing the natural grade control and increasing the *channel* slope to increase sediment transport capacity through and downstream of the bridge site was also briefly investigated. However, it was concluded that approximately 2000 feet of expensive "hard" excavation would be required to achieve this.

Further investigation to identify a possible solution to this problem is beyond the scope of the WCMP. However, because of the complexity of the problem, the poorly defined *hydraulics* at the site, and the potential cost of not taking action (flood damage and maintenance), it is highly recommended that an independent study be undertaken to identify feasible solutions and develop a recommended solution for implementation. A possible side benefit of a solution may be a reduction in the *erosion* hazard area in the vicinity of the bridge, especially in the west overbank area. An in-depth study to identify possible solutions to the problem should include the following tasks:

- ★ Prepare new topographic mapping of the area at a scale of 1 inch=100 feet, a contour interval of 1 foot, and a DTM grid spacing of 25 feet. Include ortho-rectified color aerial photographs of the study area.

- ★ Develop and evaluate a minimum of three alternative solutions to the problem, including removal and replacement of the bridge, and defining a method to prevent the breakout of flow over the east and west banks upstream of the New River Road Bridge. (see Section 6B)

- ★ Conduct a detailed two-dimensional flow hydraulic analysis on the New River Road Reach over the full range of discharges (Q_2, Q_{10}, Q_{25} and Q_{100}) for existing conditions, pre-bridge conditions, and for each alternative solution considered.



New River Road Bridge at Skunk Creek

- ★ Investigate the need for mapping a 100-year floodway for the breakout flow over the west bank upstream of the New River Road Bridge. Include definition of a floodway for the Skunk Creek tributary from sub-basin S-7 that combines with the breakout flow.

New River Road Break-Out Area

- ★ Prepare a personal safety hazard assessment for the existing residences in the flow breakout area, if any are identified, similar to that done for the residences in the floodway as a part of the WCMP. Consider recommendation for an alternative project acquisition program.

- ★ Conduct a detailed sediment transport analysis of the New River Road Reach over the full range of discharges for existing conditions, pre-bridge conditions, and for each alternative solution considered.

- ★ Conduct an equilibrium slope and armoring analysis over the full range of discharges for existing conditions, pre-bridge conditions, and for each alternative solution considered.

- ★ Conduct a subsurface investigation to identify the location of bedrock, caliche and other potential geologic control features through the *reach*.

- ★ Perform sediment gradation testing of surface and subsurface sediments every 500 feet through the *reach*.

- ★ Evaluate the impact of each alternative on local *scour* at the bridge and the capacity of the bridge foundations over the full range of discharges considered.

- ★ Evaluate the impact of each alternative on the limits of the *erosion* hazard zones, as identified and established by this master plan study.

- ★ Provide sufficient plan drawings and conceptual details to describe the alternatives being evaluated.

- ★ Provide a final summary report with cost estimates for the alternatives and recommend an alternative for further development and implementation.

2. Skunk Creek between the WCMP north study limits and the Tonto National Forest Boundary.

The WCMP study limits end at a point 2,200 feet upstream of the New River Road Bridge over Skunk Creek. The WCMP study was not extended north to the Tonto National Forest boundary because detailed topographic mapping is not available for the entire area of that *reach* of Skunk Creek. During the course of the WCMP study, it was noted that there is a high potential for existing residences to be located within a future 100-year floodway of Skunk Creek and its tributaries upstream of the WCMP study area. The upstream *reach* is also subject to *erosion* hazards similar to the lower reaches. It is recommended that the WCMP be extended north to the Tonto National Forest boundary for the purpose of defining *erosion* hazard areas verifying the presence of existing residences in high-hazard locations, and supplying information to those residents. This work could be done under the Adobe Dam Area Drainage Master Plan. The recommended work tasks to be performed, at a minimum, include:

- ★ Topographic Mapping. Prepare new topographic mapping as required to supplement the existing

mapping available from the District. Mapping and surveying are to be according to the District's latest guidelines and have a minimum contour interval of 2-feet.

- Existing Condition Floodplain Delineation. Delineate the existing condition 100-year flood plain and floodway for Skunk Creek between the north WCMP study limits and the Tonto National Forest boundary. Coordinate the new floodplain and floodway limits with the results of the Topographic Mapping and Floodplain Delineation Study for Tributaries to Skunk Creek.

- Finished Floor Elevations. Survey the finished floor and adjacent ground elevations of all existing residences within the 100-year floodplain.

- Erosion Hazard Zones. Delineate the severe and lateral migration erosion hazard zone for the study area using methodology similar to that used for the WCMP.

- Hazard Assessment. Prepare a hazard assessment rating for each residence located within the 100-year floodway and the Severe Erosion Hazard Zone using methodology similar to that used for the WCMP.

- Low-Impact Structural Management Plan. Define a *non-encroachment area* based on the Lateral Migration Erosion Hazard Zone, in conformance with the approach used for the WCMP.

- Public Involvement. Conduct a public notification and input process regarding the results of the floodplain/floodway delineation, the *erosion* hazard zones and the Low-Impact Structural Management Plan. Conduct individual meetings with property owners of residences in high-hazard areas for the purpose of informing them of the hazards.

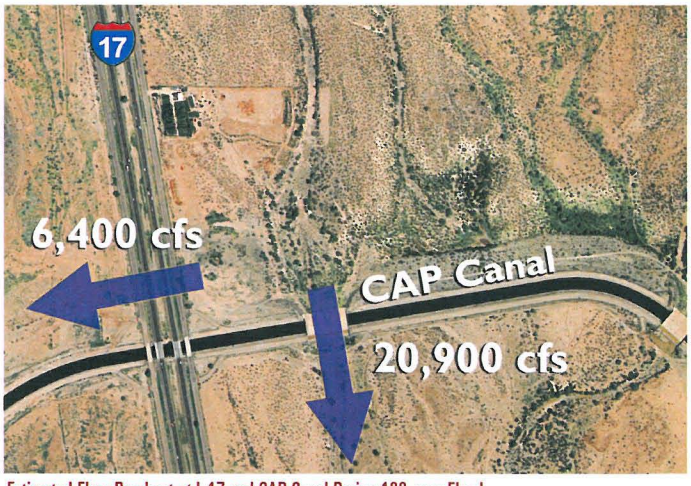
- Implementation. Define an implementation strategy for regulating the Low-Impact Structural Management Plan non-encroachment area that is compatible with the WCMP implementation plan.

3. CAP Canal and I-17 Flow Breakout.

An important public safety hazard was identified where Skunk Creek and Sonoran Wash cross the CAP Canal at the south study limit of the WCMP adjacent to I-17. That hazard is described in section 5B of this report. To summarize the problem, a significant amount of stormwater is expected to overtop the CAP Canal and I-17 during events greater than the 26-year flood. The average flow depth over I-17 during a 100-year flood, for example, is estimated to be 2.5 feet. The possible consequences of the breakouts in this area include:

- Flooding of new developments west of I-17 previously thought to be safe from Skunk Creek.

- Isolation of areas flooded by Skunk Creek in the New River area from vehicular emergency response units that must access the area using I-17.



Estimated Flow Breakout at I-17 and CAP Canal During 100-year Flood

- Possible flooding of new developments east of Skunk Creek and south of the CAP Canal.

- Damage to, and failure of, the CAP Canal embankments.

It is recommended that this problem area be studied in more detail, that the areas of possible flood inundation west of I-17 be mapped, that alternative methods of solving the breakout problem be defined and analyzed, and that a solution be recommended. The following is the recommended scope of work for key tasks associated with the proposed project:

- Data Collection. Collect and review pertinent data from the District and other outside sources. Data to be collected shall include previous flood hazard reports and *hydrology* for the study area; existing topographic mapping; historical flooding information; as-built plans for existing structures; FEMA Flood Hazard Boundary Maps and any Letters of Map Amendment and/or Revisions, and other pertinent information.

- Topographic Mapping. Prepare new topographic mapping as required to supplement the existing mapping available from the District. Mapping and surveying are to be according to the District's latest guidelines.

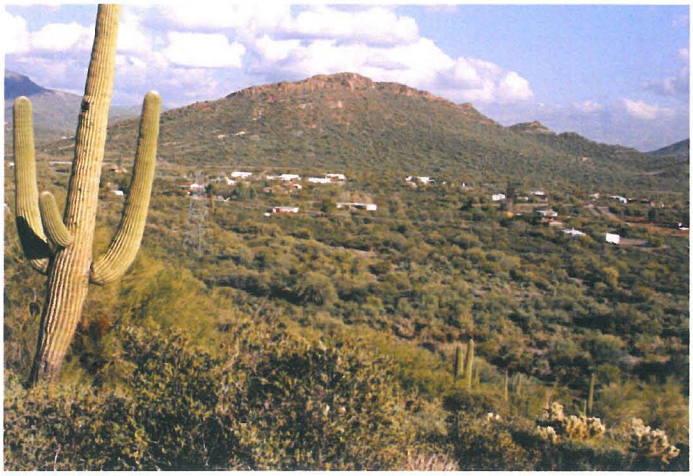
- Existing Condition Modeling. Delineate the 100-year floodplain west of I-17 resulting from the Skunk Creek breakout using two-dimensional hydraulic modeling methods and interface the results with the two-dimensional model prepared as a part of the WCMP in Attachment 7.

- Prepare, analyze and evaluate alternative solutions to include:

  1. Widen the CAP Overchutes. Widen the CAP overchutes in the model so that all of the flow during a 100-year flood is forced down Skunk Creek and establish how wide they need to be.

  2. Extend the existing Levee System. Extend the levee system in the model along the banks of Skunk Creek to keep all of the 100-year, 24-hour peak discharge within the limits of the existing and proposed levee system. Establish the extent and size of these additional levees.

- Predevelopment Condition Model. Investigate historical data and establish a predevelopment condition model to show the conditions of Skunk Creek prior to development within the study area, including construction of the CAP Canal.



Skunk Creek Watershed

4. Watershed Management.

The ADMP should address the following watershed management issues:

- Identify the watercourses to be preserved. Define watercourses where channelization or *floodplain encroachment* may be necessary, and verify that resulting travel times through the watershed still match existing natural conditions as closely as possible.

- Refine existing watershed management guide lines so that sediment loads in the natural *watercourse* system do not increase or decrease significantly as a result of development or other human disturbances. Where significant changes may result, identify appropriate mitigation measures for implementation by developers to maintain long-term *watercourse* stability.

- Refine existing management methods to maintain peak discharges for the 2-, 10- and 100-year storms at or below the future watershed condition levels estimated in the WCMP.

- ★ Refine methods to maintain the release of future condition runoff volumes to the watercourses from the 2-, 10- and 100-year storms as close as possible to the WCMP estimated existing watershed condition runoff volumes. Coordinate this with the previous item. This approach is necessary to help meet the goal of minimizing changes to *sediment yield*, and to support natural riparian vegetation along the watercourses.

- ★ Strongly support implementation of the North Black Canyon Corridor Plan and the MAG 1995 General Land Use Plan for the watershed.

5. Establishment of a Monitoring and Maintenance Program.

At the present time the WCMP remains only a plan. There is no way to predict when or if any of the structural elements discussed in this report may be implemented. Until there are changes to the natural *watercourse*, the District may choose to adopt none or selected elements of the of the recommended monitoring and maintenance plan presented in Section 8 herein. After, or if, a management plan for the study watercourses is adopted by the Flood Control District Board of Directors, a monitoring and maintenance plan specific to the adopted management plan is recommended. Such a plan, built around the guidelines set forth in Section 8, could be implemented over a five to 10-year period as development progresses in the study area, and District budget allows. Finally, it is recommended that, new information and discoveries that become available during the monitoring period be used to update the monitoring and maintenance plan as appropriate.

Skunk Creek

10 Glossary

100-year Storm. A storm with a 100-year recurrence interval. The 100-year storm for the study area results from 5.0-inches of precipitation within a 24-hour period. The 2-year and 10-year storms result from a 24-hour precipitation of 2.3-inches and 3.4-inches, respectively.

Acre-feet. An acre-foot of sediment is an acre of land covered by sediment 1 foot deep.

Aggradation. Aggradation is the progressive raising, over time, of a channel bed in a reach due to sedimentation.

Anastomosing. A stream pattern characterized by a net-like or interwoven channel pattern, with individual flow paths better defined or permanent than braided channel flow paths.

Avulsion. An avulsion occurs when the main channel relocates to another part of the floodplain during a flood. This movement may occur suddenly as a result of a single large storm, although a series of floods over a long period of time may also contribute to the avulsive process.

Bed-form Scour. The bed-form scour component accounts for the dynamic changes that occur in the shape of a moveable channel bed during passage of a flood. The bed of a sand and gravel channel actually forms wave-like anti-dunes with accompanying troughs, which migrate during a flood event. The trough depth must be included in the estimate of total scour depth.

Braided Watercourse. A braided watercourse is one which contains multiple channels that interconnect with each other. The floodplain of a braided watercourse is typically broader than other types of watercourses.

Channel. For the purpose of this study, a channel is defined as the portion of a cross section of a watercourse that carries stormwater. A channel is characterized by its bed and banks. The channel bed is made up of sand, gravel and/or cobbles. The channel banks may be heavily vegetated or have exposed soils. A watercourse cross section can have multiple channels. These channels may vary in elevation in relation to each other.

Computer Models. Computer models are used in this study to simulate natural functions for existing watershed and watercourse conditions, and to predict future watershed and watercourse conditions. The following computer models are used in this study:

Hydrology: US Army Corps of Engineers HEC-1 program.
Hydraulics: US Army Corps of Engineers HEC-2 and HEC-RAS programs.
Sediment Transport: US Army Corps of Engineers HEC-6 program.

Cumulative Impacts. For the purpose of this study, cumulative impacts are a decrease in public safety, or an increase in cost to the public, within, upstream or downstream of the WCMP study area, resulting from implementation of a proposed management alternative. The key indicator for determining the existence of cumulative impacts is an increase in peak discharge resulting from floodplain encroachment. A change in peak discharge, increasing in the downstream direction as a result of floodplain encroachment, typically results in increases in flow depth and velocity, and adversely affects the sedimentation and erosion characteristics of the watercourse. These effects can jeopardize existing structural flood control improvements or result in increased damage to property. Cumulative impacts have the effect of increasing the cost of floodplain management to the public.

Degradation. Degradation is the progressive lowering, over time, of the channel bed in a reach due to erosion.

Ephemeral Watercourse. An ephemeral watercourse is one in which runoff occurs only in direct response to precipitation. An ephemeral watercourse does not have water flowing in it year round.

Erosion. For the purpose of this study, erosion is defined as the natural process of flowing water removing soil, sand, gravel, or cobbles within a watercourse. Erosion has the effect of changing the watercourse geometry and increasing conveyance capacity. Erosion occurs naturally along all watercourses, but can be accelerated by human activities such as removal of bank vegetation, sand and gravel mining, or urbanization.

Erosion Control Zone. A land area adjoining a body of water or adjacent to or located partially or wholly within a delineated floodplain which due to the soil instability, is likely to suffer flood-related erosion damage. The Severe and Lateral Migration Erosion Hazard Zones comprise the Erosion Hazard Zone for the WCMP.

Existing Watershed Conditions. For the purpose of this study, existing watershed conditions are defined as the watershed conditions at the beginning of the WCMP project in April 1998.

FEMA Base Flood Elevation. The FEMA Base Flood Elevation (BFE) is the elevation of the 100-year water surface elevation at the location in question.

FEMA 100-year Floodplain. The FEMA 100-year floodplain is defined by FEMA as an area that is flooded by a 100-year recurrence interval storm. The area so defined is based on existing watershed and watercourse conditions at the time of the study. It does not include the effects, over time, of erosion and sedimentation in the watercourse.

Floodplain Encroachment. Floodplain encroachment, as defined by FEMA, means that development, including residential or commercial improvements, could be constructed within the FEMA 100-year floodway fringe. This could be accomplished using fill to raise building floor elevations above the FEMA 100-year floodplain elevation, or constructing levees to isolate the FEMA 100-year floodway fringe from the FEMA 100-year floodway.

FEMA 100-year Floodway. The FEMA 100-year floodway is defined by FEMA as an area that is reserved for conveyance of floodwaters, in which buildings or other obstructions are not allowed. The FEMA 100-year floodway limits are established by determining the amount of fill that can be placed in the 100-year floodplain without increasing the 100-year depth of flow by more than 1-foot.

FEMA 100-year Floodway Fringe. The FEMA 100-year floodway fringe is defined by FEMA as the area inside the FEMA 100-year floodplain and outside the FEMA 100-year floodway. According to FEMA regulations, buildings or other obstructions to flow can be constructed in the FEMA 100-year floodway fringe provided the structures used for human habitation are raised above the BFE.

Future Watershed Conditions. For the purpose of this study, future watershed conditions are defined as the watershed conditions resulting from future build-out development of the watershed in accordance with the 1995 MAG General Land Use Plan.

Gabion Mattress. A gabion mattress is a wire basket filled with rock that is used as a structural measure for erosion protection.

Geomorphology. Geomorphology is the study of earth landforms and the processes that shape and change them.

Habitat Value. Habitat value refers to the suitability of the landscape for wildlife. Relative habitat values were determined for the study area and were assigned as high, medium, and low.

Hydraulics. For the purposes of this project, hydraulics is defined as the study of the ability of the watercourse to carry storm water. The hydraulic models are used to estimate the depth, width, velocity,

energy, and travel time of flow through the study area.

Hydrology. For the purposes of this project, hydrology is defined as the study of surface water runoff from the contributing watersheds. The hydrology models are used to estimate watershed runoff volumes and peak flow rates in relation to time during storm events, for both existing and future conditions.

Lateral Channel Migration. For the purpose of this study, lateral channel migration is defined as the movement of a channel within its floodplain through the processes of bank erosion or channel avulsions. Bank erosion is a natural process whereby soil material is removed from the channel banks during floods.

Main Channel. The main channel is defined as a channel that is continuous throughout the watercourse and carries the most flow.

Maximum Depth Bank Protection. Maximum depth bank protection is used where a watercourse management alternative allows development within the FEMA 100-year floodway fringe and the main channel is either at that location or can potentially migrate horizontally to that location. Maximum depth bank protection is located according to the requirements of the watercourse management alternatives. For example, the Full Structural Alternative presented in section VII specifies that maximum depth bank protection be constructed along the FEMA 100-year floodway limits.

Minimum Depth Bank Protection. Minimum depth bank protection is used where a watercourse management alternative allows development within the FEMA 100-year floodway fringe, but the main channel is not expected to migrate horizontally to that location. The minimum depth bank protection required must be constructed to the same height as the maximum depth bank protection, but the below-ground depth requirement is much less. The below-ground depth requirement for minimum depth bank protection is 3 feet.

Natural Angle of Repose. The maximum angle of slope that can be maintained by the soil material in a channel bank.

Non-Encroachment Area. For the purpose of this study, a non-encroachment area is the area within a watercourse management alternative where floodplain encroachment is not allowed. The uses permitted within the non-encroachment area are:

- ★ Drainage and stormwater conveyance, in an undisturbed desert state.
- ★ Open-space, unimproved (undisturbed desert with native landscape enhancements/ restoration permitted).
- ★ Open-space, improved (limited to passive and active recreational activities including hiking/ riding trails and similar activities within a desert landscape).
- ★ Homes or other structures may be constructed within this area, outside the FEMA 100-year floodway, provided the structure and its foundation is designed to withstand the forces which may be imposed upon it by floodwaters, erosion, sedimentation and channel migration, to the satisfaction of the District. It must also be proven that the structure or structures will not result in cumulative impacts, or negatively impact adjacent properties. The design must be prepared and sealed by a professional civil or structural engineer licensed to practice within the State of Arizona.

Reach. For the purpose of this study, a reach is defined as a portion of a watercourse in which watercourse characteristics are similar throughout the reach. Reaches can be defined based on hydrologic, hydraulic or geomorphologic similarities, or on similarities in biologic, visual, or landscape characteristics.

Recurrence Interval. A recurrence interval storm or flood is defined as a storm or flood that has a specific probability of occurring within any given

year. For example, the 100-year recurrence interval storm or flood has a 1 % probability of being equaled or exceeded in any given year. The other two recurrence interval storms or floods considered in this study are the 2-year (50 % probability) and 10-year (10 % probability).

Regulatory Line. For the purpose of this study, the Regulatory Line is the Lateral Migration Erosion Hazard Zone limits or the FEMA 100-year floodplain, whichever is furthest from the main channel.

Riprap. A bank protection measure composed of fractured rock of differing sizes.

Scour. For the purpose of this study, scour is defined as a lowering of the channel bed by erosion. Scour occurs at natural or man-made obstructions to flow, or at channel banks. Examples of natural obstructions are trees in the channel, or constrictions in the channel. Man-made obstructions include bridge piers and grade-control structures.

Sediment Yield. Sediment yield is the amount of soil (mainly silt, sand and some gravel) that erodes from the watershed and enters the watercourse system.

Sedimentation. For the purpose of this study, sedimentation is defined as the natural process of flowing water depositing soil, sand, gravel and cobbles in the watercourse or on the floodplain. Deposition in the main channel has the effect of changing the shape and dimensions of the channel and decreasing its conveyance capacity.

Soil Cement. Soil cement is a structural erosion protection method that consists of mixing cement with native soils and water, and compacting it in place, and in layers to form a material that is resistant to erosion.

Watercourse. For the purpose of this study, a watercourse is defined as the entire length of a wash to be studied, including the width necessary for the watercourse to function naturally. This includes the watercourse channels, over-bank floodplains, and the area the watercourse has occupied in recent geologic time (<10,000 years).

Watercourse Conditions. The watercourse conditions used in hydraulic modeling are the main channel geometry (i.e., depth, width and slope) and its floodplain (areas outside the main channel that carry water), and roughness (resistance to flow). The main channel and floodplain makeup the watercourse cross section.

Watershed Conditions. A watershed is the land contributing area that collects rainfall and directs it to a watercourse. The primary watershed conditions used in hydrologic modeling are the percentage of contributing area that is impervious to rainfall, the vegetative cover, soil characteristics relating to the ability to absorb and store.

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