CHANGES IN CHANNEL MORPHOLOGY ALONG LOWER CIENEGA CREEK, CIENEGA CREEK NATURAL PRESERVE, 1980 - 1998

April 2002

Prepared by
Pima Association of Governments
for
Pima County Flood Control District

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INTRODUCTION

Background

Cienega Creek is an important water, recreation, and wildlife resource located southeast of Tucson, Arizona (Figure 1). The creek begins at an elevation of approximately 5700 feet in the Canelo Hills, south of the community of Sonoita, Arizona, and continues roughly 40 to 45 miles to an elevation of about 3200 feet at Pantano Wash, near the community of Vail, Arizona. The stream has several distinct, physically separated perennial reaches along its total length. Cienega Creek is one of the few low-elevation streams in Pima County that exhibit perennial flow.

Streamflow is diverted at the Pantano Dam, located at the downstream end of the creek, in Section 14 of Township 16 South, Range 16 East, roughly 1.5 miles upstream from Colossal Cave Road (Figure 1). Perennial streamflow in the creek ends at, or just downstream from, the dam. At the dam, the Cienega Creek watershed covers 457 square miles (USGS, 2000). Pantano Wash begins at the confluence of Cienega Creek and Agua Verde Creek, located less than one-mile upstream of the dam. However, for simplicity, this report will refer to the portion of Pantano Wash between the confluence and the dam as part of Cienega Creek.

The Cienega Creek Natural Preserve, established in 1986, occupies 3979 acres of land with Cienega Creek being the central feature. The property is owned by Pima County Flood Control District and jointly managed by the Flood Control District and Pima County Parks and Recreation Department. The Preserve extends from the former headquarters of the Empirita Ranch south of Interstate 10, to Colossal Cave Road. Portions of Davidson Canyon and Agua Verde Creek, two major tributaries to Cienega Creek, are also included within the Preserve (McGann and Assoc., 1994).

The presence of surface water combined with riparian vegetation creates an important habitat within the Preserve for large and diverse populations of mammals, birds, fish, reptiles, and amphibians. These conditions create an area with high values for wildlife habitat, recreation, and scenic quality. The natural condition of the Preserve is believed to facilitate natural groundwater recharge and reduce the intensity of flood flows from the Cienega Creek Basin (McGann and Assoc., 1994).

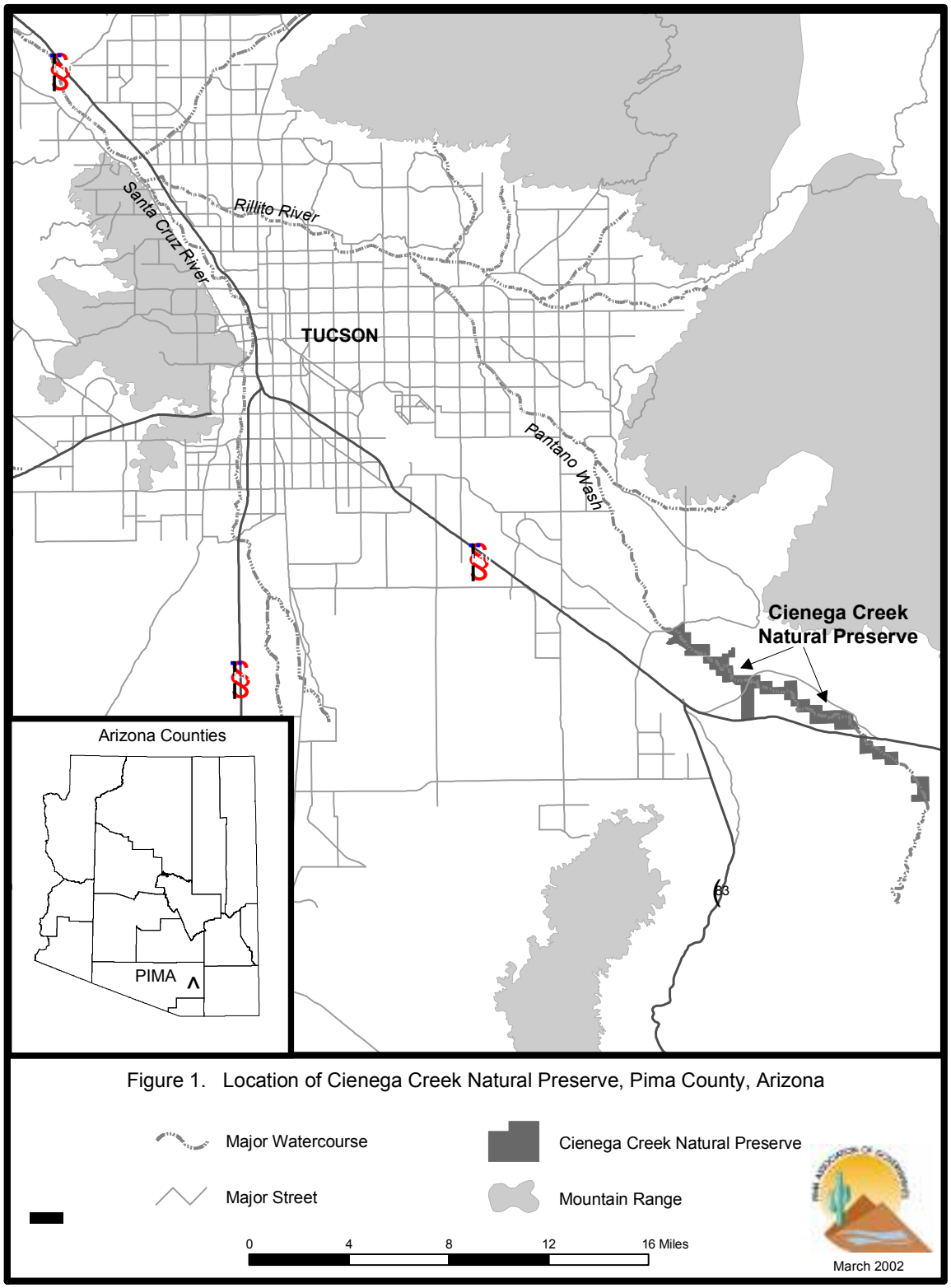

Figure 1. Location of Cienega Creek Natural Preserve, Pima County, Arizona

The Flood Control District recognizes that the resources of the Preserve are dynamic, and that changes have occurred, and will continue to occur, in response to the implementation of the Cienega Creek Natural Preserve Management Plan. The District also recognizes that land uses on lands surrounding the Preserve have changed in recent years and that changes will continue to occur (McGann and Assoc., 1994).

The climate of the Cienega Creek watershed is often dominated by winter precipitation (rain and snow) and summer monsoons. The summer monsoons produce infrequent, short-duration, high discharge stream flows that can be highly erosive. These storms often occur on a localized scale. Winter precipitation events are often longer-duration and more regional in scale than the summer monsoons. These climate systems are quite variable in time, place, and size and thus create a variable flow regime in Cienega Creek.

Purpose and Scope

The purpose of this study was to identify long-term changes in channel morphology along Cienega Creek within the Cienega Creek Natural Preserve. The study area included Cienega Creek, from the "Pantano Jungle" area to the Pantano Dam, a distance of over eight miles. This portion of the creek was referred to as lower Cienega Creek for this study.

Pima Association of Governments (PAG) conducted this study as part of the Fiscal Year 2000-2001 Work Program with Pima County Flood Control District.

This study focused on the thalweg and active channel of lower Cienega Creek. These channel features were delineated using available aerial photography (1980, 1990, 1998) and measured using Geographic Information System (GIS) tools. Survey equipment and techniques were not utilized for this study.

Cienega Creek Baseflow and Groundwater Levels

As part of an on-going element of its work program for Pima County, PAG has monitored the surface water and groundwater conditions of lower Cienega Creek since the early 1990's. On a monthly basis, PAG measured depth to water in three monitoring wells in the study area and measured stream discharge at two sites in the study area. PAG also monitored length of stream flow along two reaches of the study area on a quarterly basis. The results are summarized below through 1998, to coincide with the latest aerial photograph date.

The length of surface flow downstream from "Pantano Jungle", located in the Pantano Reach of this study, decreased substantially between 1994 and 1998. This decrease in flow extent coincided with a drop in groundwater levels in the Jungle area and a decrease in stream discharge immediately downstream of the area during the same time period.

The groundwater level in a well located adjacent to the Section 34 reach of this study remained stable from 1994 to 1998. Surface flow in this reach was not monitored.

Stream discharge near the Marsh Station Road crossing, also called the Three Bridges area, remained fairly stable from 1994 to 1998. Surface flow length in Davidson Canyon near the

confluence with Cienega Creek increased in this time period. No groundwater measurements were taken near this area, which is included in the Davidson Canyon reach of this study.

In monitoring sites at the downstream end of the Preserve, in the Agua Verde reach of this study, the length of surface flow and groundwater levels have remained fairly stable from year to year between 1994 and 1998

Definitions

The terms used to describe fluvial processes can vary widely, mainly because the high variability between fluvial systems often makes assigning specific terms difficult and inappropriate (Parker, 1995). Figure 3 shows a typical cross-section of Cienega Creek. Definitions of terms used in this report are as follows:

CHANNEL – the part of a watercourse that carries flow. A *low-flow channel* is formed by base flows or by receding flood flow, and may occur as a distinct, incised feature or may be distinguishable only by subtle changes in composition of channel material or occurrence of vegetation. A *high-flow channel* is formed by flood flow. Immediately following a flood, a high-flow channel generally is a distinct feature delineated by vegetation boundaries and well-defined channel banks, but degradation of the banks and revegetation can rapidly obscure boundaries of the high-flow channel (Parker, 1995). A *bankfull channel*, also referred to as active channel, is defined by the bankfull stage, which is the elevation at which flow begins to overtop its natural channel (NDWP, 2002). The absence of vegetation can be a secondary indicator of the bankfull channel. Bankfull stage in lower Cienega Creek is typically defined by floods having recurrence intervals of 1.5 years (Moody and Odem, 1999).

ACTIVE CHANNEL - For this study, the definition of active channel is based on channel features visible on aerial photographs of the Preserve, and incorporates characteristics of both the high-flow channel and the bankfull channel. Since bankfull stage is extremely difficult to identify in aerial photographs, the active channel could not be defined as being the bankfull channel. The active channel is essentially the width of the stream channel that conveys flows greater than baseflow, but not exceeding the flood of July 29, 1988 (7420 cfs), which created an obvious eroded surface bare of vegetation, as seen in the 1990 aerial photographs. The July 1988 flood had a recurrence interval greater than five years, but less than ten years (Pope et al., 1998). Since the recurrence interval for bankfull discharge in lower Cienega Creek is 1.5 years, it was likely that the 1988 flood overtopped the bankfull channel in certain reaches along the creek. In aerial photographs of most reaches, the active channel was distinguishable by visible changes in sediment slope and composition, and the absence of vegetation. Vegetation islands are relatively stable vegetated bars and can exist within the banks of the active channel. A conceptual illustration of the active channel is provided in Figure 2.

CHANNEL CHANGE - generally means a change in channel geometry or bed elevation; a change in its position, course, or pattern; and change in bed material, bank material, or vegetation density (Parker, 1995). Changes in bed elevation were not included in this study.

SINUOSITY - a measure of the amount of meander of a stream reach. It is the ratio of the thalweg length to the valley, or reach, length (Meador et al., 1993; Ritter et al., 1995). The thalweg is

almost always longer than the reach length, which is the straight-line distance measured along the axis of the reach. A straight, non-meandering stream system would have a sinuosity value of 1.0, while a meandering stream would have a sinuosity value greater than 1.0, depending on the degree of meander. Sinuosity can also be used as a measure for habitat along a stream (Meador et al., 1993). A sinuous, or meandering, stream often hosts more diverse riffle and pool habitat than a straight, non-meandering stream.

THALWEG - the line connecting the deepest points of the active channel and migrates back and forth across the channel bottom (Ritter et al., 1995; Meador et al., 1993). If the deepest parts of Cienega Creek were not obvious on the aerial photographs, because the channel was dry or obstructed by overhanging vegetation, then the thalweg was defined as the line connecting the mid-point between the banks of the active channel. The thalweg length is directly related to sinuosity.

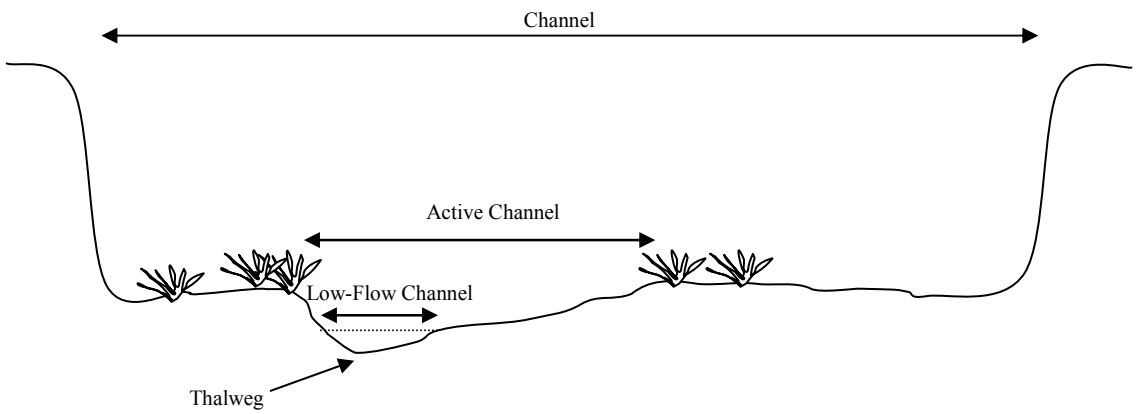

Figure 2. Conceptual Cross-Section of Cienega Creek (not to scale)

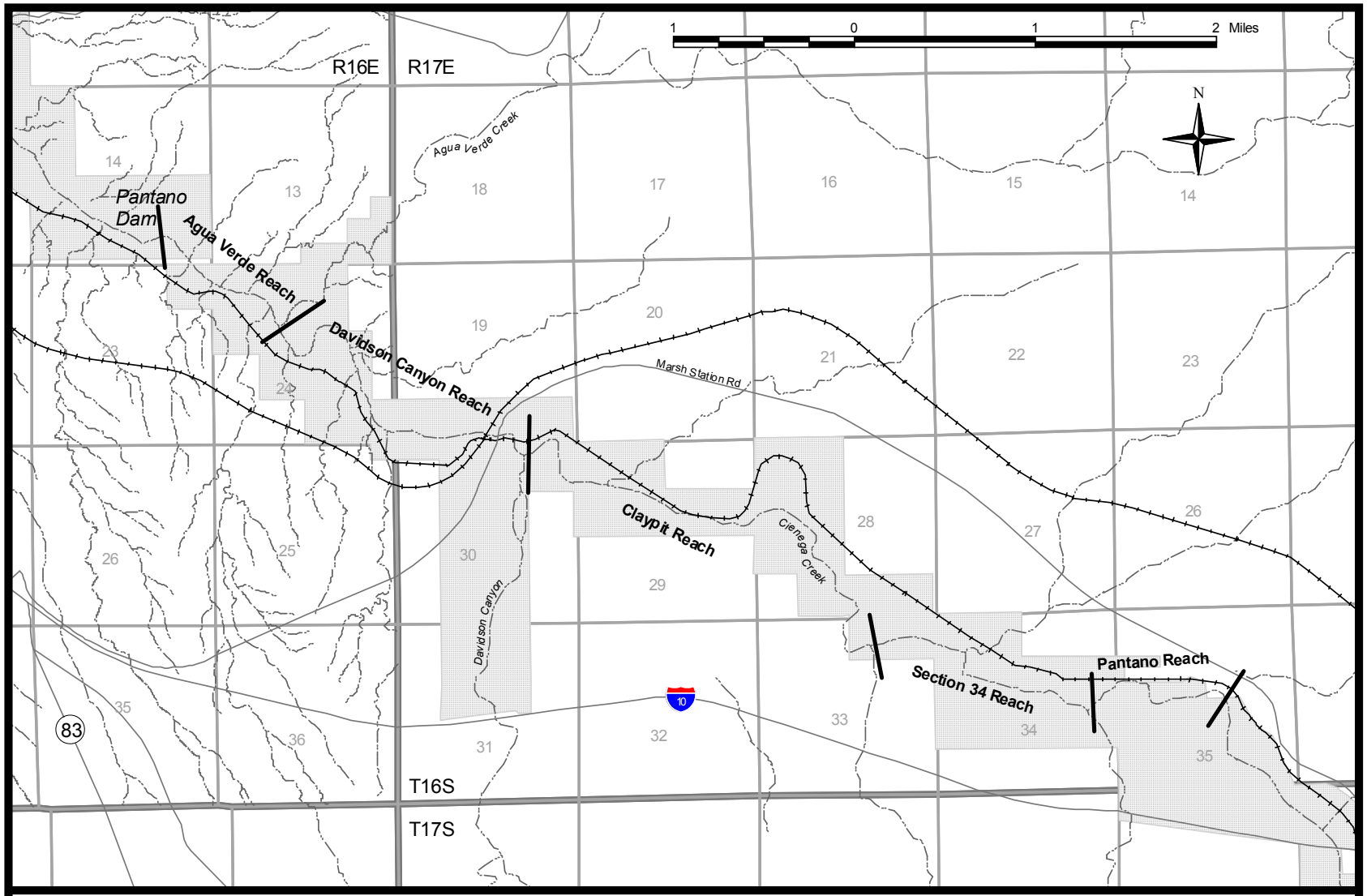

Figure 3. Study Reaches for Channel Change Assessment along Cienega Creek, 1980 - 1998.

Major Street
Railroad Tracks
Wash
Cienega Creek Natural Preserve
Study Reach End/Begin Location
Township/Range Line
Section Line

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METHODOLOGY

Study Reach Designation

The length of lower Cienega Creek was divided into the following five study reaches, going downstream from the Jungle: Pantano, Section 34, Claypit, Davidson Canyon, and Agua Verde. The Pantano Dam was the downstream extent of the study area. The portions of the creek and Preserve upstream of the Jungle area, including the parcels south of I-10, were not included in this study. These study reaches were delineated and named in collaboration with staff at Arizona Department of Environmental Quality (ADEQ), who were conducting research along Cienega Creek at the time of this study. The study reaches for this project match the study reaches for the ADEQ project. Each reach was delineated to begin and end at the confluence with a major tributary, as shown in Figure 3, except for the Agua Verde reach. The Agua Verde reach ended at the Pantano Dam, which acts as a grade control. The beginning of each reach was located roughly in the center of the channel on the upstream side of the confluence.

Aerial Imagery

Two types of aerial imagery were used for this study (Table 1). Unrectified blue-line aerial photographs were used to identify and delineate the channel features of interest, and digital ortho-rectified quarter quadrangles (DOQQs) were used as a base map for the digitizing process. A quarter quadrangle is one-quarter of a 7.5-minute topographic quadrangle.

Table 1. Aerial Images Used to Assess Channel Changes along Lower Cienega Creek.

Name/Location	**Year**	**Scale/Resolution**	**Type**
T16S R16E Sects. 13,14,23,24	1980, 1990, 1998	1 inch = 400 feet	Blue-line aerial photograph
T16S R17E Sects. 25,26,35,36	1980, 1990, 1998	1 inch = 400 feet	Blue-line aerial photograph
T16S R17E Sects. 27,28,33.34	1980, 1990, 1998	1 inch = 400 feet	Blue-line aerial photograph
T16S R17E Sects. 29,30,31,32	1980, 1990, 1998	1 inch = 400 feet	Blue-line aerial photograph
Rincon Peak SW	1992	1 meter resolution	USGS DOQQ
The Narrows NW	1996	1 meter resolution	USGS DOQQ
Vail SE	1992	1 meter resolution	USGS DOQQ

Although blue-line aerial photographs are useful to identify features and structures in a given area, they often contain some degree of distortion because they do not maintain a constant scale across the image. This can occur from factors such as the tilt of the camera or plane.

Orthophotographs, including DOQQs, are digital aerial photographs that have been processed to maintain a constant scale across the image, and, therefore, are more readily useable for spatial analysis and measurements. Unlike blue-line photographs, DOQQs have accurate location information associated with them.

The blue-line aerial photographs for the years 1980, 1990, and 1998 were obtained for this project from Pima County Mapping and Records. These years were chosen for this study because they were the only years available from the County. All the photographs were scaled at one inch equals 400 feet (1" = 400'). Each photograph frame covered an area of four full sections, or four square miles.

These sets of photographs were useful because they were taken at the same scale and they covered a time period of almost 20 years. The photographs taken in 1980 were used to represent the time period prior to the acquisition of the Preserve property. The 1990 photographs show channel features a few years after the Preserve was established in 1986, while the 1998 photographs show channel conditions more than ten years after the establishment of the Preserve. Sets of photographs taken at the same scale were desired because it was believed that similar sized features were visible in each set.

United States Geological Survey (USGS) DOQQs were used for the digitizing element of this project. The images were provided to PAG by staff at the University of Arizona's Arizona Regional Image Archive (ARIA). As shown on Table 1, three DOQQs were used: The Narrows NW, Rincon Peak SW, and Vail SE.

Delineation

This study focused on two channel features of lower Cienega Creek: the thalweg and the active channel.

THALWEG – The thalweg was delineated based on features visible on the aerial images. Surface flow was visible as dark streaks on the blue-line aerial photographs. The thalweg was drawn down the center of the visible path of surface flow. In reaches that had braided flow, the thalweg was drawn to follow the braid that seemed to be the primary flow path. If no primary flow path was obvious, then one braid was arbitrarily picked as the thalweg. In dry reaches, the thalweg was drawn down the centerline of the delineated active channel.

In some reaches, particularly in the 1998 photos, the tree canopy blocked the channel bottom from view. In these reaches, the thalweg was arbitrarily drawn in the center of the delineated active channel, and was drawn to be fairly straight between two identifiable points due to the lack of information on the meander. This occurred in less than 5% of the study area in the 1998 photographs. Table 2 summarizes the difficulty level of delineating the thalweg in each reach.

ACTIVE CHANNEL – The channel edges were primarily delineated by obvious changes in vegetation type and density, and, to a lesser extent, changes in soil coloration, as seen on the aerial imagery. For the most part, the active channel was taken to be the width of the unvegetated channel. The active channel edges were traced directly onto each blue-line aerial photograph and, as closely as possible, followed the tops of the channel banks. If the channel

banks were not identifiable in the photograph, then vegetation was used to delineate the active channel. A vegetation island was delineated if the active channel existed on both sides of a stable bar.

In some reaches, particularly in the 1998 photos, the active channel could not be seen through the dense, overhanging tree canopy. In these cases, a visible break in the tree line was used as an indicator of the location of the active channel. If no break in the tree line was found, the active channel was mapped as a generally straight reach between identifiable points, due to the lack of information on the meander. A brief visual overview of the aerial photos showed that this was necessary in less than 10% of the study area in the 1998 photographs. In these densely vegetated reaches, flood flows were assumed to flow in the baseflow channel and between the individual trees along the channel banks, therefore no vegetation islands were delineated.

Image Registration and Digitizing

After the channel features were delineated on the blue-line aerial photographs, they were digitized into ArcView GIS layers, using a CalComp digitizing board (4'x 6') and ArcView GIS tools. In order to make the resulting GIS layers more useful for possible future analyses, the blue-line aerial photographs were registered to the DOQQs. By doing this, the layers would assume the location information that was embedded in the DOQQs (NAD83 / UTM Zone 12). This would allow the layers from this project to be overlayed onto GIS files from previous or future projects.

The blue-line aerials were, in essence, "rubber-sheeted" to the DOQQs using identifiable objects, such as street intersections, bridges, and vegetation that were visible in both images. For example, a street intersection visible in the blue-line photos would be registered to the same street intersection visible in the DOQQ. At least four objects, preferably located at the corners of an area of interest, were needed in each blue-line aerial photograph for it to be registered to the DOQQ. Due to the lack of streets and other infrastructure in and near the Preserve, vegetation was often the most convenient object used to register the blue-lines photos. In order to complete the registration process, the ArcView GIS software required the blue-line photographs to register to the DOQQs within an acceptable error limit, which could be defined by the user. PAG defined the error limit to be approximately 2 feet (Root Mean Square map error). In some areas, due to factors described in the Sources of Error section of this report, the aerial photograph was not able to register to the DOQQ within the acceptable limit. When this occurred, PAG repeated the process using different registration points to get the lowest amount of error possible. The registration errors ranged from 0.5 feet to 7 feet, with most areas registering within the 2-foot limit.

Most of the study reaches spanned across multiple blue-line aerial photographs. However, the edges of adjacent blue-line photos did not accurately align with each other. PAG also found that, although they were ortho-rectified, the edges of adjacent DOQQs did not accurately align to each other either. Therefore, a single blue line photo had to be registered to a single DOQQ. If the blue-line photo spanned multiple DOQQs, then it was registered separately to each DOQQ.

Registration of an entire blue-line photograph to a DOQQ was not possible without creating an unacceptable error. Therefore, PAG divided the creek into many small segments to obtain a registration within the allowable error limit.

Once a small area was registered, ArcView GIS tools were used to digitize the active channel edges and the thalweg within that specified area. This process was repeated for each small segment for each blue-line photo year (1980, 1990, and 1998). In all, approximately 13 small segments were digitized for each photo year, roughly 35 segments in total. The same segments were not used in each photo year because in many cases it was necessary to use different registration points in different years. For example, vegetation growth sometimes made it impossible to identify the same individual plant or tree in a later year, or dirt road intersections became more faint or changed geometry.

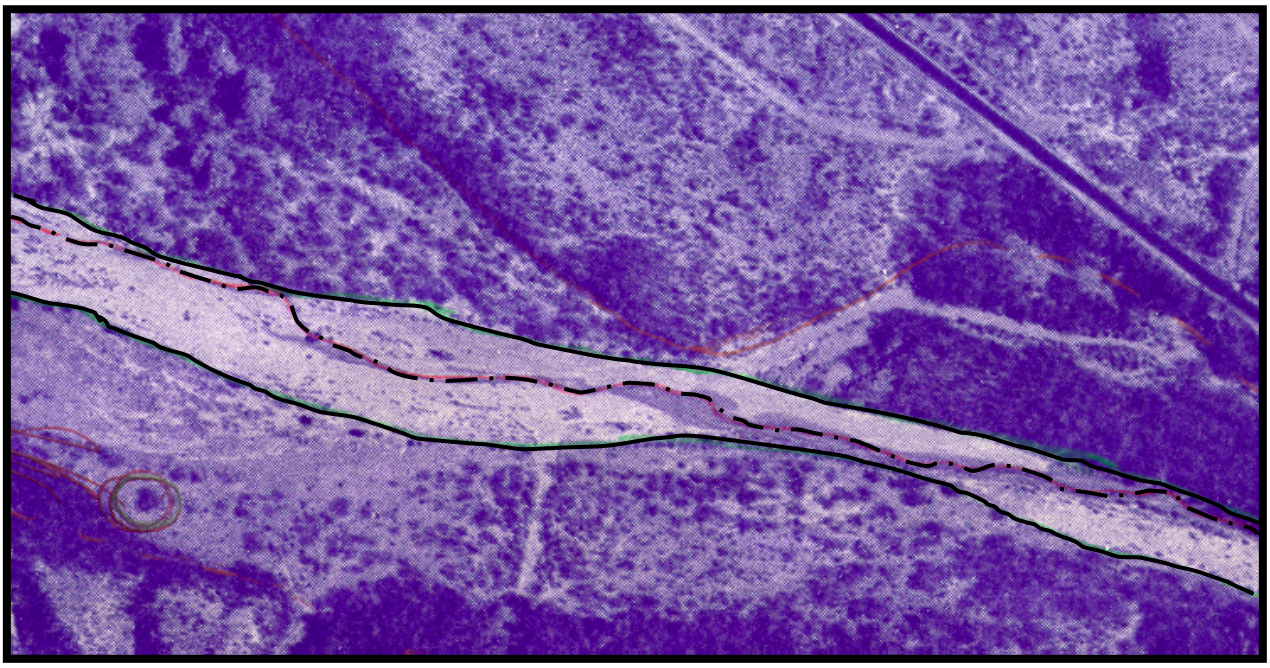
All the segments for each year were then cleaned and joined to form one continuous GIS layer for the active channel and one for the thalweg. The continuous GIS layer was then divided into the five specified study reaches for analysis.

ArcView GIS tools were used to measure the area of the active channel and length of the thalweg in each of the five study reaches for each photo year.

Table 2. Clarity of Thalweg in Aerial Photographs

	1980	1990	1998
Pantano Reach	Flow visible in downstream half of reach; dry channel in upstream half	Same as 1980, but shorter dry segment	View obstructed by tree canopy for much of reach; flow visible where no canopy obstruction
Section 34 Reach	Flow visible in some segments, but mostly blurred by poor photo quality	Flow visible through most of reach; tree canopy obstructed view in a few segments	View obstructed by tree canopy for much of reach; flow visible where no canopy obstruction
Claypit Reach	Flow visible through almost entire reach; a few segments blurred by poor photo quality	Flow visible through almost entire reach; few dry segments; minor view obstruction by tree canopy	View obstructed by tree canopy in certain segments; flow visible where no canopy obstruction; dry channel on upstream and downstream ends of reach
Davidson Canyon Reach	Flow visible through entire reach	Flow visible in upstream and downstream portions of reach; dry channel for middle portion of reach	Flow visible in upstream portions of reach; view of some segments obstructed by tree canopy; dry channel through most of reach
Agua Verde Reach	Flow visible through almost entire reach; a few segments blurred by poor photo quality	Flow visible through entire reach	View obstructed by tree canopy for much of reach; flow visible where no tree obstruction; dry channel in upstream portions of reach

Figure 4. Sample Delineations of Active Channel and Thalweg.



Active Channel (solid lines); Thalweg (dashed line)
Image scanned from blue-line aerial photograph (1990), 1”=400’

RESULTS

Thalweg Length and Sinuosity

The thalweg length of each reach did not vary appreciably during the study period, as shown on Table 3 and in Figure 5. All reaches, however, experienced a reduction in thalweg length from 1980 to 1998. The change in length ranged from a <1% reduction in the Section 34 and Agua Verde reaches to an almost 3% reduction in the Claypit reach. In total, the creek's thalweg decreased in length by a little less than 2% during the study period.

During the 1980's, there was a very slight increase in thalweg length in every study reach, except the Claypit reach. However, the lengths decreased by <1% to 6% from 1990 to 1998.

The thalweg shifted back and forth across the channel system during the study period. There was no obvious pattern in the shift or reduction in length from year to year.

Table 3. Lower Cienega Creek Thalweg Length and Sinuosity

Reach Name	**Thalweg Length (feet)**			**Reach Length* (feet)**	**Sinuosity****		
	1980	**1990**	**1998**		**1980**	**1990**	**1998**
Pantano Reach	4974	4987	4859	3947	1.26	1.26	1.23
Section 34 Reach	7477	7825	7421	6437	1.16	1.22	1.15
Claypit Reach	16,132	16,047	15,712	11,555	1.40	1.39	1.36
Davidson Canyon Reach	11,037	11,591	10,866	8192	1.35	1.41	1.33
Agua Verde Reach	4813	4820	4800	4265	1.13	1.13	1.13
TOTAL	**44433**	**45270**	**43658**	**34396**	**1.29**	**1.32**	**1.27**

* Reach Length is straight-line aerial distance from center of channel at beginning of reach to center of channel at end of reach. Can also be called valley length.

** Sinuosity = (Thalweg Length / Reach Length)

Since sinuosity is directly related to the thalweg length, the changes in the creek's sinuosity during the study period followed the same patterns as the changes in thalweg length, as shown on Figure 6. The sinuosity of each reach and the creek as a whole is presented on Table 3.

Like the thalweg lengths, sinuosity did not change appreciably during the study period. Among the study reaches, the sinuosity ranged from 1.13 in the Agua Verde reach to 1.41 in the Davidson Canyon reach. The largest fluctuations were seen in the Section 34 and Davidson Canyon reaches, while the smallest fluctuation was seen in the Agua Verde reach. The sinuosity of the creek as a whole ranged from 1.27 in 1998 to 1.32 in 1990.

The Claypit and Davidson Canyon reaches had the most meander throughout the study period, with average sinuosity values of 1.38 and 1.36, respectively. A stream with a sinuosity value of greater than 1.5 would be considered a highly meandering stream (Rosgen and Silvey, 1998). Lower Cienega Creek was a moderately meandering stream system during the study period.

Figure 8 shows a segment of the Pantano study reach that represents the degree of change in active channel area and thalweg path along lower Cienega Creek.

Active Channel Area

The active channel in each of the five study reaches along lower Cienega Creek decreased in area during the study period, as shown on Table 4 and in Figure 7. The decrease ranged from 31% in the Section 34 reach to 54% in the Davidson Canyon reach, with an average decrease in area of 45%. The active channel of the entire lower Cienega Creek decreased in area by 44%. The vast majority of the reduction in channel area occurred between 1990 and 1998.

Table 4. Lower Cienega Creek Active Channel Area

Reach Name	**Active Channel Area (acres)**			**Change in Area, 1980 – 1998***
	1980	**1990**	**1998**	
Pantano Reach	11.5	12.4	5.5	-52%
Section 34 Reach	15.7	14.8	10.9	-31%
Claypit Reach	43.4	42.0	26.8	-38%
Davidson Canyon Reach	13.0	8.7	6.0	-54%
Agua Verde Reach	27.8	31.1	13.7	-51%
TOTAL	**111.4**	**109.0**	**62.9**	**-44%**

The area of the Pantano reach active channel was reduced by 52% during the study period. The channel area expanded by 8% between 1980 and 1990, from 11.5 acres to 12.4 acres. This might have been due to scouring and deposition processes from a greater than 5-yr flood event that occurred in Cienega Creek in July 1988. However, between 1990 and 1998, this reach experienced a 56% decrease in active channel area, from 12.4 acres to 5.5 acres. As seen in Figure 2, this was the shortest reach in the study.

The Section 34 reach showed the least change of all the study reaches, with a 31% decrease in active channel area, from 15.7 acres to 10.9 acres, during the study period. The area of this reach changed from 15.7 acres to 14.8 acres (6% decrease) between 1980 and 1990, and then from 14.8 acres to 10.9 acres (26% decrease) between 1990 and 1998. The relative lack of change might be due to the fact that vegetation existed along the banks and within the active channel of this reach throughout the study period, unlike the other reaches, which were almost completely bare of vegetation in 1980.

The Claypit reach experienced an overall 38% decrease in active channel area, from 43.4 acres to 26.8 acres, during the study period. The area of this reach decreased by 3%, from 43.4 acres to 42.0 acres, between 1980 and 1990, and then decreased by 36%, from 42.0 acres to 26.8 acres, between 1990 and 1998. A portion of this reach was bounded by bedrock and therefore did not experience any appreciable change in active channel area during the study period.

The active channel in the Davidson Canyon reach experienced the largest amount of change during the study period, relative to the other study reaches, with a 54% decrease in area from 13.0 acres to 6.0 acres. There was a 33% decrease in area, from 13.0 acres to 8.7 acres, between 1980 and 1990, and a 31% decrease, from 8.7 acres to 6.0 acres, between 1990 and 1998. This reach had the smallest active channel area of all reaches throughout the study period, except for the Pantano reach in 1998.

The active channel in the Agua Verde reach experienced an overall 51% decrease in area during the study period. It expanded by 12%, from 27.8 acres to 31.1 acres, between 1980 and 1990, but then shrunk by 56%, from 31.1 acres to 13.7 acres, between 1990 and 1998.

Possible Sources of Error

The quality and the scale of the blue-line aerial photographs used for this study probably introduced error into the results. The banks of the active channel were especially difficult to delineate with great accuracy. Although the channel features were visible and fairly distinct in the 1990 and 1998 photos, they were slightly blurred in the 1980 photographs. The difference in photo quality between these years was mainly due to the difference in the materials used for the photograph negatives, according to Pima County Mapping and Records staff. Besides making the delineation process more difficult, the blurred quality of the 1980 photographs also made it more problematic to identify landscape features that could be used to register the photographs to the DOQQs.

The scale of the photographs (1”=400’) was also a possible contributor of error. At this scale, the width of a pencil mark could have introduced an error of several feet. The scale also made identifying the active channel boundaries more difficult. The banks were more easily identifiable using stereopair photographs and negatives available at Mapping and Records, but these types of photographs were not available for all the years of interest, and the scale still did not allow for easy and accurate delineation.

Overhanging tree cover could have also been an appreciable source of error. In several areas of the creek, particularly the Section 34 and Agua Verde reaches, the tree cover obscured the view of the channel. In these areas, it is possible that the active channel was delineated to be wider than reality and/or not accurately located. This was especially problematic in the 1998 aerial photographs. As stated in the Delineation section of this report, the active channel and thalweg were delineated as accurately as possible using breaks in the tree line or other indicators. However, in a few areas, the active channel and thalweg had to be arbitrarily delineated due to the complete lack of indication of the location of the channel.

The inherent minor distortions of the blue-line aerial photographs, as explained in the Aerial Imagery Section of this report, probably introduced error. However, this error was probably minor compared to other possible sources of error, especially the overhanging tree canopy.

Figure 5. Changes in Thalweg Length in Lower Cienega Creek, 1980 - 1998

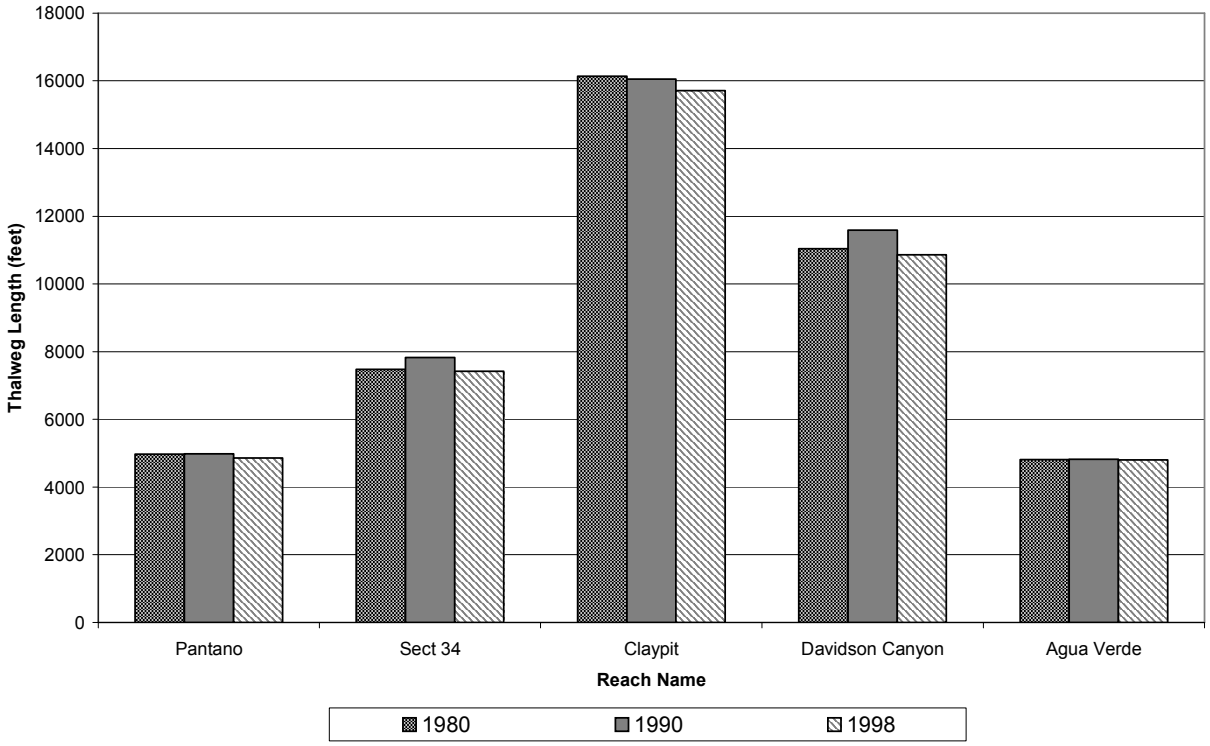


Figure 6. Changes in Sinuosity of Lower Cienega Creek, 1980 - 1998

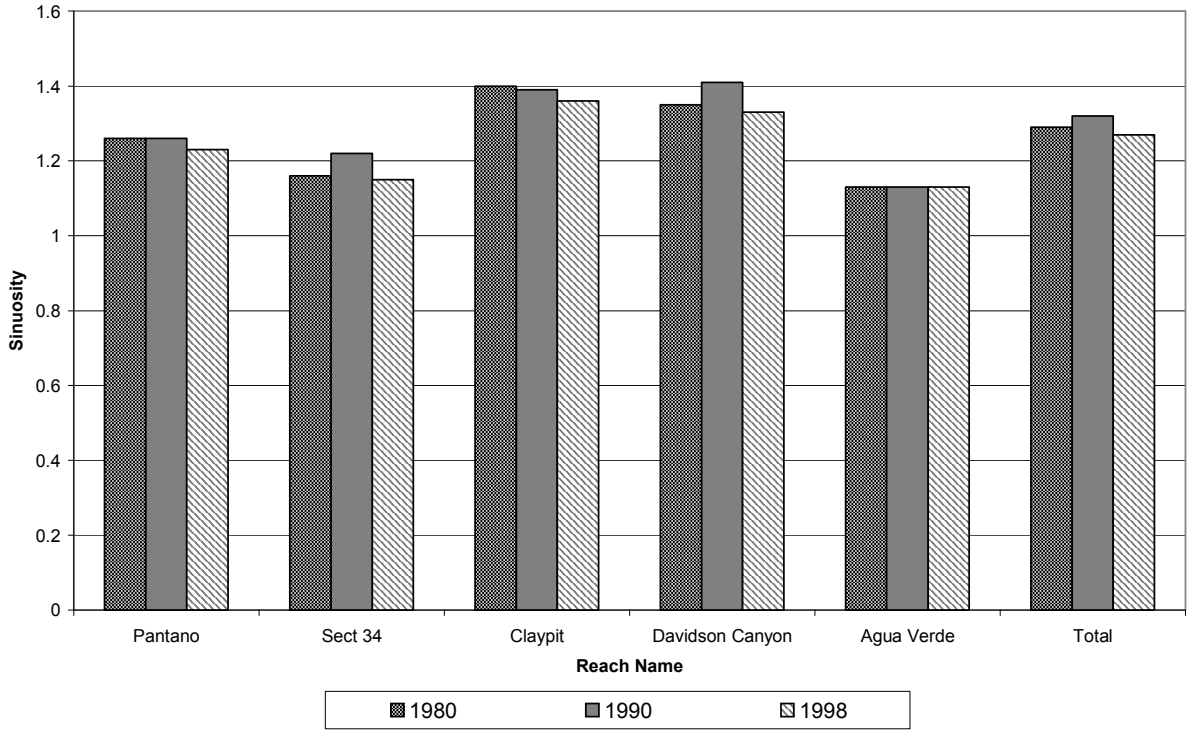


Figure 7. Changes in Active Channel Area of Lower Cienega Creek, 1980 - 1998

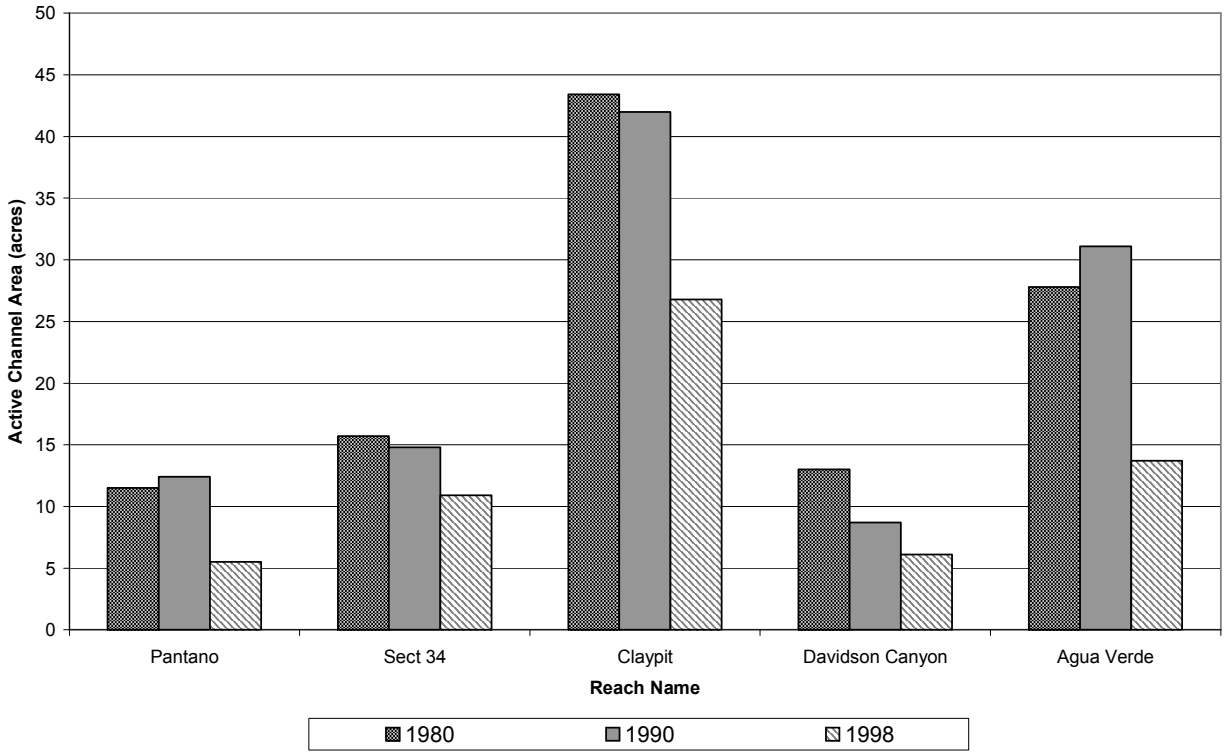
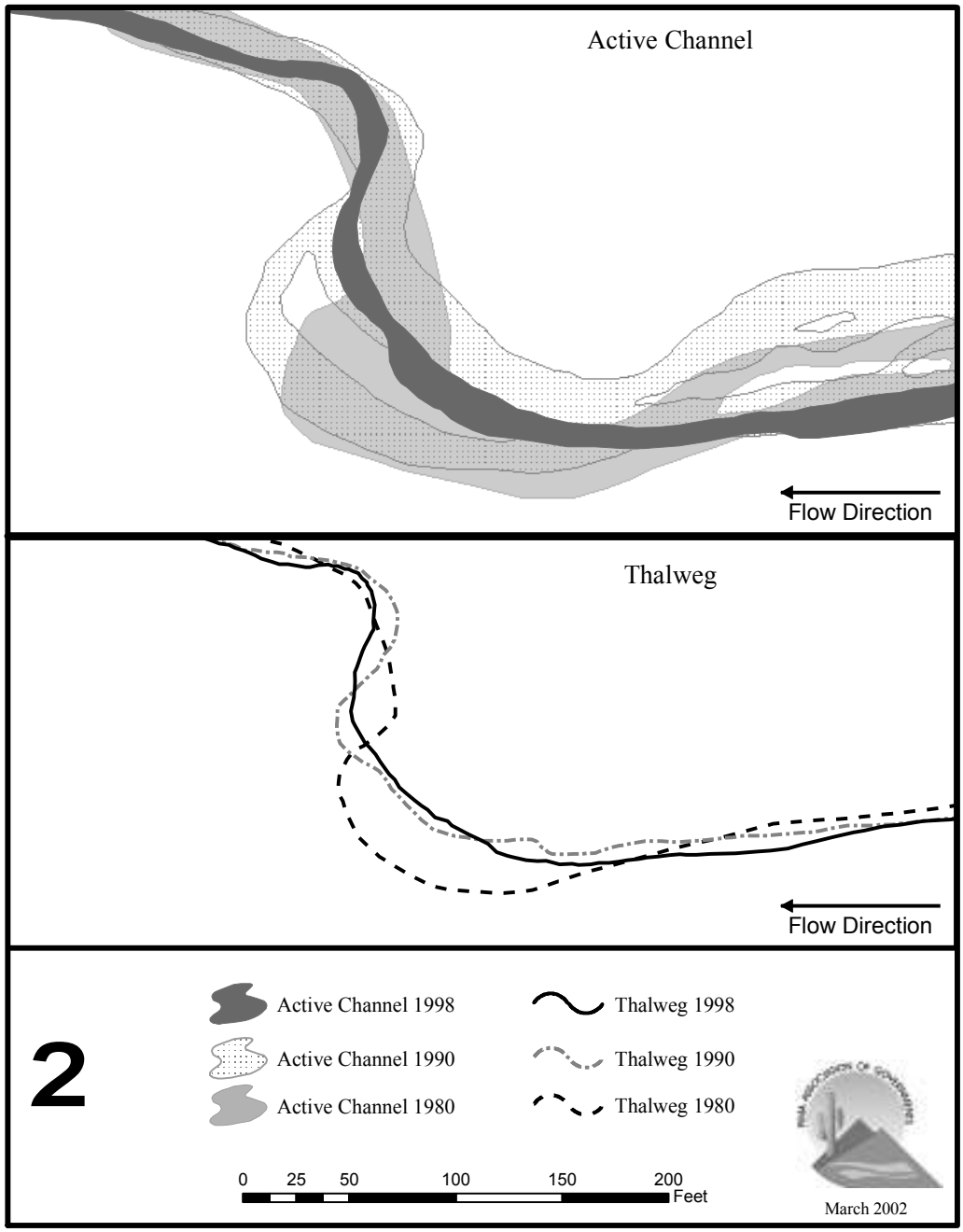


Figure 8. Sample of Change in Location of Active Channel and Thalweg, 1980 - 1998
Segment of the Pantano Reach, Lower Cienega Creek



DISCUSSION OF POSSIBLE INFLUENCES ON CHANNEL CHANGE

This study clearly showed that the area of lower Cienega Creek's active channel had appreciably decreased from 1980 to 1998, while sinuosity remained fairly constant. A variety of factors, such as flood events, changes in vegetation cover, channel incision, and land use changes, could have caused this.

Flood Events

Changes in flood frequency and intensity in recent decades might, in part, explain the observed changes in channel morphology in lower Cienega Creek between 1980 and 1998. Figure 9 shows annual peak flows between water years 1959 and 1998. Overall, the size of annual peak flows has decreased since the early 1980's. Annual peak flows greater than a 5-year flood event occurred in eight years from 1959 to 1972. Since 1972, there have been three years with annual peak flows greater than the 5-year flood recurrence interval: 1981, 1984, and 1988. A flow of 6450 cfs is considered a five-year flood event, while a ten-year flood would have a discharge of 10,400 cubic feet per second (cfs) (Pope et al., 1998). Figure 10 shows that the frequency of large flood events (>2000cfs) has decreased since the early 1970's. Smaller flood flows (<2000 cfs) that are sustained over a long period of time can also have influence on channel morphology. However, an analysis of these flows was not in the scope of this project.

On July 29, 1988, a flood flow with a discharge of 7420 cfs was recorded by a USGS stream gage station at the Pantano Dam (USGS, 2000). Aerial photographs (1"=100') taken in the summer of 1988 show the southeastern portions of the Preserve prior to the flood and the northwestern portions of the Preserve after the flood. In photos taken after the flood, the active channel was clearly defined by the absence of vegetation. The widening of certain study reaches between 1980 and 1990 might be explained by the scouring and deposition processes of this isolated flood event.

An assessment of weather cycles and how they might relate to the conditions of the watershed was outside of the scope for this project, as was an investigation on flows sustained over long periods of time. These factors might help explain some of the channel changes observed during this study. An investigation of changes in bankfull discharge and recurrence intervals was also outside the scope of the project.

Vegetation Changes

The aerial photographs showed an appreciable increase in vegetation density along lower Cienega Creek between 1980 and 1998. This might, in part, explain the decrease in active channel area during the same time period. Despite poor photo quality, the blue-line aerial photographs taken in 1980 showed a wide active channel that, for the most part, lacked overhanging tree cover and channel bank vegetation. There were relatively few vegetation islands within the active channel at that time. By 1990, a noticeable encroachment on the creek by the riparian tree and understory plant communities had occurred. The tree canopy began to obscure the view of the channel and larger channel islands were delineated in aerial photographs taken in that year. The aerial photographs taken in 1998 showed a noticeable amount of vegetation growth along lower Cienega Creek since 1990, as shown on Figure 9. There were

many reaches that were completely covered by the tree canopy, making it impossible to see the creek channel. The size and number of vegetation islands also increased between 1990 and 1998.

An increase in vegetation density within the active channel and along the channel banks could cause a reduction in flood flow intensity and scouring potential by dispersing the energy associated with the flow. The slowing and dispersal of flood flows by vegetation also allows additional time for this water to infiltrate and recharge groundwater aquifers.

To better understand the relationship between vegetation growth and changes in channel morphology, a more detailed study would be necessary. Vegetation growth was not measured in this study.

A brief visual assessment of the aerial photographs showed that reaches along the creek that exhibited streamflow throughout the study period were more likely to have dense vegetation encroachment during the study period than dry reaches. However, considerable vegetation growth occurred along a dry reach of the Pantano Reach, presumably aided by shallow water levels in the underlying aquifer.

Changes in Land Use

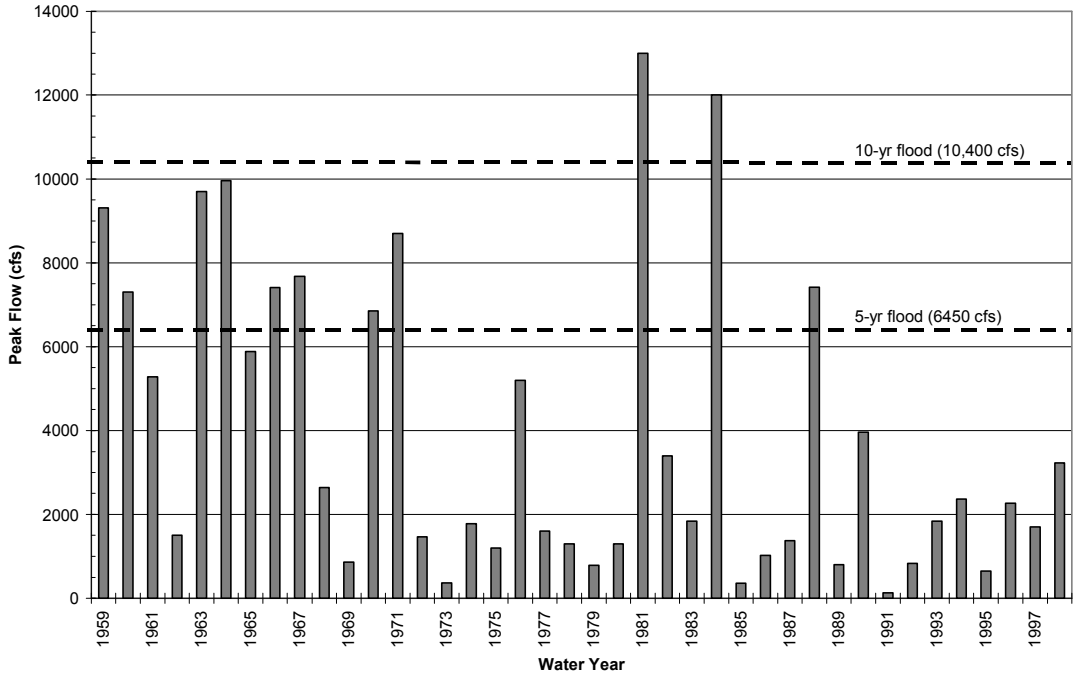
Prior to the establishment of the Cienega Creek Natural Preserve in 1986, certain activities with the potential to increase streambank erosion and vegetation removal, such as cattle grazing and off-road vehicle travel, occurred in the channel of lower Cienega Creek and along its banks. In order to protect the resources of the area, the County prohibited these activities when the Preserve was established. These restrictions were implemented in order to provide public access without damaging the natural and scenic resources of the site (McGann and Assoc., 1994).

Intense use of a stream channel by activities such as cattle grazing and vehicle travel can potentially damage the vegetation and soil structure of the channel and floodplain and, thus, increase the scouring potential of flood flows, and reduce vegetation growth and recruitment.

A more detailed study would be needed to better understand the relationship between changes in land use and changes in channel morphology. Current and historic aerial photographs might be useful tools in such a study.

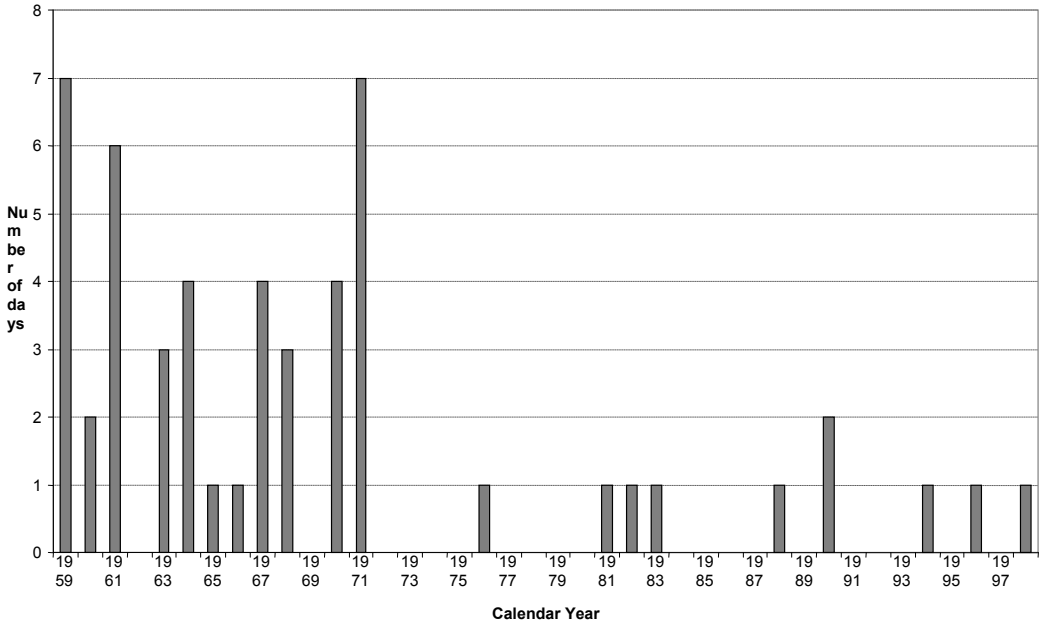
Figure 9. Cienega Creek Annual Peak Flow, 1959 - 1998

USGS Stream Gaging Station, Pantano Wash near Vail (Pantano Dam)



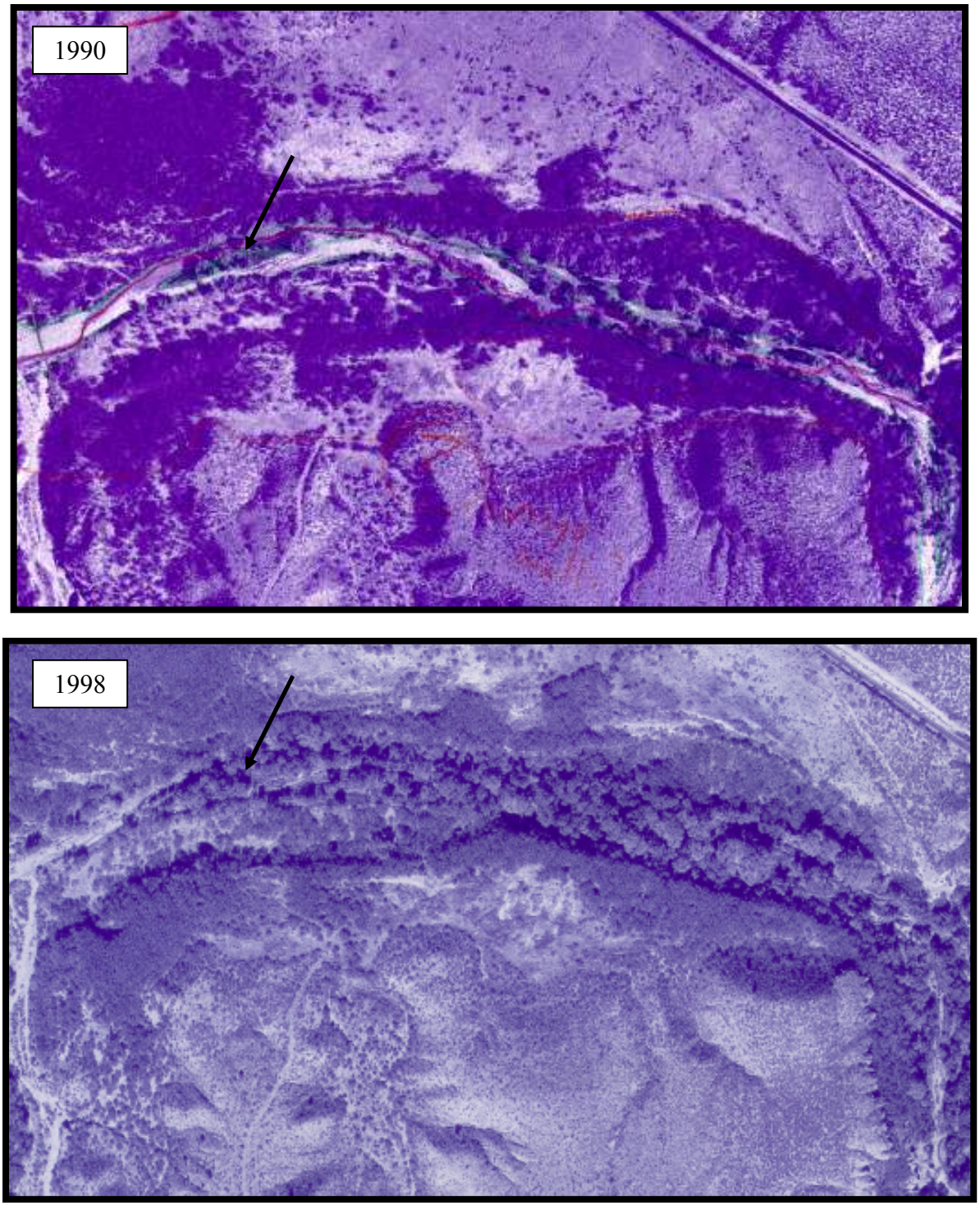
Data source: USGS stream gage data, summarized in PAG 2000.

Figure 10. Number of flows over 2000 cfs per calendar year.



Data source: USGS stream gage data, summarized in PAG 2000.

Figure 11. Example of Vegetation Growth Along Lower Cienega Creek, 1990-1998
Portion of Section 34 Study Reach



Images scanned from blue-line aerial photographs, 1”=400’.
Arrow points to same vegetation island in respective photographs.

SUMMARY AND CONCLUSIONS

- Between 1980 and 1998, a noticeable decrease in active channel area occurred along Cienega Creek within the Cienega Creek Natural Preserve.
- The length of the thalweg (and sinuosity) of lower Cienega Creek did not change much between 1980 and 1998. The sinuosity values for the study reaches would classify lower Cienega Creek as a moderately meandering stream system.
- Blue-line aerial photographs were useful to identify channel features along lower Cienega Creek, but the scale of the photographs probably introduced error to the results. Overhanging tree cover also introduced error to the results.
- The blue-line aerial photographs showed a considerable increase in vegetation density within the channel, along the channel banks, and within the floodplain.
- Possible factors that might have influenced the changes in channel morphology along lower Cienega Creek from 1980 to 1998 include less intense and less frequent flood flows since the early 1970's, a noticeable increase in vegetation growth along the channel banks, and the restriction of activities that have high potential for increasing streambank erosion and vegetation removal.
- No obvious trends existed between baseflow conditions of lower Cienega Creek and changes in channel morphology during the study period, except in the Pantano study reach where a decrease in active channel area coincided with a decrease in baseflow.

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