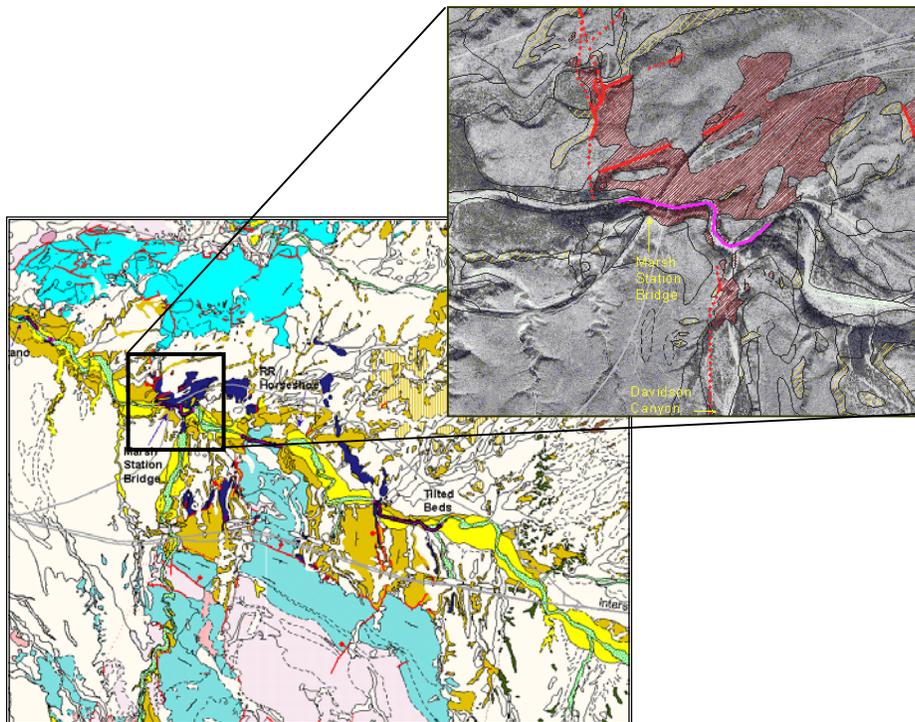


Geologic Influences on the Hydrology of Lower Cienega Creek



December 2003

Prepared by
Pima Association of Governments



Pima Association of Governments

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Lower Cienega Creek Geology and Hydrology Interface

Purpose

This study was originally undertaken in order to take a first-order look at the relationship between vegetation coverage and the geology along lower Cienega Creek. The impetus for the project was the fact that the Arizona Geological Survey (AzGS) had remapped the Cienega Creek area in 2001, but the hydrologic character of the creek had not been re-evaluated in light of the new mapping. During the course of working on this project, it became clear that this geologically complex area had not been adequately described in the literature since the geologic mapping took place. Therefore, the scope was expanded to include a description of several geologic units, the faulting, and the relevance of these features to the hydrogeology of the region. In addition, available water quality studies were described and evaluated.

On a broad level, this project is one step in a long-term effort to establish the constraints on water resources in the Cienega Creek Natural Preserve. The reach of Cienega Creek between Interstate 10 and the diversion dam east of Vail, Arizona has been designated a Unique Water within the State of Arizona. This classification identifies the stream as an outstanding State resource water. The Cienega Creek Natural Preserve, established in 1986, is owned by Pima County Flood Control District and includes most of this lower part of Cienega Creek. This project was conducted by Pima Association of Governments (PAG) as part of the FY 2002/2003 Work Program with Pima County Flood Control District.

Background

Cienega Creek is an important water, recreation, and wildlife resource located southeast of Tucson, Arizona. It is one of the few low-elevation streams in Pima County that exhibit significant perennial flow. Development in the Cienega basin has been in the planning stages for almost 20 years. In 1986, the Empirita Ranch Area Plan was drafted indicating a plan to develop a satellite community south of interstate 10, east of the Cienega Creek Natural Preserve. Although the community has not been built, concerns about the effect of groundwater withdrawals and their potential affects on flows in Cienega Creek has prompted long-term monitoring of surface and groundwater resources in the region. Currently, land uses in the surrounding area include livestock grazing and low density residential (Montgomery and Assoc., 1985).

Cienega Creek originates in the Canelo Hills and continues roughly 50 miles toward the northwest where it becomes Pantano Wash. From its origin, Cienega Creek flows through the upper Cienega basin, which is a wide alluvial basin separating the Northern Santa Rita and Empire Mountains to the west and the Whetstone Mountains to the east. A bedrock high, called the "Narrows" on the Narrows USGS Quadrangle, divides the upper basin from the lower basin. It serves as a hydrologic barrier and is characterized by riparian vegetation and perennial flow. After the "Narrows", Cienega Creek continues

northward through the lower alluvial basin until it bends west/northwest in the vicinity of Anderson and Wakefield Canyons. Northwest of the I-10 crossing, Cienega Creek again crosses a bedrock high, and once more it is characterized by perennial flow.

In the *Unique Waters Final Nomination report for Cienega Creek* (Fonseca, et. al., 1990), researchers state that groundwater is found primarily in basin-fill and recent alluvial deposits. This and other reports also state that some groundwater is found in the Pantano Formation (Kennard, et. al., 1988) and possibly in fractured openings in concealed faults in the bedrock units. Where the bedrock is exposed or lies just beneath ground surface, its encroachment on the alluvial aquifer is the likely reason that water is forced to the surface. However, there are many types of bedrock and alluvium in the Cienega Creek area and the effect they may have on subsurface flows or the potential effects of structural features on the flow regime has not been assessed. This project seeks to evaluate the bedrock high concept in a more informed way.

Maps

A series of seven maps are included at the end of this report. The reader will probably use all the maps together, so they are grouped at the end of the report instead of being dispersed throughout the text. Figure 1 is a location map on an aerial photograph base. Landmarks and wash names are labeled and the preserve boundary is shown. Figure 2 is a generalized geologic map at the same scale and extent as Figure 1. This map shows the main roads and a few place names projected over the geologic map to help the reader compare the geology to the aerial photograph shown in Figure 1. Figures 3-7 are a series of larger scale maps, which show selected geologic units and the extent of surface water baseflows projected over aerial photographic base maps. The maps progress west to east across the Cienega Preserve.

Data Sources

Geologic Mapping

The Arizona Geological Survey (AzGS) provided ESRI Arc Info coverages of geologic maps for the following quadrangles: Mount Fagen, the Narrows, and the southern part of Vail, and Rincon Peak. This mapping was conducted in 2001 by AzGS geologists, with revisions completed in 2002 for some maps. Mapping was funded by the National Geologic Mapping Program. Geographic data were projected in UTM Zone 12, on North American datum 1927 (NAD 27). Unified map units for the four quadrangles had not been developed at the time of this investigation. Although some inconsistencies in map units were evident, they did not prohibit general geologic interpretations.

Aerial Photography

Aerial imagery used for this project were digital ortho-rectified quarter quadrangles (DOQQs) available from the United States Geological Survey (USGS). For Mount Fagan and the Vail quadrangles, 1992 black and white images at one meter resolution were used. For Rincon Peak and the Narrows quadrangles, 1996 color images at one meter resolution were used. UTM zone 12 NAD 27 imagery was reprojected from NAD 1983 to NAD 1927, so that they could be combined with the geologic information.

Extent of Surface Flow Observations

PAG staff has been observing the extent of surface flow in the Cienega Natural Preserve since June 1999. Flow extent observations are made by walking along lower Cienega Creek from where it is crossed by Interstate 10 to the Pantano Dam. Yearly walk throughs were conducted in June 1999, June 2000, and June 2001. Walk throughs were conducted on a quarterly basis on the following dates: September 18, 2001, December 14, 2001, March 22, 2002, June 19, 2002, September 19, 2002, December 17, 2002, and March 25, 2003. The lowest flows during the year have consistently been found during the June walk through. Therefore, baseflows shown in Figures 3-7 show the typical low flow extent, which is a summary of observations made on the following dates: June 1999, June 2000, June 2001, and June 2002.

Water Quality Studies

In the Lower Cienega area, few investigations have included water chemistry analyses of surface water beyond measuring the field parameters: temperature, pH and electrical conductivity. Two were conducted recently by PAG: *Lower Cienega Basin Source Water Study*, PAG 2000; and *Contribution of Davidson Canyon to Baseflows in Cienega Creek*, PAG, 2003. Temperature and EC were measured systematically and this information was included in the Master's these titled *Geologic Controls on the Occurrence and Movement of Water in the Lower Cienega Creek Basin*, by Ellett 1994.

Modeling Studies

Several Master's theses conducted in the early to mid-1990s featured hydrologic

modeling near the Cienega Creek area. One of these studies, conducted by Damaris Chong-Diaz is often cited in hydrologic reviews of the region because it focused on an evaluation of the hydrologic connection between groundwater resources in the Empirita Ranch area and surface flows within the Cienega Preserve (Chong-Diaz, 1995). This modeling project indicated that groundwater levels within the preserve would be drawn down as a result of pumping in the upstream Empirita Ranch area. However, the researcher also stated that the model was somewhat inconclusive because it was extremely sensitive to the hydraulic conductivity values used, as well as to other assumptions, and changing these inputs could dramatically change the modeling results. Geologic mapping presented in this report might help future modelers better analyze the connection between surface flows and groundwater.

Geologic Summary

The geologic history summarized in this report is primarily based on information provided on three geologic maps produced by the Arizona Geological Survey (AZGS) in 2001.

Geologic Map of the Narrows 7.5' Quadrangle and the Southern Part of the Rincon Peak 7.5' Quadrangle, Eastern Pima County Arizona, Digital Geologic Map 10, Spencer, J.E. et. al., Revised May 2002.

Geologic Map of the Mount Fagan 7.5' Quadrangle, Eastern Pima County, Digital Geologic Map 11, Ferguson, C.A., et. al., November 2001.

Geologic Map of the Southern Part of the Vail 7.5' Quadrangle, Digital Geologic Map 12, Richard, S.M., et. al., Revised July 2002.

In addition, discussions with Stephen M. Richard of the AZGS helped PAG staff interpret mapped features and to place the mapped area within a broader geologic context (Richard and Harris, 1996). Figure 2 shows a generalized geologic map of the Cienega Preserve area.

Because the geology in the Cienega Creek area is very complex, PAG generalized mapping by the AZGS; grouping units according to age and degree of lithification. Distinctions were made based on rough estimates of the formations' potential to impede or aid subsurface flow (Figure 2). The original Arizona Geological Survey's geologic maps should be consulted for a more in-depth understanding of the geology. A brief description of geologic groupings used in this report is provided below.

In general, Alluvial deposits are displayed in four groupings: 1) modern river channel deposits, 2) Holocene floodplain deposits less than 10,000 years old, 3) floodplain deposits greater than 10,000 years old, and 4) all other Quaternary deposits including uplands and hillside units. This degree of differentiation is shown because alluvial deposits are more likely aquifers than the bedrock units. The Pantano Formation underlies the river alluvium throughout much of the preserve. Because it contains variably consolidated rocks, several of the facies and subunits are broken out on the maps. Tertiary/pre-Tertiary map units other than the Pantano are grouped into four map units, generally separating granitic rocks, sedimentary rocks, and carbonate rocks. Bedding orientations are shown sparingly, just to give the reader a general sense of the strike and dip of the stratified units on Figure 2 of the report. Faulting is described in the text, but is only minimally symbolized on Figure 2.

The Cienega Creek Natural Preserve is located in the lower Cienega basin at the southern end of the Rincon Mountains. On a broad scale, this area is within the Basin and Range physiographic province of the southwestern United States: a region that is characterized by a series of broad, relatively flat, alluvial valleys separated by linear, sharply-rising mountain ranges. The basins were formed by horst and graben faulting during the Tertiary period, mostly during the Miocene (23.8 - 5.3 million years ago). In the Southwest, these geologic systems are characterized by low-angle normal faults (detachment faults), which were often mapped as reverse faults in early mapping efforts (Drewes, 1980). Detachment systems also contain high angle normal faults and regional scale folds. These features are apparent where the bedrock is exposed in the mountain ranges and at the basin margins, such as in the Cienega Preserve area. The

large alluvial basins, typical of the Basin and Range province, are generally filled by locally-derived sediments. The thickness of the basin alluvium may vary from a few thousand feet to more than ten thousand feet (Anderson, 1985).

Structure and Stratigraphy

The Cienega basin formed during two phases of deformation within the late Tertiary period (S. Richard, personal communication). The following list outlines both the tectonic and sedimentation history in the basin.

- | | |
|------------------------|---|
| Pre 30 Ma ¹ | The Bisbee formation and associated Cretaceous rocks were deposited on the pre-Tertiary bedrock including upper Paleozoic carbonates. Faulting caused deformation of Bisbee units until they were steeply dipping to overturned. |
| ~ 30 Ma
to 15 Ma | Large-scale low angle normal faulting along Catalina-Rincon detachment fault caused hanging wall rocks to be transported 18 to 20 kilometers to the southwest relative to the underlying crystalline rocks of the Rincon Mountains.

Syn-deformational deposition of the Pantano Formation, causing lower portions of the Pantano formation to be cut by high angle north-trending normal faults, while upper parts of the Pantano remained undeformed. Facies changes were rapid because depositional environments were often narrow or rapidly changing.

Volcanic rocks were intruded and were interbedded with the Pantano Formation near the base and middle of the section. Rock avalanche and sedimentary breccia units are also interbedded with the Pantano. |
| ~15 Ma | Formation of the Cienega basin. Large faults formed on the eastern side of Cienega Basin against the Whetstone Mountain front. A regional scale syncline formed in the center of the basin and rocks in the Cienega area were gently tilted to the east. |
| 30 to 15 Ma | Pleistocene and more recent alluvial deposits |
| 10,000 yrs | Holocene Floodplain and terrace deposits. |
| 100 yrs | Stream entrenchment and deposition of late Holocene (recent) river channel deposits. |

Pantano Formation

In the lower Cienega Creek area, the Pantano Formation is the most widely exposed sedimentary bedrock unit. The following description is based on mapping conducted by the Arizona Geological Survey and discussions with Steve Richard of their office. Understanding the Pantano's distribution and recognizing it in the field can be difficult for researchers without extensive geologic mapping experience. This is partly because the

¹ Ma is the abbreviation used for millions of years

Pantano is extremely varied in composition in this area, ranging from conglomerates to very fine grained sandstones and mudstones, to gypsum evaporites, to rock slide avalanche breccias, and andesitic volcanic rocks. Different parts of the Pantano were deposited in different depositional environments and new source rocks were exposed during syndepositional faulting. As a result, the Pantano includes several facies which have distinct rock character imparted by their different depositional environments (Balcer, 1984). In general, the Pantano becomes more consolidated from east to west (down section), but also due to facies changes.

In the region surrounding Cienega Creek Preserve, the Pantano formation dips gently to steeply eastward because it is located along the westward flank of the synclinal structure centered in the main part of the Cienega Basin. The upper part of the Pantano is exposed in the east and the lower part of the section is exposed in the west. Many exposures throughout the Cienega basin are covered by Quaternary alluvium, making detailed geologic studies difficult.

The Agua Verde facies of the Pantano is exposed northeast of the Cienega Preserve as shown in Figure 2. Southern exposures of the Agua Verde facies are finer grained than the northern part of the facies, because the source rocks were located to the north during deposition. The Wakefield Canyon facies is exposed in the eastern part of the Cienega Creek Preserve (east of Jungle area), and more extensively southeast of the Preserve (Figure 2). The Wakefield Canyon facies fines to the north, where it interfingers with the similarly fine-grained Agua Verde facies in the Cienega preserve area (Spencer et. al, 2001). Because of its fine-grained nature, the Pantano is mapped as undifferentiated in much of the Preserve area.

The rock type and the degree of lithification is variable in the Pantano Formation across the Cienega Preserve. Place names mentioned in the following description are shown on Figure 2. Much of the Pantano has been mapped as undivided mudstones, sandstones and conglomerates. East of Tilted Beds, the Pantano consists of fine grained silts and mudstones, which do not crop out well partly because they are poorly consolidated (Steven Richard, personal communication). In the Tilted Beds area, there are good exposures of silty sandstones interbedded with coarse sandstones and conglomerates as well as other units that are more consolidated. From the Tilted Beds area westward, the highly consolidated lower Pantano is intermittently exposed. West of the railroad horseshoe landmark, this unit has been identified as the Davidson Canyon facies of the Pantano (not differentiated on Figure 2) (Ferguson et. al., 2001; Richard, et. al. 2001). The degree of lithification may have bearing on the hydraulic connection between the Pantano and the overlying alluvial deposits.

Andesitic volcanic rocks and some pyroclastic deposits interfingered with other facies of the Pantano formation are exposed in three main areas along Cienega Creek. Near Marsh Station Bridge volcanic and associated intrusive rocks are extensively exposed. This may have been the intrusive center during the 30-15 MA volcanism. Andesites are also found at two other locations along the creek: at the bend in the river east of Fleming Tank Wash and near the Tilted Beds site (Figures 2 and 6). These deposits and the underlying section of the Pantano are probably repeated sections that were displaced along the down-to-the-west normal faults exposed in this area. Where exposed, the andesitic rocks are very well consolidated and would strongly impede flow in the subsurface.

One other Pantano unit worth noting is the rock avalanche breccia, which cross the Preserve at its eastern end, just east of the Jungle area (Figures 2, 6, and 7). Although the breccias are not exposed along the creek they are likely present in the subsurface and may have hydrologic importance. In the Preserve area, the breccias are derived from Paleozoic limestone, and dissolution of limestone fragments might cause increased permeability within this unit.

River Alluvial Deposits

Along Cienega Creek, alluvial deposits comprise the dominant geologic unit surrounding the channel bottom. Over time, the creek has cut down through the surrounding rock units. Initially, alluvial units were deposited over wide flood plains, but over time the channel became narrower and cut down through the older deposits leaving them abandoned on the higher ground surrounding the channel. Late and middle Pleistocene river terrace deposits are found outside the Holocene deposits, where they occur. Closer to the river Holocene-aged floodplain and terrace deposits, probably less than 10,000 years old, can be found in many locations. Late Holocene channel deposits, which are probably less than 100 years old, are found in the channel bottom (Figure 2).

A transition in the extent of river floodplain deposits occurs across the length of the preserve. This transition occurs near the railroad horseshoe landmark. East of this landmark, unconsolidated late Holocene floodplain and terrace deposits often extend 1000 feet on either side of the channel bottom. West of the landmark, the younger terrace deposits are largely absent, and older Holocene and Pleistocene deposits commonly abut the Creek.

The lateral extensiveness, depth, and degree of consolidation of recent alluvial deposits probably has a strong effect on the hydrologic continuity along Cienega Creek. However, many of these deposits are physically higher than the stream bed deposits because terraces were abandoned as the stream was downcut. No information is available about how deeply the alluvial deposits might underlie the recent channel deposits.

Structural Features

Several fault zones of varying ages have been mapped within the Preserve area. Their hydrologic importance is unknown partly because fault rocks have not been evaluated to determine if they are potentially water bearing or serve as hydrologic barriers.

A complex system of faults has been mapped in the Paleozoic limestones northeast of the Pantano Dam site. Researchers at the Arizona Geologic Survey indicated that these faults are cross-cut by later Oligocene to early Miocene faults associated with the Catalina-Rincon Detachment Fault (Steve Richard, personal communication). The Catalina -Rincon Detachment Fault separates Paleozoic limestones and the Rincon Valley granodiorite in the hanging wall from underlying footwall granitic and gneissic metamorphic rocks (Figure 2). Although bedrock exposures along the Cienega Creek are sparse, it is reasonable to assume that the detachment fault underlies the limestone units in the Pantano Dam area. Rocks overlying the detachment faults are commonly brecciated and highly faulted which may increase their hydraulic conductivity. It is unclear if this is a factor in the Cienega area, but it may have contributed to the

development of the aquifer tapped by the Del Lago well near Pantano Dam.

South of Cienega Creek, two major faulting episodes are evident. Early east-west trending structures are steeply dipping normal faults, with down-to-the north displacement. None of these structures are seen in the immediate vicinity of Cienega Creek, but they are evident in the nearby Cretaceous/Jurassic sedimentary rocks (Figure 2). Younger north-south trending normal faults cut the east-west structures and these do intersect the creek. Many of the recognized faults are observed adjacent to andesitic volcanic rocks, where they are mappable because the andesite is a distinctive marker bed (Steve Richard, personal communication).

The most prominent north-south-trending fault zone is the Davidson Canyon Fault zone, which has been mapped from the Cienega Creek area southward along the western flank of the Empire Mountains. Three splays of this fault zone intersect Cienega Creek. South of the creek splays are found along Davidson Canyon in the Mule Wash drainage area (Figures 2, 4, and 5). The westernmost splay is found along the western boundary of the Marsh Station Bridge andesite, north of Cienega Creek (Figure 4). This fault system is moderately to steeply westward dipping with down-to-the-west displacement.

Near the center of the Preserve, between Fleming Tank Wash and the Tilted Beds site, there is a relatively minor fault which parallels the northwest trending andesitic volcanic body, and probably repeats the neighboring section of Pantano and andesitic rocks. Near Cienega Creek this fault is mapped on the eastern side of the andesite, and it is shallowly dipping to the west with down-to-the-west displacement.

Geologic Controls on Flow

Vegetation Trends

One purpose of this project was to evaluate the degree to which vegetation trends reflect the underlying geologic features. Vegetation cover is one indicator of the availability of water in the near surface. Because the type and density of vegetation is difficult to assess without field verification, the objective was to broadly review the lateral extent of vegetation and to note if there were any prominent changes in vegetative cover that could be correlated with changes in the bedrock geology.

In Cienega Creek, vegetation cover is best developed in areas with well developed river alluvial and/or terrace deposits (Figures 3 - 7). Vegetative cover is concentrated along the valley floor, but extends beyond the valley floor into tributaries if they contain river alluvium. In general, this indicates that the near surface water is largely contained within the river alluvium.

Although the aquifer may be recharged by upwelling of water through less consolidated bedrock units, which may include fault rocks or sedimentary breccias, this question cannot be fully addressed without analyzing water chemistry from either side of the structure or sedimentary unit. However, vegetation cover did not increase or abruptly stop near the faults. This implies that the any influx of water along the fault zone was not sufficient to increase the lateral extent of vegetation. The sedimentary breccia portion of the Pantano Formation intersects Cienega Creek just east of the Jungle area (Figures 6 and 7). The trace of the drainage bends sharply to the north and then sharply to the west where the north-south trending breccia zone intersects the river. It is notable that the vegetative cover is well developed along this reach of the river even though the flow generally remained in the subsurface between 1999 and 2002. This portion of the creek was often flowing during the mid-1990s.

Bedrock Highs and the Extent of Baseflows

Perennial flow in the Cienega Natural Preserve area is likely due to the narrowed alluvial basins associated with the bedrock highs in the region. The bedrock highs constrict the flow of water in the subsurface, forcing more of the water to emerge as surface flow. Because the bedrock units are variably lithified, some rocks, such as the lower Pantano and the andesitic volcanic rocks, may more effectively block subsurface flow than the unconsolidated terrace deposits and the poorly consolidated upper Pantano Formation.

The reaches of Cienega Creek that typically flow during dry months are shown on Figures 2 - 7. The extent of baseflows is a summary of data collected during June for 1999, 2000, 2001, and 2002. Most of these data were collected during dry years, and flow extent would presumably be greater in wetter years. Selected geologic units and faults are shown on photographic base maps in Figures 3 - 7, allowing the reader to compare the flow extent, the vegetation trends, and the geologic features in the basin.

The flow first emerges near the Tilted Beds site, in an area where Pantano Formation and a small exposure of andesitic rocks crop out in the creek (Figure 6). Upstream of this area (eastward), the poorly consolidated upper Pantano underlies the basin, but

does not crop out. Extensive deposits of recent alluvium with well developed vegetative cover are found. The transition from poorly lithified upper Pantano Formation to better lithified lower Pantano Formation occurs near the middle of the flowing reach. To the west (downstream) of this transition, broad exposures of the well lithified Pantano Formation are found. Flow along this reach terminates approximately one mile downstream, where andesitic volcanic rocks and an associated fault zone intersecting the creek. Downstream of this location, the alluvial basin widens and is not restricted again for approximately 1 ½ miles.

The flow emerges again near the railroad horseshoe landmark (Figures 4 and 5). In this area, exposures of the well consolidated Cretaceous Bisbee Formation are found on both sides of the Creek, restricting the extent of the alluvial basin. The flow terminates at the bedrock transition from Bisbee to Pantano, which has been displaced on the down-to-the-west high angle normal fault that intersects the creek at this location.

The third baseflow reach begins near the confluence of Davidson Canyon with Cienega Creek (Figure 4). This location is also marked by outcropping of andesitic volcanic rocks, which are exposed on both sides of the river. The flow terminates downstream from Marsh Station Bridge, just past the westernmost exposure of this andesite body. In addition, the termination coincides with the eastern splay of the Davidson Canyon fault zone.

The fourth area of emergent flow is located at the western part of the Preserve. Surface flow is found in a small reach located about half way between Agua Verde Creek and the Pantano Dam (Figure 3). An additional area of emergent flow extends from approximately 1,500 feet upstream from the dam, and extends downstream until the dam, where the limestone outcrops along the river. The reach ends when it is diverted into the pipeline at the dam.

There are some similarities in the hydrologic environment for all of these areas of emergent flow along the creek. Each of these zones is associated with constrictions of the Holocene floodplain deposits and outcroppings of consolidated rock units: the Bisbee Fm., the well lithified lower Pantano Fm., the andesite, and the Paleozoic limestone. The termination of the first three areas of emergent flow are all associated with fault zones and with transitions from highly consolidated rocks to less well consolidated rocks. Areas without emergent flows are characterized by broader alluvial deposits; however, portions of the Tilted Beds area and the valley near the Pantano Dam share these characteristics.

Water Chemistry Studies

Three water chemistry studies have been conducted in the Cienega Creek area in the last ten years. Table 1 shows the type of data available, the general location of the sample sites and the dates that the water body was sampled. The following section briefly reviews the findings of these studies and then examines the findings in light of recent geologic mapping.

Table 1: Recent Water Chemistry Studies in the Cienega Preserve Area

Data Source	Data type	Sample Sites	Dates Collected
Lower Cienega Basin Source Water Study, PAG 2000	Major ions / hydrogen & oxygen stable isotopes	Cienega Creek upstream from Pantano Dam / downstream from confluence with Agua Verde Creek	9/28/98, 11/19/98, 4/29/99, 6/17/99 8/24/99, 11/19/00, 3/31/00
		Cienega Creek just upstream from the confluence with Agua Verde Creek or Cienega Creek just downstream from Marsh Station Bridge (depending on flow)	9/28/98, 11/19/98, 4/29/99, 6/17/99 8/24/99, 11/19/00, 3/31/00
		Posta Quemada Spring	9/30/98, 11/19 98, 4/29/99, 6/17/99, 8/24/99
Contribution of Davidson Canyon to Base Flows in Cienega Creek, PAG 2003	Major ions / hydrogen & oxygen stable isotopes	Davidson Canyon 1, just upstream (south) of Interstate 10.	6/4/02, 8/2/02, 10/3/02, 1/3/03, 5/8/03
		Davidson Canyon 2, just upstream from the confluence with Cienega Creek.	6/4/02, 8/2/02, 10/3/02, 1/3/03, 5/8/03
		Cienega Creek 1, just upstream from the confluence with Davidson Canyon.	6/4/02, 8/2/02, 10/3/02, 1/3/03, 5/8/03
		Cienega Creek 2, at Marsh Station Bridge.	6/4/02, 8/2/02, 10/3/02, 1/3/03, 5/8/03
Geologic Controls on the Occurrence and Movement of Water in the Lower Cienega Creek Basin, Ellett 1994.	Air Temperature, Water Temperature, Electric Conductivity	Measurements taken at 250 foot intervals between the Jungle area and Marsh Station Road Bridge.	June 11, 1994

Lower Cienega Basin Source Water Study

As part of the Lower Cienega Basin Source Water Study (PAG 2000), water chemistry data were collected from September 1998 to March 2000. The purpose of the study was to determine the source of the surface water in Cienega Creek at the downstream end of the Cienega Creek Natural Preserve near its confluence with Agua Verde Creek near the Pantano Dam. Researchers found that the water in Cienega Creek was not significantly influenced by surface flow or subflow from Agua Verde Creek. Well water from the limestone aquifer was found to be distinct from Cienega Creek surface water and chemical differences were attributed to rock water equilibration of surface water during transit through the bedrock system.

Highly faulted Paleozoic limestone outcrops along Cienega Creek near the Pantano Dam (Richard, et.al., 2001). These units have the potential for karst formation, since the rocks are similar to those in the Colossal Cave area. This geology is consistent with the idea that there is some interconnection between the bedrock aquifer in the limestone and the water in Cienega Creek. Unfortunately, there is no water in the creek downstream from the Pantano Dam. Therefore, there is no way to chemically determine if the bedrock aquifer contributes to the surface flow downstream from the dam.

In the area near the confluence of Agua Verde Creek, the Pantano has been mapped as undivided conglomerate, sandstone and mudstone. Because the Pantano is well lithified in this area, it is less likely to be hydrologically interconnected with the river alluvium. This is consistent with the findings of the Lower Cienega Basin study, which showed no change in water chemistry along this reach of Cienega Creek.

Davidson Canyon Contributions to Baseflows in Cienega Creek

During fiscal year 2002/2003, PAG investigated Davidson Canyon's water contributions to baseflows in Cienega Creek using water chemistry and stable isotope data (PAG, 2003). Five quarterly samples were collected between June 2002 and May 2003 at two locations in Davidson Canyon, and within Cienega Creek upstream and downstream of its confluence with Davidson Canyon. This study found that Davidson Canyon baseflows and subflows significantly contributed to flows in Cienega Creek. Water chemistry data indicated that as much as 24% of the flow in Cienega Creek was probably from Davidson Canyon during low flow months.

Davidson Canyon was sampled at two locations: at Davidson Canyon just upstream from its confluence with Cienega Creek (October 2002, January 2003); and upstream from Interstate 10 (June and August 2003, May 2003). The upper location was only sampled when the lower location was dry and indicates a higher-elevation water source than the lower sample location. Water chemistry was consistent at the two locations and it did not show large seasonal variations in solute concentrations. Water chemistry from Cienega Creek did not show large seasonal variations either.

As shown on Figure 2, a splay of the Davidson Canyon fault zone is inferred to be located beneath the trace of Davidson Canyon. The change in chemistry up and down Cienega Creek from its confluence with Davidson Canyon can be explained by the addition of surface water in Davidson Canyon. Although this does not preclude the

possibility that the fault rocks are bearing water to, or from, the surface, there is no evidence that water within the fault system is upwelling at this particular location.

Surface Water Temperature Measurements

In William Ellett's Master's thesis entitled *Geologic Controls on the Occurrence and Movement of Water in the Lower Cienega Creek Basin*, he analyzed the bedrock geometry of Cienega basin through modeling cross-sectional profiles of the basin based on gravity data (Ellett, 1994). These findings mainly applied to areas outside the Cienega Preserve area. As part of Ellett's work, temperature and electrical conductivity data were collected on June 11th, 1994, from flowing portions of Cienega Creek in the central and eastern part of the Preserve, between the Jungle area and Marsh Station Bridge. Where the stream was flowing, data were collected at 250 foot intervals. Flow was only continuous in the first third of the traverse and data from intermittent flow areas are very difficult to interpret because of the lack of continuity in the measurements.

Drops in temperature may indicate upwelling of cooler subflow into the warmer surface water. Ellett correlated drops in water temperature with various geologic features along the creek. He noted that the surface water temperature dropped as the channel crossed the following features: exposed bedrock at the Tilted Beds site, andesite outcrops, faults and a sandstone outcrop. Temperature data were presented graphically within the thesis, but data were not correlated to a map base, making it difficult to link the changes in temperature to geologic features.

Conclusions and Recommendations

Comparison of the recent geologic mapping with vegetation density inferred from aerial photographs and with streamflow extent observations provided a basis to evaluate the potential effects of bedrock geology on the water resources of Cienega Creek. The concept that bedrock highs restrict the alluvial basins, forcing subsurface waters to upwell, was supported by the findings of this project. The degree of the consolidation of the bedrock units may affect the amount of subflow restriction, in part because poorly consolidated units do not crop out as well, allowing for better development of wide river channel and more extensive alluvial deposits, but also potentially because of increased permeability within the bedrock unit. The hydrologic significance of the sedimentary breccia unit in the Pantano warrants further investigation.

The role of fault rocks in the hydrologic system was not conclusively determined through this investigation. The Davidson Creek water quality study suggested that water is not upwelling along the inferred western splay of the Davidson Canyon fault. The extent and density of vegetation around faults did not indicate that more, or less, water resources were available to plants in areas near fault zones. An evaluation of baseflows along the creek showed a possible link between fault zones and termination of surface water flows. However, this could have been caused by the change in rock type and changes in depth to bedrock across these fault zones.

Specifically targeted water quality studies within baseflow regions of Cienega Creek would greatly help researchers evaluate whether subflow along the creek is augmented by flow in fault zones and breccia units, and whether upwelling is a significant source of water in the creek. Temperature and conductivity profiles could provide some useful information, but repeated measurements would have to be made in a systematic way and results might have limited interpretive value. Chemical and isotopic analysis of surface water baseflows directly upstream and downstream of specific geologic features would provide the most useful information.

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Figure 1. Location Map of Cienega Creek Natural Preserve Area

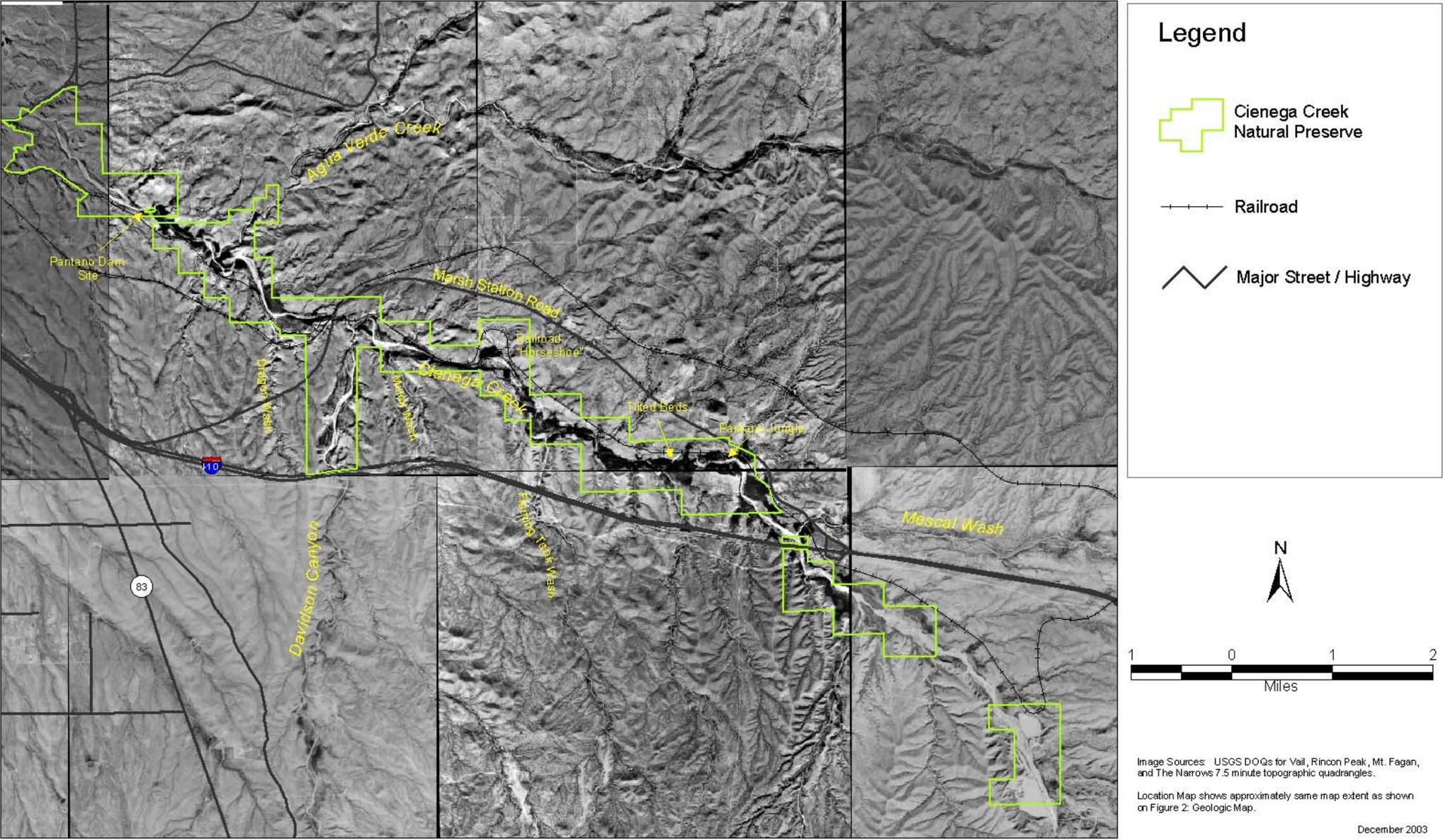
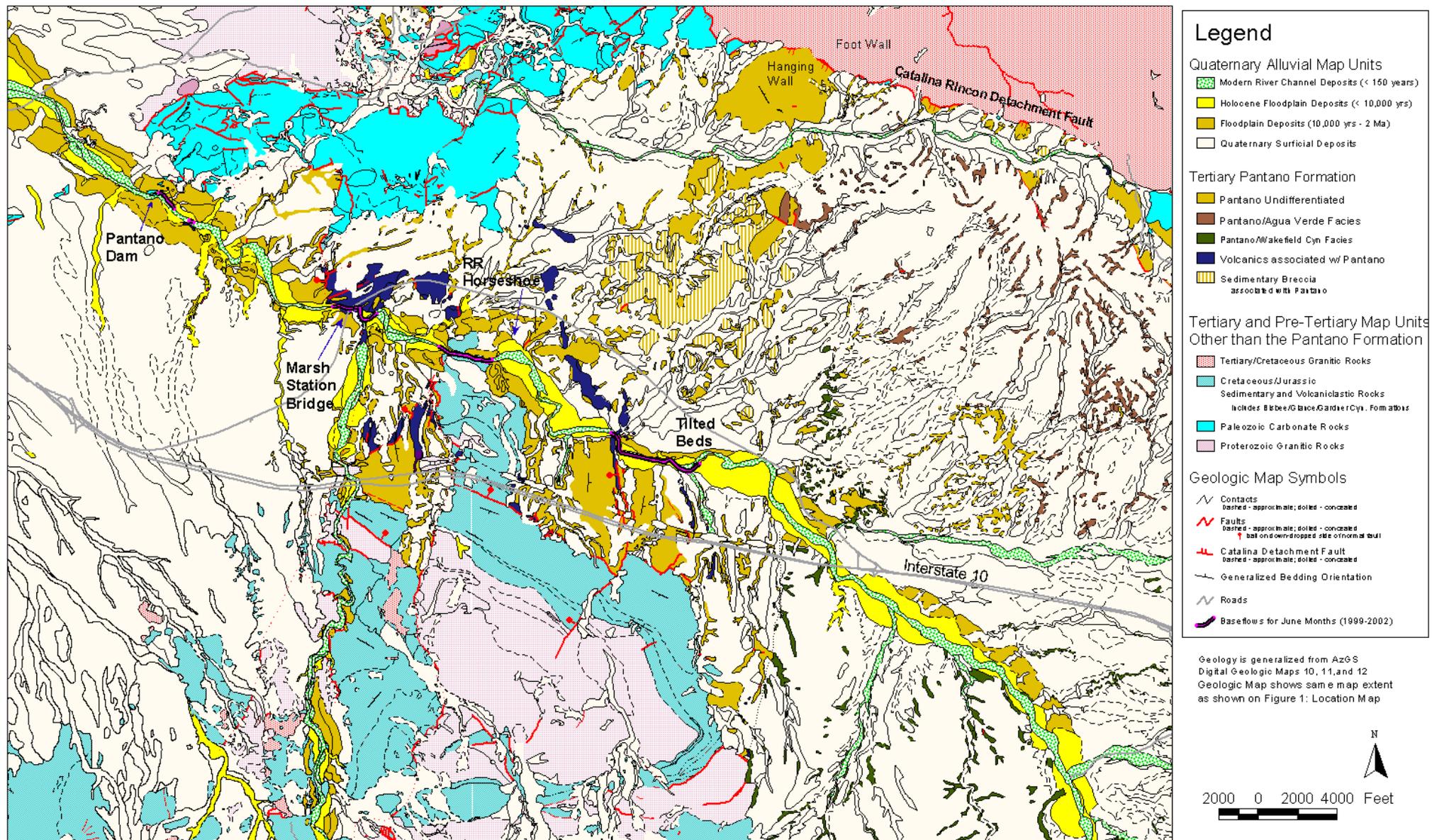


Figure 2: Generalized Geologic Map of the Cienega Creek Area



Legend

Quaternary Alluvial Map Units

- Modern River Channel Deposits (< 150 years)
- Holocene Floodplain Deposits (< 10,000 yrs)
- Floodplain Deposits (10,000 yrs - 2 Ma)
- Quaternary Surficial Deposits

Tertiary Pantano Formation

- Pantano Undifferentiated
- Pantano/Agua Verde Facies
- Pantano/Wakefield Cyn Facies
- Volcanics associated w/ Pantano
- Sedimentary Breccia associated with Pantano

Tertiary and Pre-Tertiary Map Units Other than the Pantano Formation

- Tertiary/Cretaceous Granitic Rocks
- Cretaceous/Jurassic Sedimentary and Volcaniclastic Rocks
- Paleozoic Carbonate Rocks
- Proterozoic Granitic Rocks

Geologic Map Symbols

- Contacts: Dashed - approximate; solid - concealed
- Faults: Dashed - approximate; solid - concealed
- Catalina Detachment Fault: Dashed - approximate; solid - concealed
- Generalized Bedding Orientation
- Roads
- Baseflows for June Months (1999-2002)

Geology is generalized from AzGS Digital Geologic Maps 10, 11, and 12. Geologic Map shows same map extent as shown on Figure 1: Location Map.

2000 0 2000 4000 Feet

N

Figure 3: Geologic features and baseflows in the Pantano Dam area, Cienega Creek

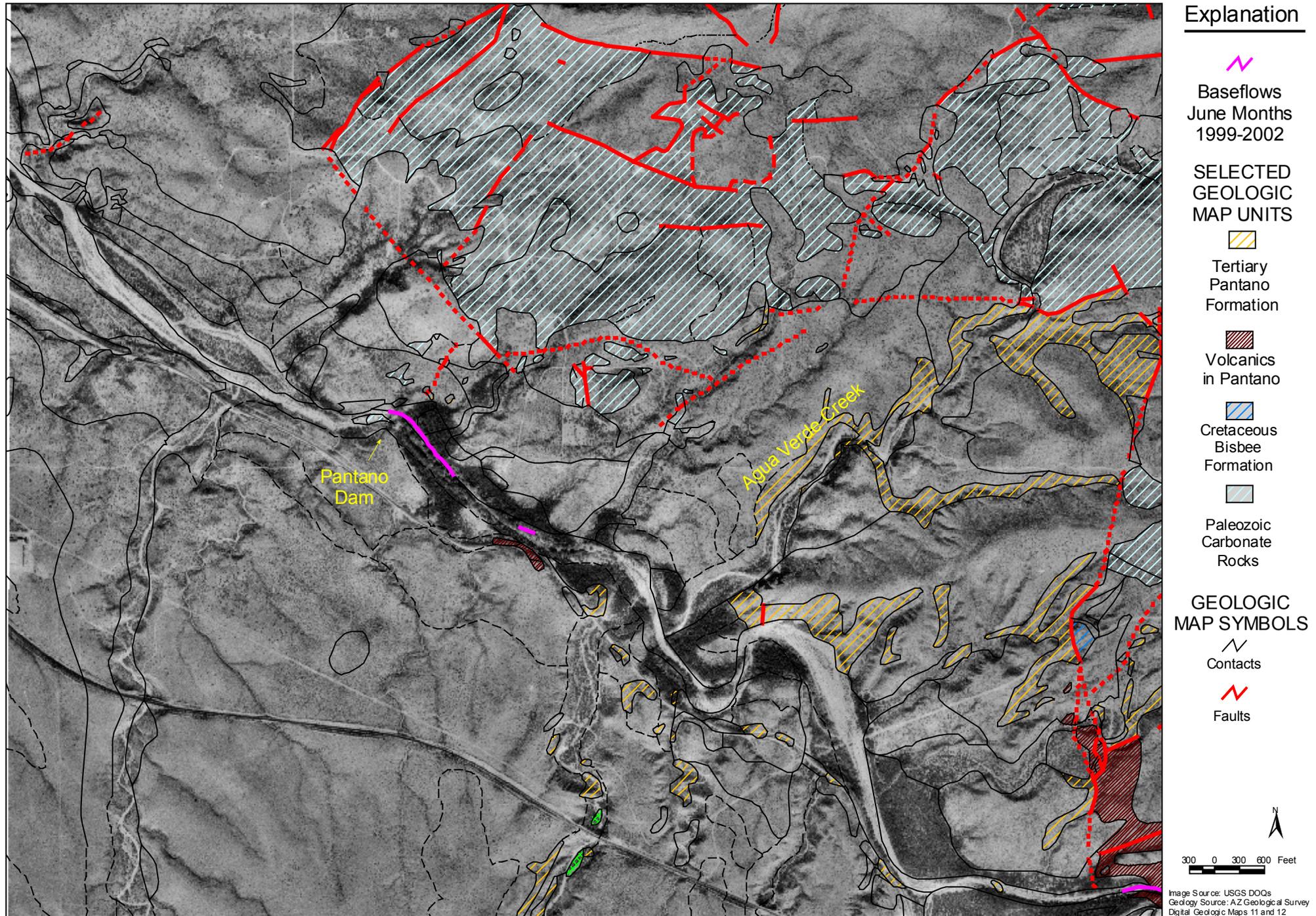


Figure 4: Geologic features and baseflows in areas north and east of Marsh Station Bridge, Cienega Creek

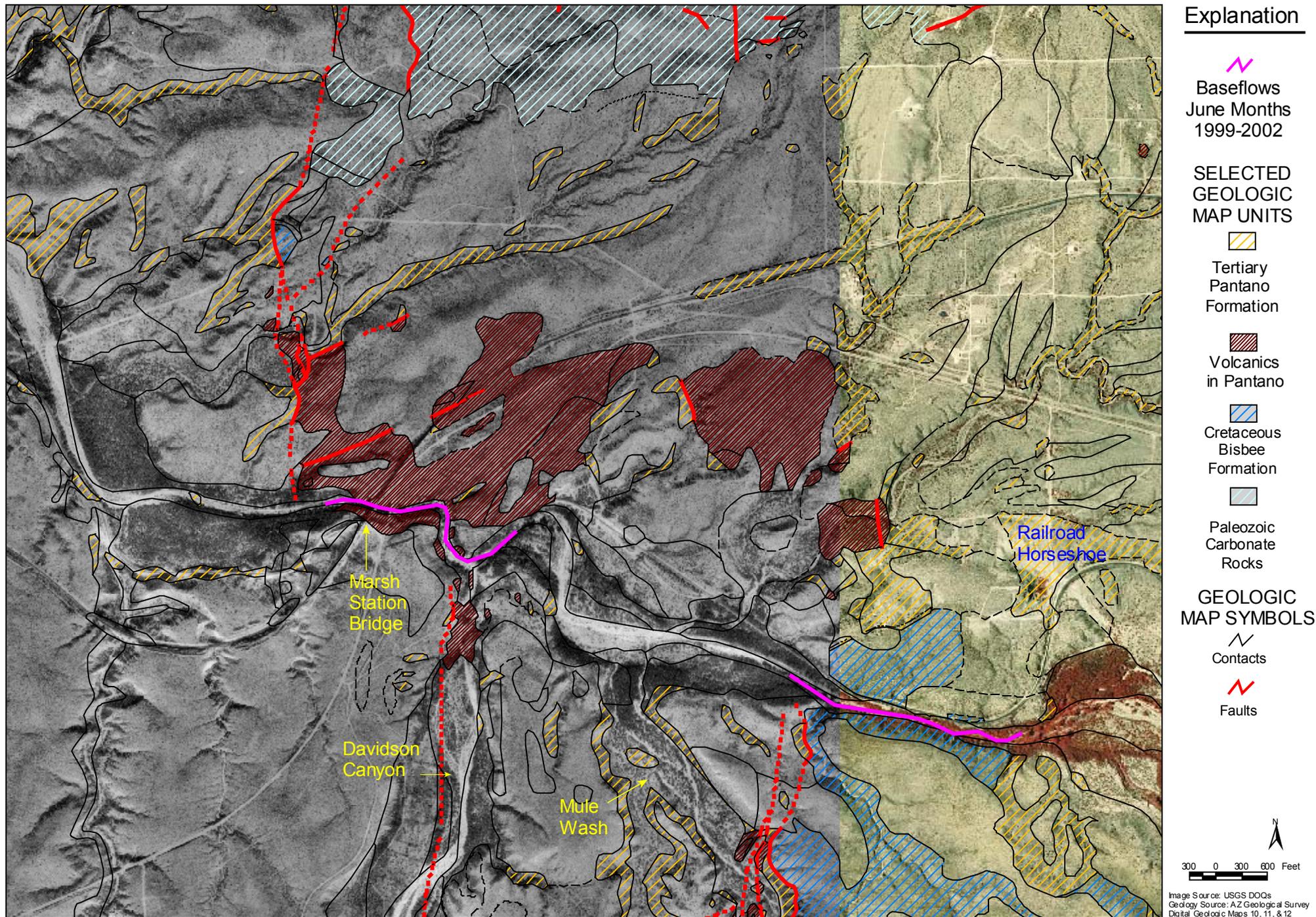


Figure 5: Geologic features and baseflows in areas south and east of Marsh Station Bridge, Cienega Creek

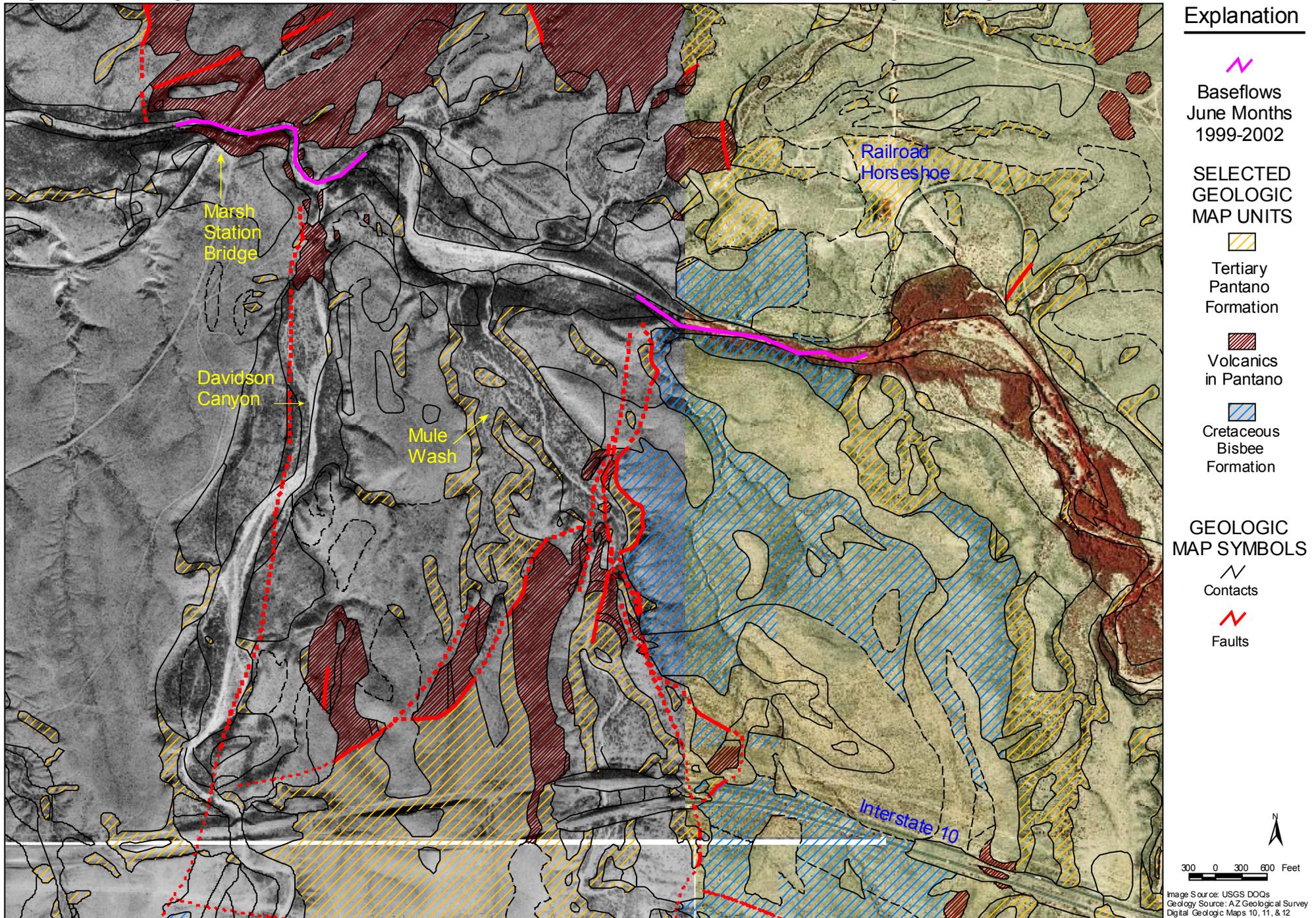


Figure 6: Geologic features and baseflows in the Tilted Beds area, Cienega Creek

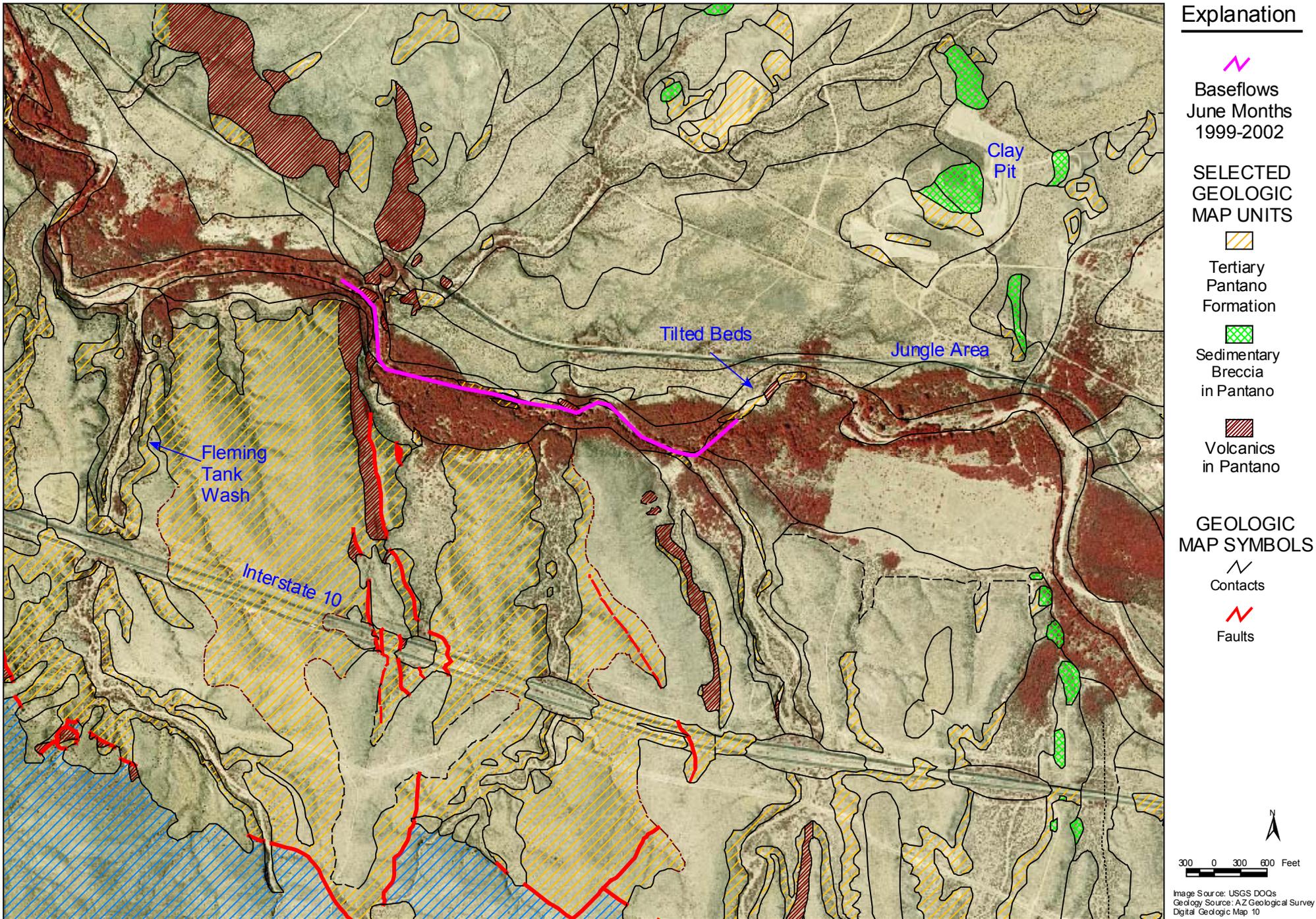


Figure 7: Geologic features and baseflows in the Jungle/Mescal Wash area, Cienega Creek

