



MEMORANDUM

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SUBJECT: **Cienega Creek Natural Preserve Surface Water and Groundwater Monitoring
Annual Report for the 2009-2010 Fiscal Year**

DATE: February 2012

Please find the enclosed Fiscal Year 2009-2010 technical report for the Cienega Creek Natural Preserve Monitoring Project. This report summarizes PAG's groundwater and surface water monitoring between July 2009 and June 2010.

If you have any questions and/or would like any additional information, please feel free to call me at 792-1093.

Pima County's Cienega Creek Natural Preserve

Surface Water and Groundwater Monitoring Project – PAG Annual Report

Fiscal Year 2009 - 2010



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



Pima Association of Governments

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Thank you to Pima County for its long-term support of the Cienega Creek monitoring program as a part of PAG's annual work plan. We greatly appreciate the following Pima County staff for supporting the monitoring, initiating program elements as needed, sharing data, providing input and coordinating with us: David Scalero, Frank Postillion and Tom Helfrich, Pima County Regional Flood Control District; Julia Fonseca and Brian Powell, Pima County Office of Conservation and Sustainability; and Don Carter and Iris Rodden, Pima County Natural Resources, Parks and Recreation.

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Introduction

Cienega Creek is an important water, recreation and wildlife resource in the Santa Cruz River watershed. It is one of the few low-elevation streams in Pima County that exhibit significant perennial flow. Perennial reaches of Cienega Creek support native fish and the surrounding riparian vegetation provides habitat for a diversity of wildlife. In recognition of its value to the state of Arizona, the reach of Cienega Creek downstream from Interstate 10 to the Del Lago Dam has been designated by the Arizona Department of Environmental Quality (ADEQ) as an "Outstanding Water," (R18-11-112) which means that site-specific water quality standards are established to maintain and protect the existing water quality. The certificate of in-stream flow rights was granted by the Arizona Department of Water Resources (ADWR) to Pima County Regional Flood Control District in December 1993 (No. 89090.0000). Both Cienega and Davidson Canyon have priority aquatic and riparian resources as specified in the Sonoran Desert Conservation Plan. This report describes work completed by Pima Association of Governments (PAG) as part of its 2009-2010 Overall Work Program, which includes monitoring in lower Cienega Creek and Davidson Canyon.

The purpose of PAG's monitoring program is to establish baseline hydrologic conditions for comparison purposes, in the event that future groundwater development or land use changes occur in the vicinity of the creek. Monthly monitoring of groundwater levels, streamflow extent and stream discharge in the preserve are conducted so that long-term trends and conditions are documented. This monitoring is consistent with the management plan for the preserve in which the goals include to maintain in-stream flows, preserve tree-sustaining shallow groundwater and preserve natives. PAG has monitored the hydrology in the Cienega Creek Natural Preserve (preserve) since 1989, in coordination with the Pima County Regional Flood Control District (PCRFCD). This report contains data collected between July 1, 2009 and June 31, 2010 (the fiscal year, i.e. monitoring year) on streamflow volume, groundwater levels, streamflow length (through the extent of the Preserve), water chemistry and photography. It also includes additional observations and studies, such as a summary of species of concern, an analysis of erosion impacts in one of the major head-cutting areas and drought reporting. Data tables and figures in this report focus on results from the 2009-2010 monitoring year, but they also show some data from previous years for comparison purposes.

The Cienega Creek Natural Preserve, which is owned by PCRFCD and co-managed by PCRFCD and Pima County Natural Resources Parks and Recreation (PCNRP&R), includes lower Cienega Creek and portions of lower Davidson Canyon. For ease of reading, the following geographically distinct areas are referred to in these terms throughout the report.

- Cienega Creek
This area is defined as reach of lower Cienega Creek between Interstate 10 and the diversion dam east of Vail, Arizona. This area is the main focus of PAG's hydrologic monitoring program.
- Cienega Creek Natural Preserve
This area includes lower Cienega Creek, Empirita Ranch south of I-10, and monitoring sites in lower Davidson Canyon.
- Cienega Watershed
This area includes the Preserve area and monitoring sites in upper Davidson Canyon (not in the Preserve, south of I-10)
- Upper Cienega Creek
The report does not include upper Cienega Creek which includes the Las Ciénegas Natural Conservation Area, managed by the U.S. Bureau of Land Management (BLM). Las Ciénegas is where the headwaters begin and flow north.

The locations of all of the monitoring sites are shown in Figures 1A and 1B. During FY 09-10, monitoring methods and locations remained essentially the same as in past years, with any exceptions for this year explained in this report. The specific methodology for each aspect of monitoring is described within its corresponding section. PAG has further documentation for protocols, forms and metadata available in-house, as well as reports from previous years available in the PAG on-line library.

Figure 1A. PAG Monitoring Site Locations in the Cienega Creek Watershed

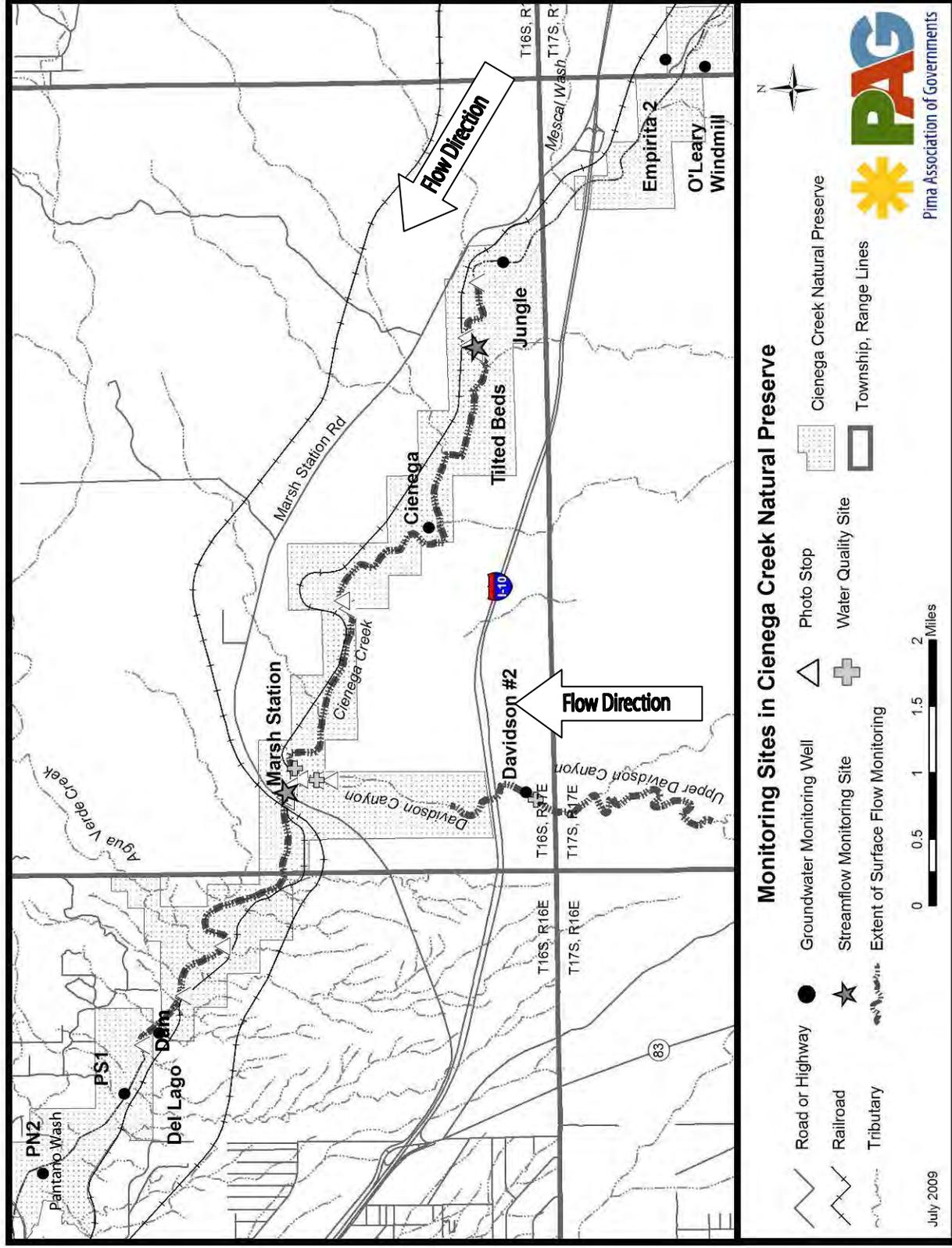


Figure 1B. PAG Water Quality Monitoring Site Locations



Water Quality Sampling Sites

Legend

- Water Quality Sample Site
- ★ Monitoring Sites
- Ephemeral Flow
- Perennial Flow
- Streets
- Dirt roads
- Railroad



Streamflow Volume

Methods

In Fiscal Year 2009-2010, PAG took monthly streamflow volume measurements at two sites using a USGS Pygmy Flow Meter and calculated the discharge (Q) in cubic feet per second (CFS). The sites are Marsh Station Road Bridge, downstream from the Cienega/Davidson confluence, and Tilted Beds, several miles upstream from Marsh Station (Figure 1A).

PAG monitors the streamflow during baseflow conditions, as required in the methodology of the program. Baseflows are produced by discharges from the shallow aquifer into the stream channel without the direct influence of surface runoff. If a significant rainfall event occurs within three days prior to a scheduled field event, the sampling is postponed until drier conditions prevail and runoff is thought to no longer have a direct influence on streamflow in the canyon. Baseflow is determined through County gages on the PC ALERT Web site, <http://alert.rfcd.pima.gov/scripts/pima.pl>, including rain gage numbers 4280, 4310, 4220 and 4250, and stream gage numbers 4283 (Cienega at I-10), 4313 (Davidson Canyon) and 4253 (Pantano at Vail). Field staff does not conduct monitoring under hazardous conditions, such as during flood flows or lightning storms.

Based on standard guidelines, streamflow measurements are taken at a location along the stream where the channel is relatively straight and streamflow is fairly uniform. When possible, points of converging and diverging flow paths are avoided. The stream form changes with each monthly visit and so the site location varies by up to 30 feet.

Results

FY 2009-2010 Results

The range in seasonal fluctuation was notably smaller in this monitoring year. In FY 09-10, streamflow at the Marsh Station site ranged from a low of 0.08 cfs (in September 2009) to a high of 1.07 cfs (in March 2010) (Table 1). This is a range of 0.99 cfs, whereas the previous monitoring year fluctuated by 1.78 cfs.

Tilted Beds was dry during FY 09-10, with the exception of January 2010, when isolated patches of water with immeasurable movement were observed (Table 1). Tilted Beds has a pattern of ephemeral flow for 2-3 years, followed by absence of flow for 2-3 years (Figure 3). The site flows generally during the winter months. However, from 2007 to 2009, Tilted Beds exhibited nearly consistent flow throughout the year. This site's flow may be ephemeral because it is more impacted by sedimentation and erosion processes than the Marsh Station site.

Historical Trends

Annual average streamflow remained lower than last year's levels at the streamflow sites. Streamflow data for this fiscal year are shown in Table 1, while Figure 2 graphically presents the streamflow trends for the past two fiscal years. To provide a longer term perspective on flow trends, Figure 3 shows discharge data from 1993 to the present.

Since monitoring began in 1993, annual average flow has declined over time. Annually averaged flow has fluctuated up and down within the long-term downward trend of streamflow volume at our perennial streamflow measuring site, Marsh Station (Figure 4). The two upward swings in annual average flow became lower each time (around 2001 and around 2008). Low periods of flow similarly became lower (during 1996-2000, 2002- 2006, and 2010) each period. The annual average streamflow at Marsh Station was lower this monitoring year than the last by 0.77 cfs (Table 1).

Within each monitoring year, there are normally seasonal peaks with winter rains and summer monsoon rains. Seasonal patterns can be seen in Figure 3. The downward trend has cyclical rises in the wet seasons of winter storms and summer monsoon rains. From 1993-2004, the highest seasonal peak usually accompanied winter rains. In the drought years of 2001-2004, winter rains sustained flow levels. From 2005-2009, the pattern switched and summer monsoon flows were higher than winter flows. Thus, for the less severe drought period of 2005-2009, it was the monsoons that were critical in bringing up the average flow levels (Figure 4). Fiscal year 09-10 was starkly unique in that there was no summer peak (Figure 2). This corresponds to the deficiency of monsoon storms and resulted in the record lowest annual average flow. The differences in the two seasonal flow periods would benefit from further analysis because they have profoundly different influences on the ecology of the stream.

Table 1. Monthly Streamflow Volumes (July 2009 - June 2010)

DATE	FLOW (cfs) Marsh Station	FLOW (cfs) Tilted Beds
Monthly Monitoring Data		
July 2009	0.290	0.00
August 2009	0.120	0.00
September 2009	0.080	0.00
October 2009	0.150	0.00
November 2009	0.130	0.00
December 2009	0.270	0.00
January 2010	0.540	0*
February 2010	0.830	0.00
March 2010	1.070	0.00
April 2010	0.670	0.00
May 2010	0.350	0.00
June 2010	0.180	0.00
Recent Annual Mean Flows		
2006-2007 AVERAGE	1.06	0.00
2007-2008 AVERAGE	0.99	0.07
2008-2009 AVERAGE	1.16	0.09
2009-2010 AVERAGE	0.39	0.00
Relative Flow Per Specified Period		
06-07 to 07-08 CHANGE ⁽¹⁾	- 0.07	+ 0.07
07-08 to 08-09 CHANGE ⁽¹⁾	+ 0.17	+ 0.02
08-09 to 09-10 CHANGE ⁽¹⁾	- 0.77	- 0.09

Table Notes

PAG measured all flows with a USGS Pygmy Flow Meter.

* = Slow water movement is present, but flow is not measurable with the Pygmy meter

1 = "CHANGE" is defined as the difference between annual averages

"+" = Increase in discharge

"-" = Decrease in discharge

Figure 2. Monthly Streamflow Volume at Tilted Beds and Marsh Station Sites (July 2008 - June 2010)

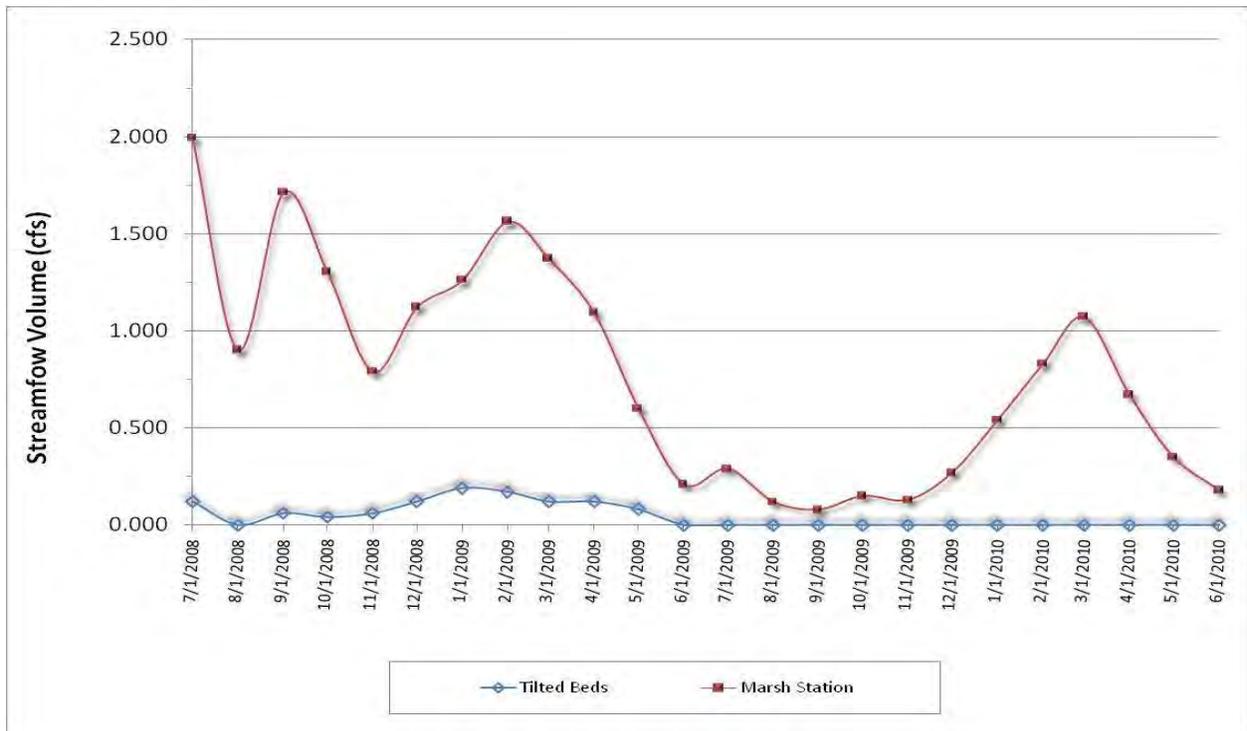


Figure 3. Monthly Streamflow Volume at Tilted Beds and Marsh Station Sites (1993 – 2010)

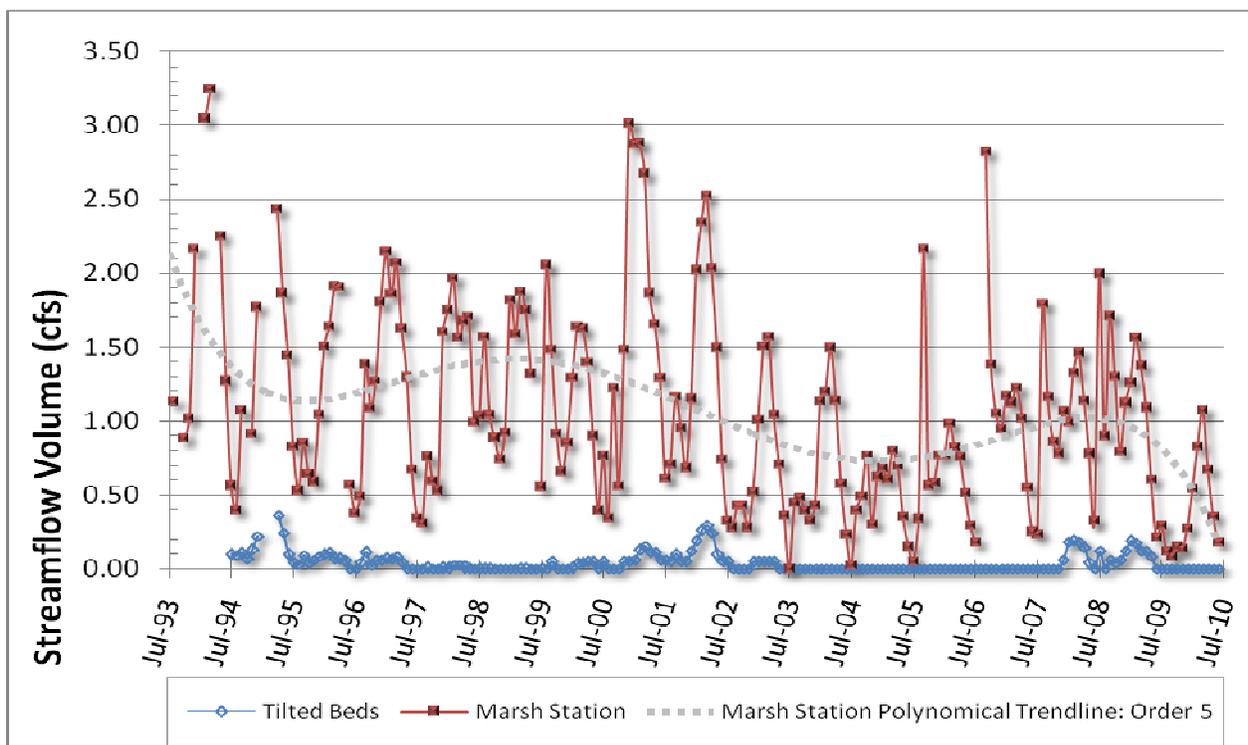
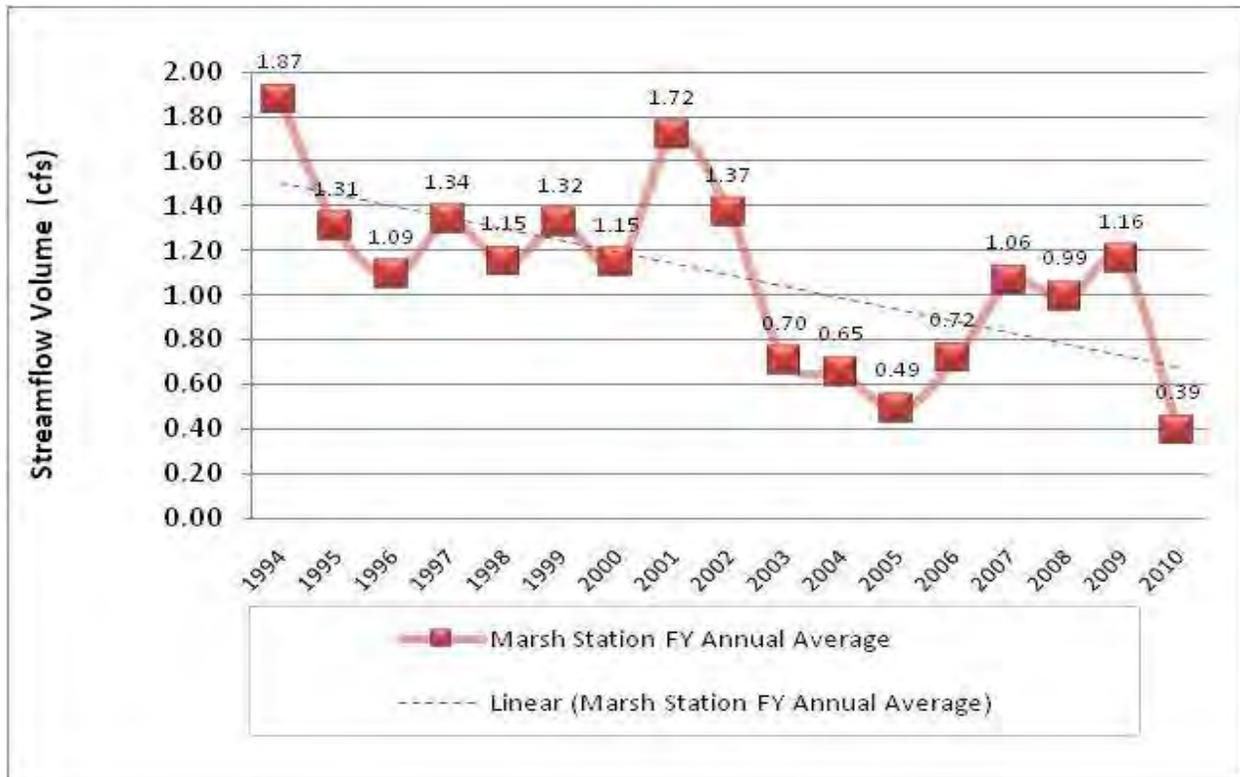


Figure 4. Annual Mean Streamflow Volume Trends at Marsh Station (FY 93-94 to FY 09-10)



Groundwater Levels

Methods

Depths to groundwater were measured at eight wells with either a Solinst Water Level Meter or with *in situ* transducers. The wells are distributed throughout the preserve length and are named (Figure 1A). On a monthly basis, PAG monitored the Jungle, Cienega, Del Lago 1 and Empirita 2 (when accessible) well sites. Davidson 2 continued to be monitored on a quarterly schedule. The PS-1 and PN-2 wells were monitored four times a day by ADWR transducers. If any monitor dates fell outside of this schedule, it is noted in Table 2. Because the O'Leary well had a pump installed in June 2007, which influenced subsequent water levels, it has been removed from the monitoring program and calculations.

Results

Long-Term Trends

Trends in groundwater levels follow trends of streamflow closely. Recent mean annual changes are displayed in Figure 5 and Table 3, while Figure 6 exhibits the long-term trends, showing water level data from 1994 to the present. In FY 09-10, annual mean water levels dropped appreciably at all wells, reaching one of the most severe drought stages on our records because of the lack of summer monsoons. With the exception of June 2006 to June 2009, when water levels increased, yearly declines in groundwater levels were exhibited since 1994, with a rise in 2001. In 2002, drought began to appreciably impact the Cienega Creek Natural Preserve. In the two years prior to this monitoring year, water levels rose at some wells and fell at others, creating an average of slightly increased water levels in FY 06-07 and FY 08-09, but they never averaged above pre-drought levels. More information on trends, including measurements of declines, is also available in the drought section of this report in which two wells with consistent records are compared to create means. Due to inaccessibility of the other wells, inconsistency of records prevents comparison means of all well levels through time.

Seasonal Patterns

Figure 7 presents seasonal fluctuations in water level data for this monitoring year and the previous fiscal year. Seasonal trends were observable at most monitoring wells, although FY 09-10 showed an atypical pattern. Typically, groundwater levels rose most dramatically in August and September, with additional smaller increases in January at most wells. Due to a lack of summer rains, there was no post-monsoon peak in FY 09-10. The degree of seasonal fluctuation at each well depended on the amount of precipitation, the proximity to the creek and the geology. The Jungle and Cienega wells experienced gradual seasonal changes, whereas the wells downstream of Del Lago dam (PS-1 and PN-2) have the largest seasonal response. The Del Lago well was unique in that it expressed large seasonal change in years in which groundwater levels were higher and yet had stable water levels with minimal seasonal responses throughout the low water years of 2003-2006, as well as with the absence of the monsoon in 2009. As is the case with the Jungle and Cienega wells, the groundwater levels seemed to fluctuate less where the underlying bedrock and topography create shallower groundwater zones and where there are more stable perennial flows within gaining stream reaches.

Streamflow Near Wells

By observing flow presence in the stream adjacent to each of the well sites, PAG observed the groundwater level associated with surface flow at each site. The streamflow presence near the Cienega well site appears to correspond to a depth to water at the well of less than 13 feet, near the Jungle well site when the depth is less than 30 feet and near the Davidson well site when the depth is around 12 feet. At one site, Empirita, PAG has not seen flow, so the associated shallow groundwater level is not known. Del Lago is the sole site that has perennial flow and no groundwater levels associated with surface flow in our records.

More sites exhibited no baseflow this monitoring year than last year. None of the groundwater levels associated with flow was reached in FY 09-10 at the Cienega, Jungle and Davidson sites. In contrast, in FY 08-09, streamflow was present at most well sites from July through September (Table 2). The flow at PS-1 and PN-2 in March 2010 was due to surface flow released at the dam and was not due to groundwater surfacing above the sediment. Those groundwater levels do not regularly cause flow sightings at these sites.

Table 2. Depth to Groundwater and Streamflow Presence at Cienega Creek Natural Preserve Monitor Well Sites

Monthly Monitoring in Fiscal Year: July 2009 – June 2010

DATE	DEL LAGO-1		CIENEGA		JUNGLE		EMPIRITA-2 ⁽³⁾		DAVIDSON-2 ⁽¹⁾		PS-1 ⁽²⁾		PN-2 ⁽²⁾	
	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth
7/14/09	71.9	y, .20 ft	18.9	n	33.1	n	81.4	n			57.1	n	193.4	n
8/18/09	75.9	y, .19 ft	19.8	n	34.2	n	81.7	n			54.7	n	197.4	n
9/17/09	76.3	y, .15 ft	20.1	n	34.8	n	82.0	n	21.4	n	56.9	n	200.8	n
10/14/09	77.5	y, .13 ft	20.6	n	35.5	n	82.3	n			58.2	n	203.5	n
11/12/09	77.6	y, .17 ft	20.7	n	35.8	n	82.7	n			59.5	n	206.2	n
12/21/09	77.6	y, .21 ft	19.4	n	35.8	n	83.2	n	25.4	n	60.4	n	209.8	n
1/26/10	76.4	y, .11 ft	16.9	n	35.6	n	83.6	n			60.4	n	212.8	n
2/19/10	75.9	y, .18 ft	15.5	n	35.7	n	83.8	n			59.6	n	214.7	n
3/11/10	65.2	y, .53 ft	15.1	n	35.7	n	84.0	n	24.6	n	38.5	y, .72 ft	215.8	y, .45 ft
4/20/10	70.1	y, .20 ft	15.8	n	36.2	n	85.2	n			47.4	n	187.1	n
5/18/10	75.6	y, .22 ft	17.0	n	36.7	n		n			52.0	n	186.7	n
6/11/10	76.6	y, .18 ft	18.7	n	37.9	n	86.7	n	26.1	n	54.3	n	188.0	n

Note: All depths are feet below land surface. Streamflow is observed in the closest streambed location: “y” = streamflow was present, “n” = no streamflow was present. Streamflow presence is accompanied by maximum stream depth data.

*Due to fluctuation in well water depth levels from pumping, PAG is no longer monitoring the O’Leary well.

⁽¹⁾ Measured quarterly

⁽²⁾ Monitored by ADWR

⁽³⁾ Inconsistently accessible

Figure 5. Annual Change in Average Depth to Water

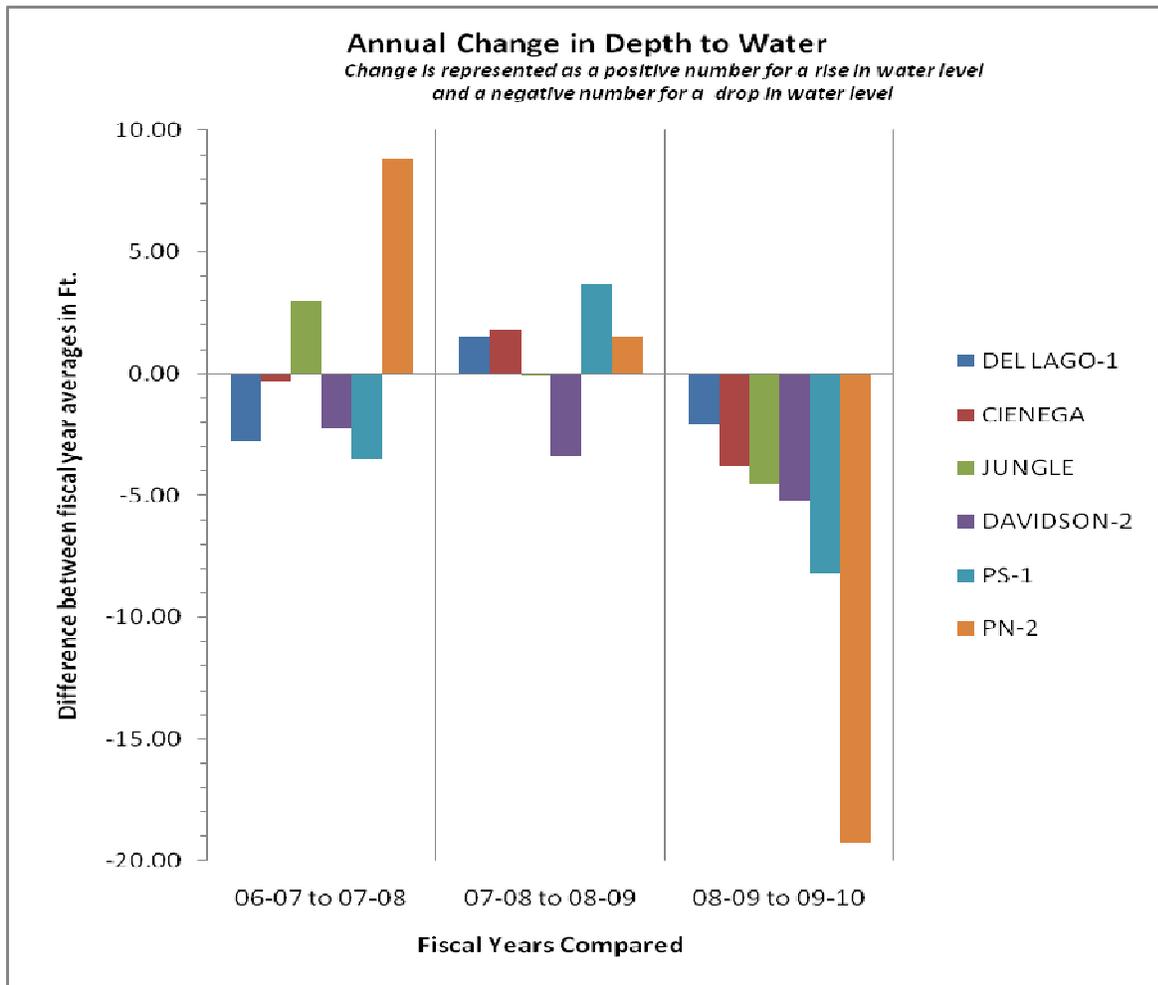


Table 3. Annual Average Depth to Water

DATE	Annual Average Depth to Water (ft.)				Annual Change (ft.)		
	06-07	07-08	08-09	09-10	06-07 to 07-08	07-08 to 08-09	08-09 to 09-10
DEL LAGO-1	69.47	72.21	70.68	74.71	-2.74	1.53	-2.07
CIENEGA	15.95	16.27	14.45	18.20	-0.32	1.82	-3.76
JUNGLE	33.99	30.98	31.02	35.56	3.01	-0.04	-4.54
DAVIDSON-2	20.30	22.55	19.17	24.37	-2.25	-3.38	-5.20
PS-1	46.88	50.38	46.71	54.91	-3.50	3.67	-8.20
PN-2	192.50	183.65	182.10	201.36	8.85	1.55	-19.26
Average	63.18	62.67	60.69	68.19	0.51	0.86	-7.17

Note:

All depths are feet below land surface.

Davidson is measured quarterly.

PS-1 and PN-2 are monitored by ADWR.

Empirita-2 and O'Leary were inconsistently available, so they are not included.

Figure 6A. Cienega Creek Natural Preserve Monthly Depth to Groundwater (June 1994 - June 2010)

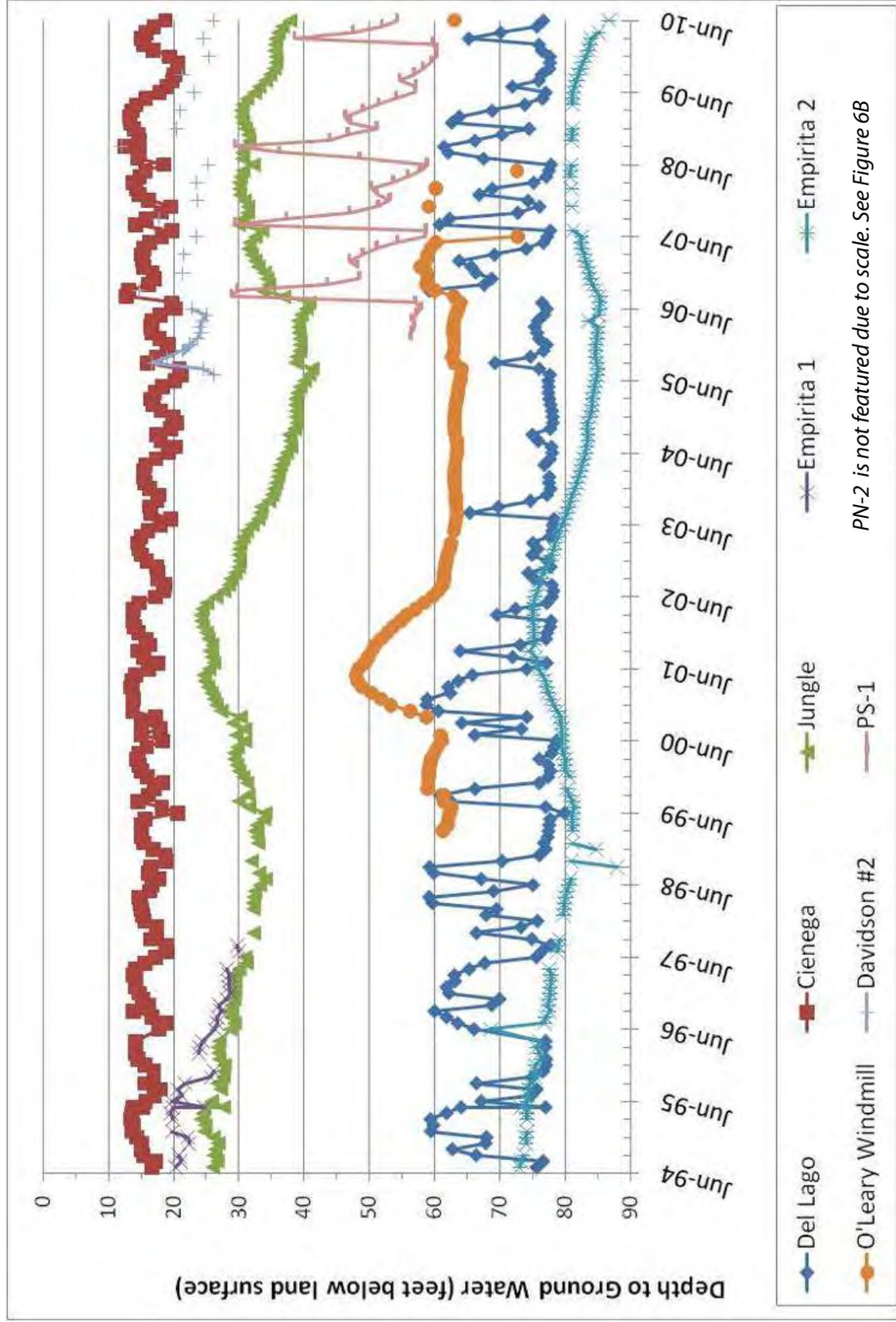


Figure 6B. PN-2 Monthly Depth to Groundwater (June 2006 - June 2010)

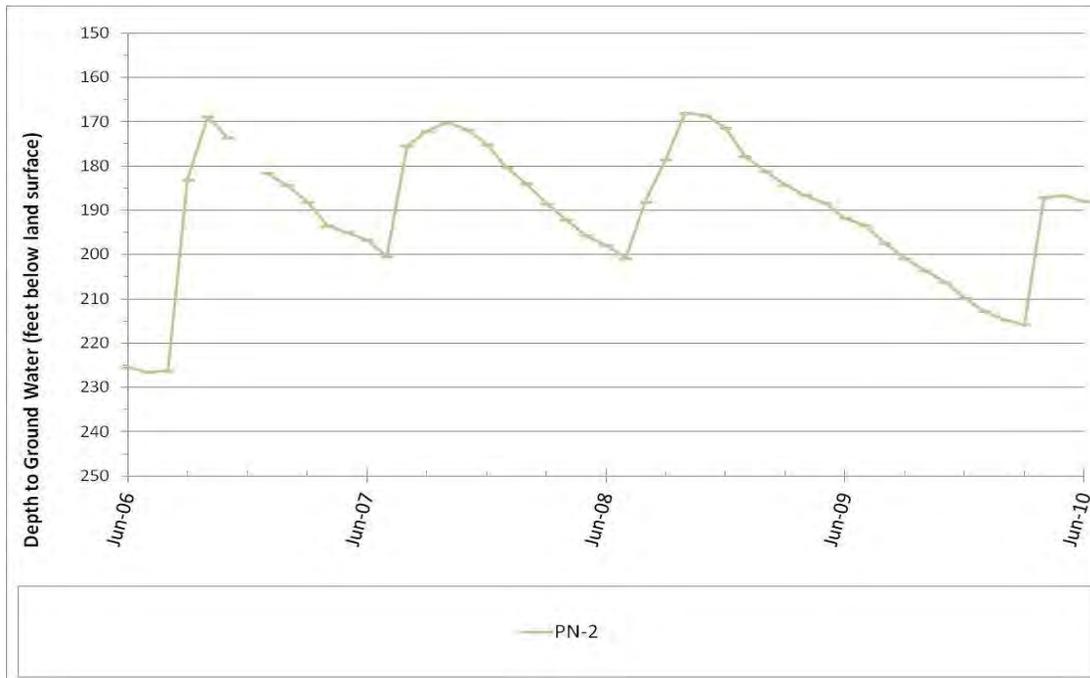
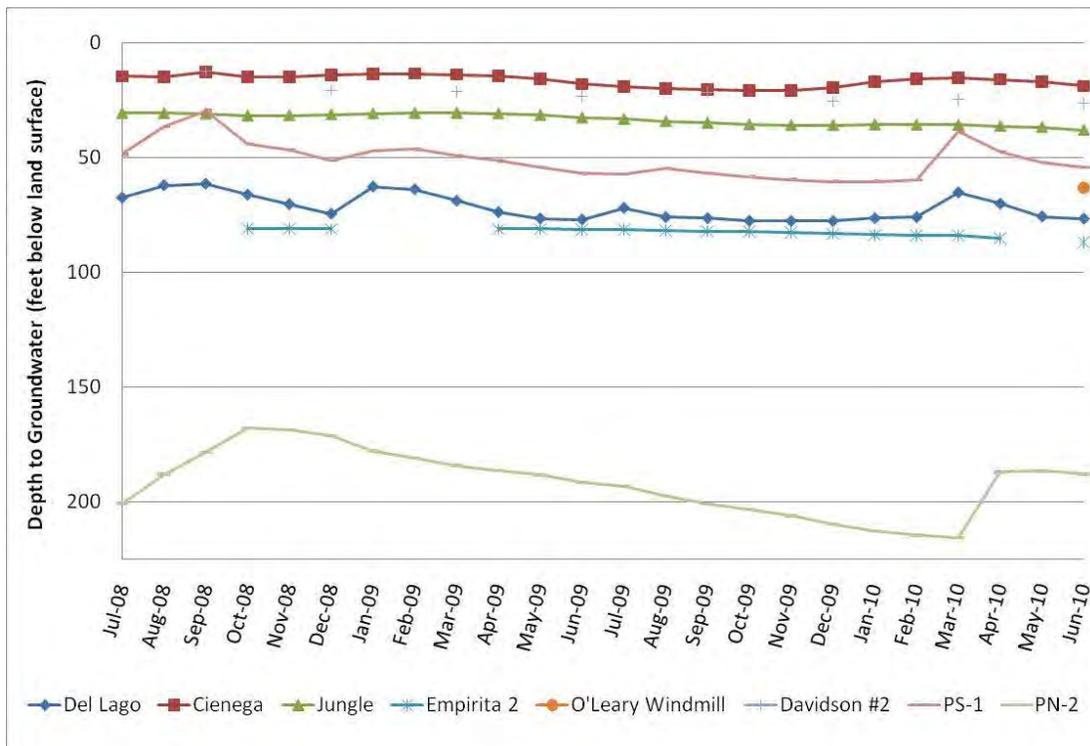


Figure 7. Cienega Creek Natural Preserve Monthly Depth to Groundwater (July 2008 - June 2010)



Data are not available for some months due to inaccessibility.

Extent of Surface Flow (Wet/Dry Mapping Walk-Throughs)

Methods

The extent of surface flow was mapped by walking the length of the creek channels and marking the location of the flows. For this report, the length of flow is referred to, the topic is the distance of stream that has flow extent, not the span of time that it is flowing. Annual wet/dry mapping was conducted during our driest month of June, between 1999 and 2001; the current quarterly schedule for the wet/dry program began during the FY 01-02 monitoring year. Quarterly mapping is conducted during the months of September, December, March and June. Cienega Creek walk-throughs begin at the ephemeral reach at Jungle Road and continue to the Pantano (Del Lago/Vail Water) diversion dam, a distance of about 8 miles (Figure 1A). Lower Davidson Canyon walk-throughs have been conducted near its confluence with Cienega Creek since FY 01-02 and in upper Davidson Canyon, south of Interstate 10 on the County's Bar V property, since FY 05-06.

The mapped extent of streamflow is processed using GIS. From 1999 to 2008, wet/dry mapping was completed on hardcopy aerial photography maps in the field and was subsequently hand digitized in GIS (ArcMap) to clip a creek shapefile line into corresponding flowing segments. In FY 07-08, PAG began using a GPS (Trimble) Unit to mark points at the beginning and end of intermittent flow. PAG continues to use GIS to clip the same Cienega streamflow shapefile line, which follows the general incision of the creek, but does not necessarily follow the small meanders, since the particular stream course changes over time. This shapefile template is from the Pima County Land Information System and was created at a 1:200,000 scale. The mapping results are shown in Figure 8 and Figure 11.

The length of surface flow for each quarterly walk-through is calculated by totaling the extent of each flowing segment. As is consistent with historical records, PAG considers the total length of creek channel within the preserve to be 9.5 miles. This includes the section of creek that begins at the I-10 crossing and flows north-west to the dam, but PAG does not walk the first 1.5 miles since it is known to be dry. All flow lengths within the Preserve, including lower Davidson Canyon, are included in the total sum of flow length. Located outside the Preserve, the sum of flow length for upper Davidson Canyon (Figure 1A) is calculated and presented separately.

Results

Historical and Current Cienega Flow Extent:

These data are evaluated for trends of average annual total distance of the surface flow length, seasonal variation, intermittency of segments and minimal perennial flow trends.

The annual average total distance of surface flow extent in the Cienega Creek Preserve since 1975 has decreased over time (Figure 10). It decreased from 7.7 miles, the average flow length from 1975 to 1992, to 4.1 miles on average since 2001. Using this flow extent data plus groundwater levels, streamflow volume and precipitation data, PAG considers the time period since 2001 to be a drought period. In the short term (Figure 9), the annual average flow extent was 3.3 miles in length during FY 09-10, a decrease of 61% from last year.

The documentation of seasonal variation helps to identify ephemeral and perennial reaches. Seasonal variation is evaluated for each year by taking the difference between the quarters with the longest and shortest total flow extents. The largest change in flow extent generally occurs as a decline between the months of March and June, which coincides with the time period when evapo-transpiration rates increase, precipitation is minimal and recharge rates decrease (Figure 8 and Table 4). With drought, increased seasonal variation of surface flow length was observed (Figure 10). The

difference between the high and low seasons' averages 3.0 miles since 2001. Prior to 1993, the difference between seasons' flow lengths ranged between 0.0 to 1.7 miles.

Mapping streamflow during the driest part of the year conservatively identifies the perennial reaches in the Preserve. As seen in Figure 8, the total flow extent in the Preserve is consistently lowest pre-monsoon, in June. Summer flow extents have declined substantially since the 1980s (Table 5, Figure 12). In July 1984, the creek flowed continuously from I-10 to the Pantano Dam, a distance of 9.5 miles (Montgomery & Associates 1993). In contrast, the average percentage of wet (i.e. flowing) creek length in the same area in June since 1999 has been 28 percent. Since 1999, the summers of 2004 and 2005 were a low point followed by a rise in flow in 2007, 2008 and 2009 (Figure 9). With a decrease in summer flow this June 2010, the creek flowed for 2.38 miles in total, composing 25 percent of the monitored preserve length (Figure 11). This was 0.3 miles less than the average since 1999. In addition to shorter total flow extent, drier years and drier seasons also generally have shorter length stream reaches, as seen in Figure 8 and Table 4.

The month with the longest total flow extent is usually either March or September (Figure 8 and Table 4). This analysis finds that a rise in annual average flow extent coincides with the longest extent occurring in September. These lengthier September extents are a result of the monsoon precipitation, which decreases drought impacts when looked at as an annual average of flow. This is consistent with this year's findings and is true for both streamflow volume and flow extent, since March had the greatest flow length and drought impacts have increased. In addition to September 2009 not exhibiting the greatest flow extent this year, for the first time on record, September had lower flow than June. September 2009 had 52% of the average September flow length. September 2009 was especially unique because it had the lowest September flow length on record, which was most likely due to a lack of monsoon rainfall in 2009. PAG had previously noted that 2004 was the lowest of the drought years, but September 2009 flow was 0.5 miles less than September 2004. However, average annual flow length in FY 04-05 was 0.7 miles shorter than in FY 09-10 and still ranks as the peak drought year.

Lower Davidson Canyon Flow Extent:

Since 2001, when mapping began in lower Davidson Canyon near the confluence with Cienega Creek, the extent of surface flow has considerably varied both annually and seasonally. Every other year, the reach alternates between near year-round flow and near year-round dryness. In FY 09-10 lower Davidson Canyon had no flow in any of the monitoring quarters (Table 4). In FY 08-09, lower Davidson Canyon had flowing extents for three quarters of the year. In FY 07-08, the reach only flowed during a single quarter, measured in September; FY 06-07 had flow year-round; and FY 05-06 had no flow year-round.

Upper Davidson Canyon Flow Extent:

The flowing reaches of upper Davidson Canyon are located at a spring next to a bedrock outcrop south of the I-10 crossing (as seen on the map in Figure 8). This is the fifth year that these surface flows were systematically mapped, but the streamflows along this reach were also noted during earlier PAG studies. Pools of considerable size, between one to three feet deep, remain along this channel, but no fish have been sighted since the summer of 2005. The only flowing quarter in Davidson Canyon in FY 09-10 was in September 2009 when it flowed for 0.58 miles (Table 4). Since monitoring began in Upper Davidson Canyon, September has been the peak flow extent, followed by progressively lower flows each quarter through the monitoring year. In FY 09-10, PAG observed the lowest September flow on our short record, followed by the first observation of consecutive quarters of no flow. June 2008 was the only other quarter where no flow was seen since monitoring began on this reach in September 2005.

Table 4. Cienega Creek, Lower Davidson Canyon and Upper Davidson Canyon, Quarterly Data for Lengths of Each Flowing Segment (Sep. 2009 - June 2010)

Flowing Reach	Length of Flowing Reach (feet)			
	September	December	March	June
	9/17/2009	12/7/2009	3/35/10	6/17/2010
Cienega Creek Reach A	245	6125	8262	182
Cienega Creek Reach B	209	3819	3498	224
Cienega Creek Reach C	3121	5931	927	26
Cienega Creek Reach D	3898	1135	175	85
Cienega Creek Reach E	1604		5715	108
Cienega Creek Reach F	578		6360	1218
Cienega Creek Reach G	658		4648	1366
Cienega Creek Reach H			328	4731
Cienega Creek Reach I			57	3016
Cienega Creek Reach J				1589
Lower Davidson Canyon Reach A	0	0	0	0
TOTAL (ft)	10313	17010	29970	12545
(miles)	1.95	3.22	5.68	2.38
Upper Davidson Canyon Reach A	19	0	0	0
Upper Davidson Canyon Reach B	888			
Upper Davidson Canyon Reach C	260			
Upper Davidson Canyon Reach D	1877			
TOTAL (ft)	3044	0	0	0
(miles)	0.58	0.00	0.00	0.00

Reaches are not numbered in sequence; they are not associated with any one fixed portion on the creek. A lower total number of reaches generally indicates less interrupted flow.

Upper Davidson Canyon reaches are mapped on different dates than Cienega Creek and lower Davidson Canyon reaches due to the length of time required to complete both creeks.

Table 5. Cienega Creek and Upper Davidson Canyon, Summer Months' Total Length of Flow Extent, (1984 -2010)

Year	Length of Cienega Creek	Length of Upper Davidson	Source	
Jul-84	50,000 ft. (9.5 miles)	No data	Errol L. Montgomery & Associates, Inc.	
May-85	50,000 ft. (9.5 miles)			
May-86	43,140 ft. (8.2 miles)			
May-87	43,200 ft. (8.2 miles)			
May-88	41,500 ft. (7.9 miles)			
May-89	34,640 ft. (6.6 miles)			
May-90	37,400 ft. (7.1 miles)			
May-91	42,160 ft. (8.0 miles)			
May-92	37,740 ft. (7.1 miles)			
<i>No data 1993-1998</i>				
Jun-99	14,290 ft. (2.7 miles)	No data	PAG	
Jun-00	14,590 ft. (2.8 miles)			
Jun-01	24,950 ft. (4.7 miles)			
Jun-02	17,220 ft. (3.3 miles)			
Jun-03	10,630 ft. (2.0 miles)			
Jun-04	8,145 ft. (1.5 miles)			
Jun-05	7,865 ft. (1.5 miles)			
Jun-06	12,025 ft. (2.3 miles)			170 ft. (.03 miles)
Jun-07	15,860 ft. (3.0 miles)			483 ft. (.09 miles)
Jun-08	14,831 ft. (2.8 miles)			0 ft. (0 miles)
Jun-09	16,127 ft. (3.1 miles)	1,187 ft (.22 miles)		
Jun-10	12,566 ft. (2.4 miles)	0 ft (0 miles)		

The length of the Cienega Creek channel from Interstate 10 to the Pantano Dam equals 50,000 ft. (9.5 miles) and includes 1,100 ft. (0.21 miles) of Lower Davidson near the confluence with Cienega in this calculation. Upper Davidson includes 22,700 ft. of creek channel (4.3 miles) from the spring south of the I-10 crossing down to the beginning of the Lower Davidson Reach. Data were collected by Errol L. Montgomery & Associates from 1984 to 1993. Data were not collected from 1993 through 1998.

Figure 8. Maps of Cienega Creek and Davidson Canyon, Quarterly Flow Extent (Sep. 2009 - June 2010)

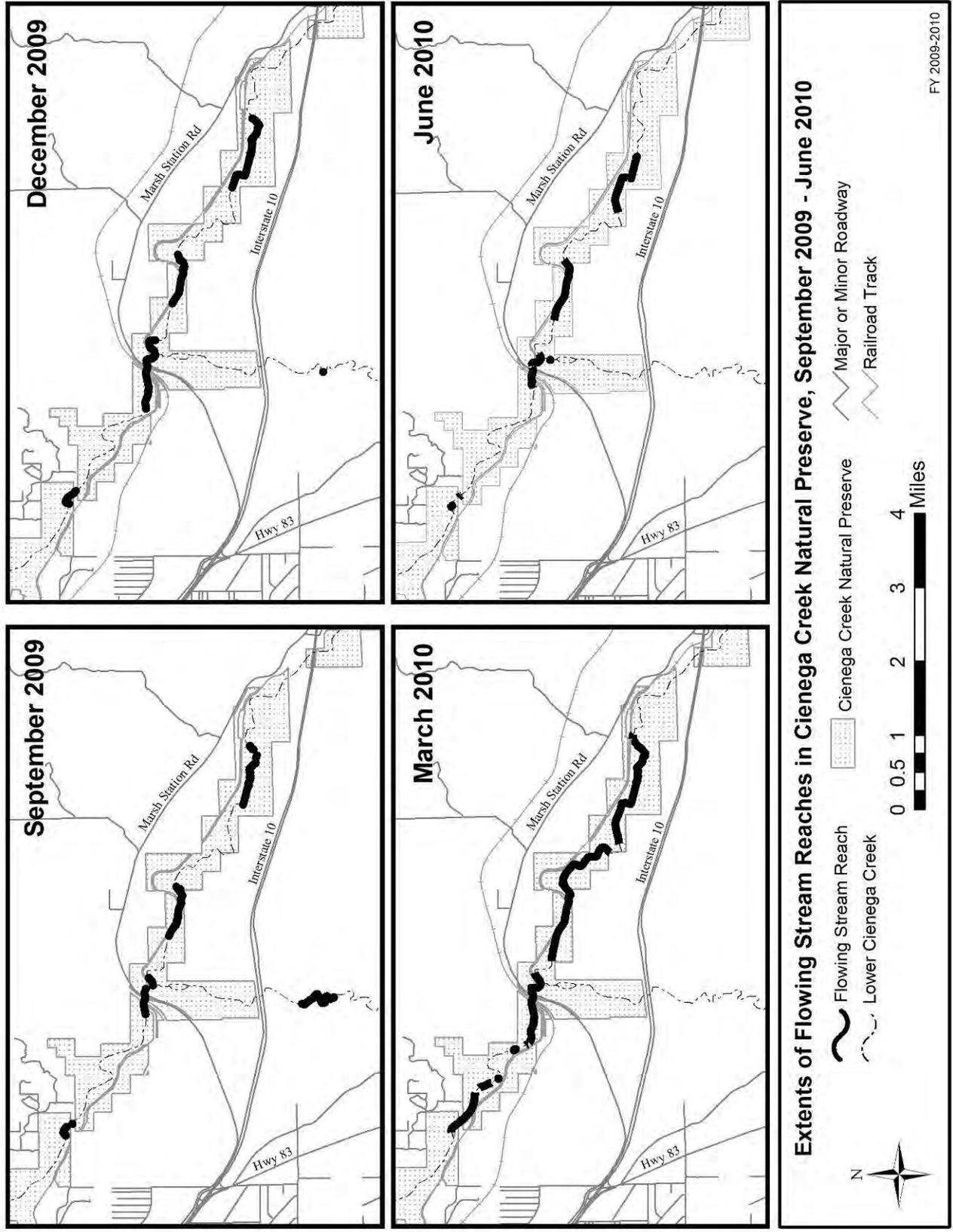


Figure 9. Cienega Creek Quarterly Flow Extent, 1999 to 2010

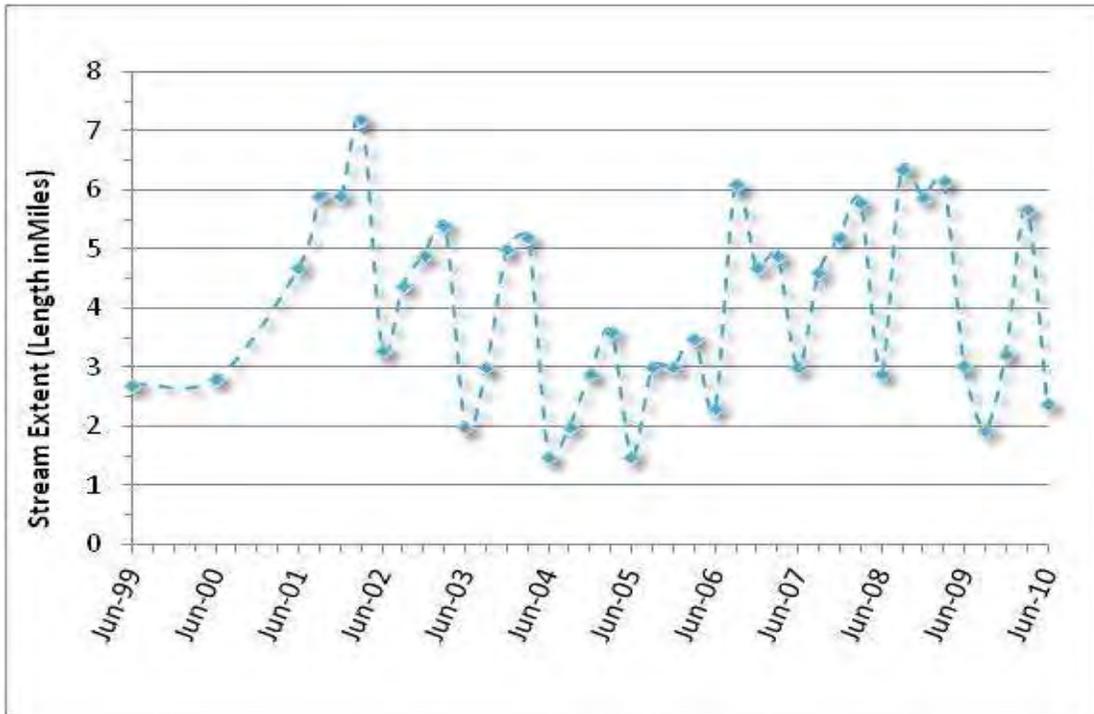
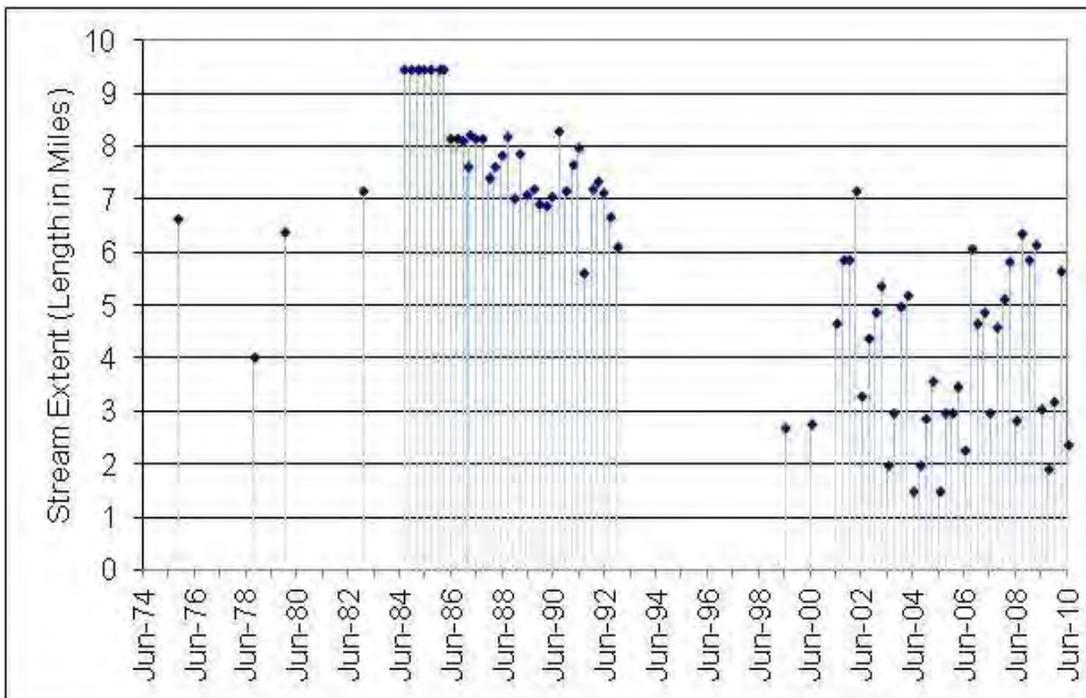


Figure 10. Cienega Creek Flow Extent, 1975 to 2010



Data prior to 1993 is from Errol L. Montgomery & Associates, (Montgomery & Associates 1993). Prior to 1984, and between 1999-2000, flow extent was measured was not consistently. Extent length was measured in October 1974, September 1978, December of 1979 and 1982, and June of 1999 and 2000, typically drier months. Length was not measured from 1993-1998. Akko other measurements were taken quarterly.

Figure 11. Map of Cienega Creek's June Flowing Reaches with Wet/Dry Pie Charts, 1999 to 2010

Cienega Creek Annual Wet/Dry Status in June

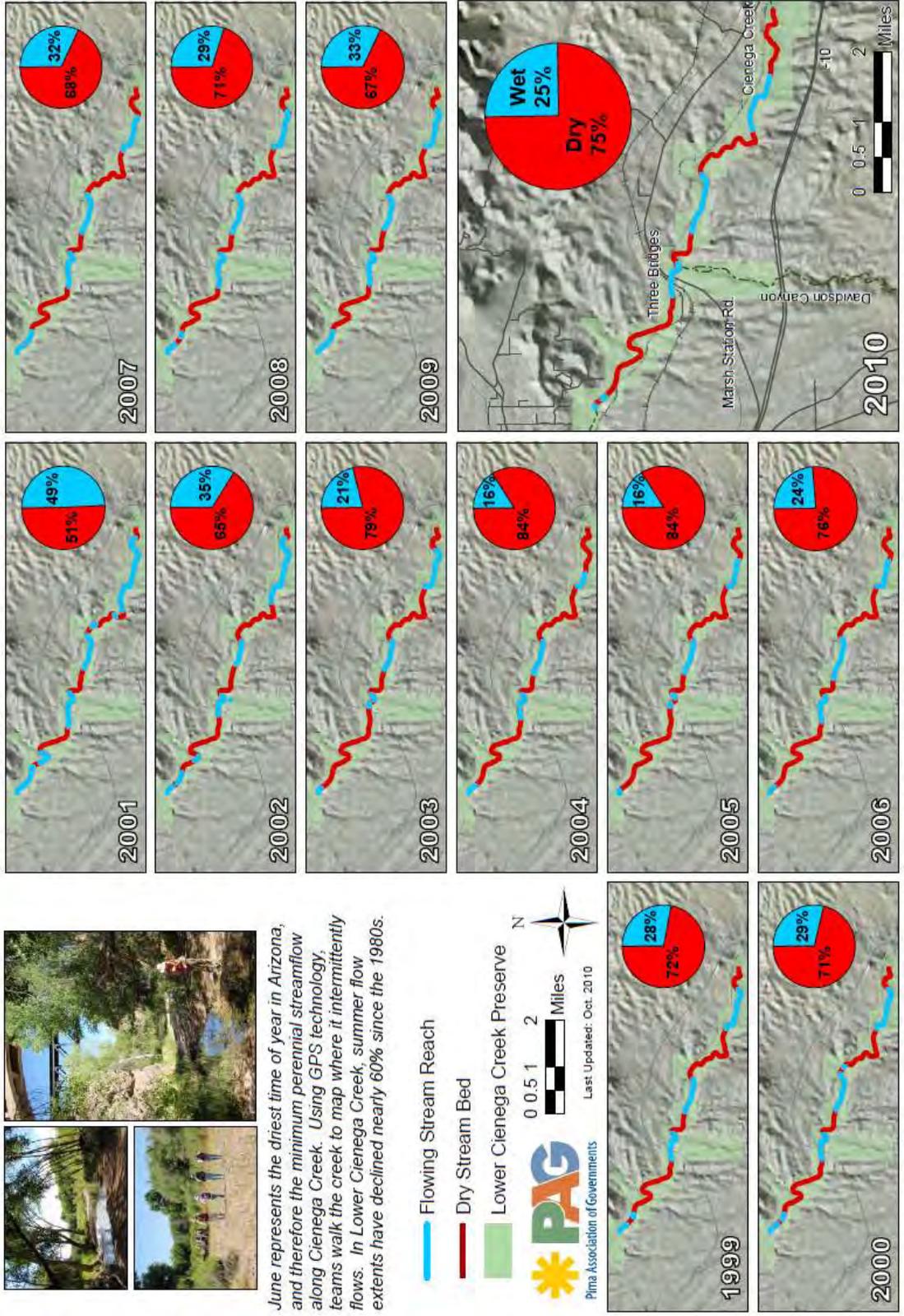
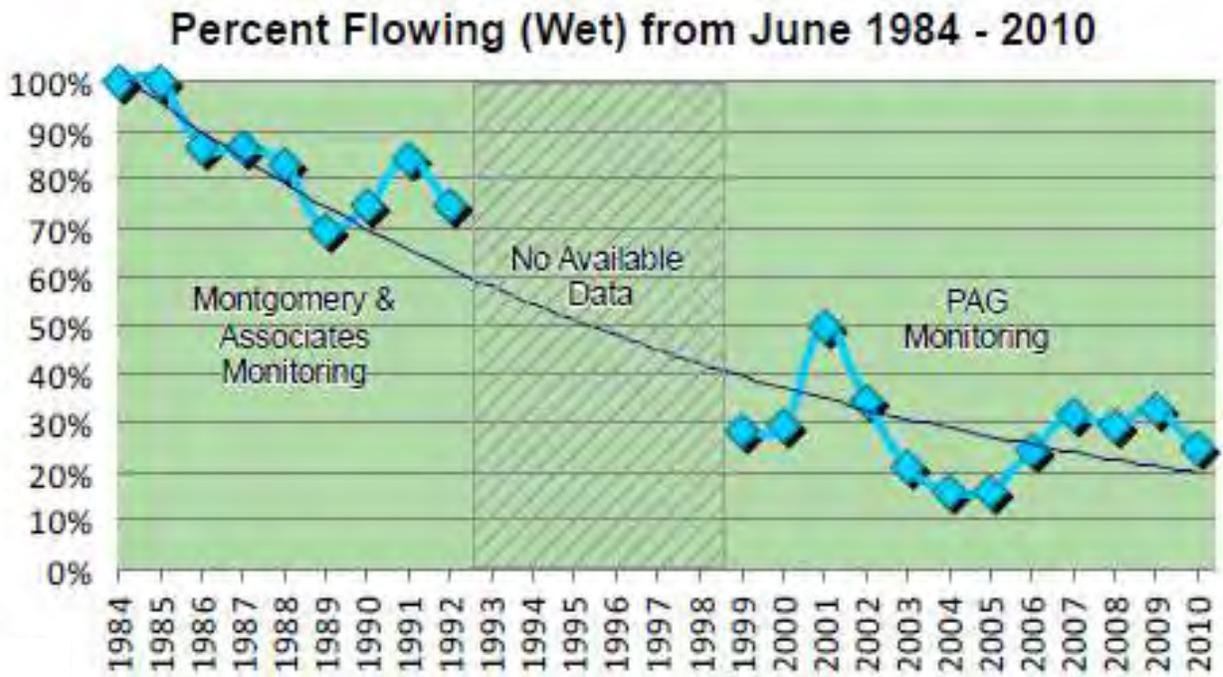


Figure 12. Graph of Percent of Creek Length Flowing in June: Perennial Flow



Water Chemistry

Methods

In January 2007, PAG began regular water quality monitoring at four monitoring sites that had also been monitored in past PAG studies. ADEQ's inclusion of Davidson Canyon as an Outstanding Arizona Water was the impetus for resuming the water quality monitoring in 2007. This monitoring will serve as additional baseline data, should the creek become impacted by upstream copper or limestone mining.

The locations of the monitoring sites for water chemistry are displayed in Figure 1B. Current monitoring stations, Davidson 3 and Davidson 2 are both located in Davidson Canyon upstream from its confluence with Cienega Creek, and both exhibit ephemeral flow conditions. Davidson 3 replaced Davidson 1 after it went dry. Cienega 1, located just upstream of the confluence with Davidson Canyon is a perennial site. Cienega 2, located downstream from the confluence at Marsh Station Bridge, is also a perennial streamflow monitoring site. ADEQ has over 10 years of historical water quality data from the Marsh Station monitoring location.

Various water quality field parameters were measured by PAG staff during walk-throughs at the four water quality sites. In addition, Cienega 2 field parameters were measured during monthly streamflow monitoring. PAG uses an Ultrameter to measure field parameters consisting of Total Dissolved Solids, temperature, conductivity and pH. At two sites, samples are collected and processed twice a year, in March and September. Sampling analytes include alkalinity, anions, TDS, metals, hardness, Nitrate, Nitrite, turbidity and Cyanide. A complete list of analytes included in sampling is not included in this report but is available upon request. One sampling site is Cienega 1 and the other sites vary depending on availability of flow. Davidson 3 is the preferred second sampling site, but if that spring is dry, PAG samples in Cienega Creek below Davidson's confluence (at Cienega 2) to measure influences of Davidson Canyon.

Prior to the field day, PAG prepares sampling analyte forms and protocols and requests PCRFC and the lab to review the updates and purchasing information. PAG keeps the chain of custody record, field parameter records and streamflow volume data. PCRFC analyzes the sampling results. The water quality Ultrameter is maintained by monthly calibration. Field notes of field parameter measurements and sampling include date and time, a description of the weather, the names of the field crew, the site name and any calibration observations. Water quality measurements are only gathered during baseflow conditions when clear, non-storm runoff water is flowing in the creek. Samples and readings are not collected from standing water, eddies or sections with immeasurable flow. Samples are collected using gloves; samples are filled so that no air is sealed into the bottle; samples are stored on ice and return to the lab in a timely manner so that analytes can be processed within 24 hours. Streamflow volume is measured to accompany all sampling efforts.

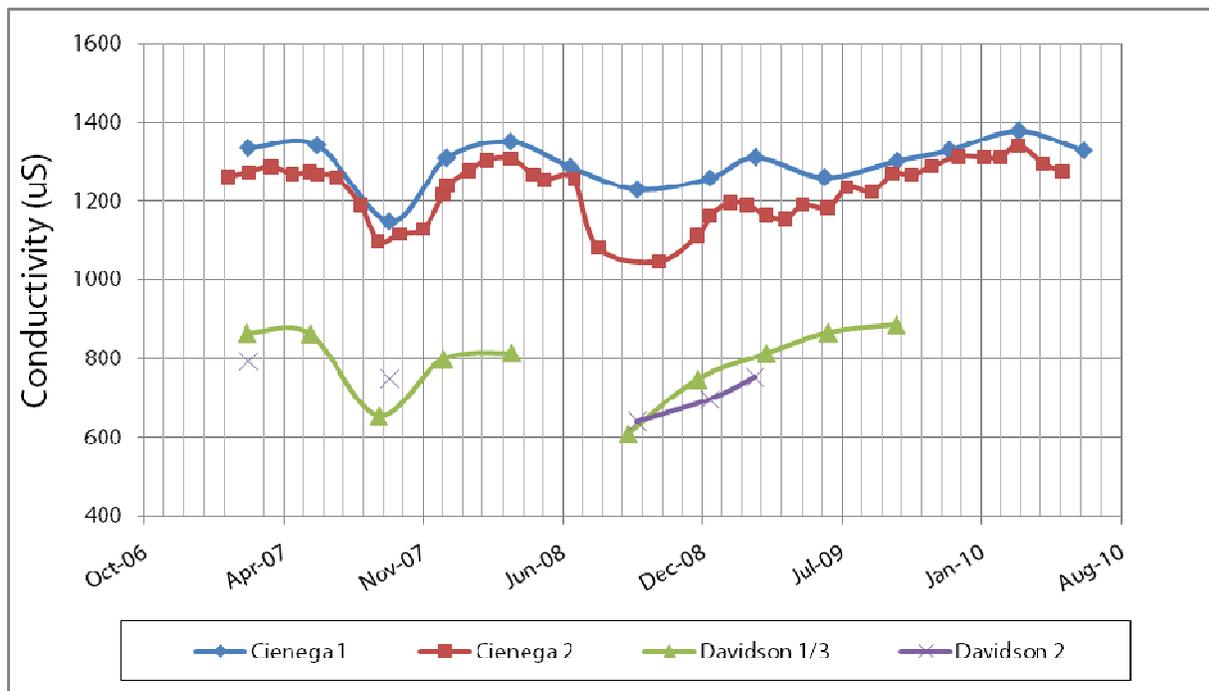
Results

Our data shows seasonal and geographic variations in water chemistry, but does not indicate any significant long-term trends. Seasonally, conductivity and total dissolved solids drops in the fall. Conductivity fluctuates by about 200 μS within a year (Figure 13). This trend was not observed in 2009, possibly due to abnormally low precipitation. The average conductivity of the Davidson Canyon sites is lower than the Cienega sites. The contribution of Davidson Canyon to baseflows in Cienega Creek may lower the conductivity at the Cienega Creek downstream from the Davidson confluence (Cienega 2). The long-term trend (Figure 14) shows that over the last nine years, conductivity increased slightly at all sites, except for a slight decrease at Davidson 2. The pH was highest at Davidson 1/Davidson 3 and at Cienega 2 (Figure 15). The temperature was lowest at Cienega 1 (Figure 16).

Further sampling and water chemistry data is available from the following sources:

- Errol L. Montgomery & Assoc. (EMA) in June 2008 at Cienega 1, Davidson 2 and Davidson 3 and in October 2008 at Cienega 1, Davidson 2 and Tilted Beds
- PAG sampling results (Test America Lab Work) taken at Davidson 3 in September 2008 and September 2009. Samples were taken at Cienega 1 and Cienega 2 in March 2010, above and below the Davidson confluence because the Davidson sites were dry at that time.
- Water Quality Studies Within The Cienega Creek Natural Preserve: Prepared by: David Scalero, Principal Hydrologist, and Frank Postillion, Chief Hydrologist, Pima County Regional Flood Control District, Water Resources Division, April 10, 2009 (analysis of EMA and PAG lab-work from 2008)
- PAG Quarterly samples were taken in 2002-2003 and a single sample in 2005 for the Unique Waters Study and more metals were sampled in 2005 for the Davidson Unique Waters Plan.
- PAG 2002-2003 quarterly samples for isotopes, chemistry and constituent sampling in the Davidson Cienega Study

Figure 13. Cienega Watershed – Seasonal Conductivity Fluctuation (January 2007 - June 2010)



Note: Davidson 3 serves as a replacement for the Davidson 1 site since March 2007. Depending on the site, readings were measured every 1-3 months, when sites had available flow. No data was collected from 2004-2006.

Figure 14. Cienega Watershed – Change in Average Conductivity per Site (2002 – 2010)

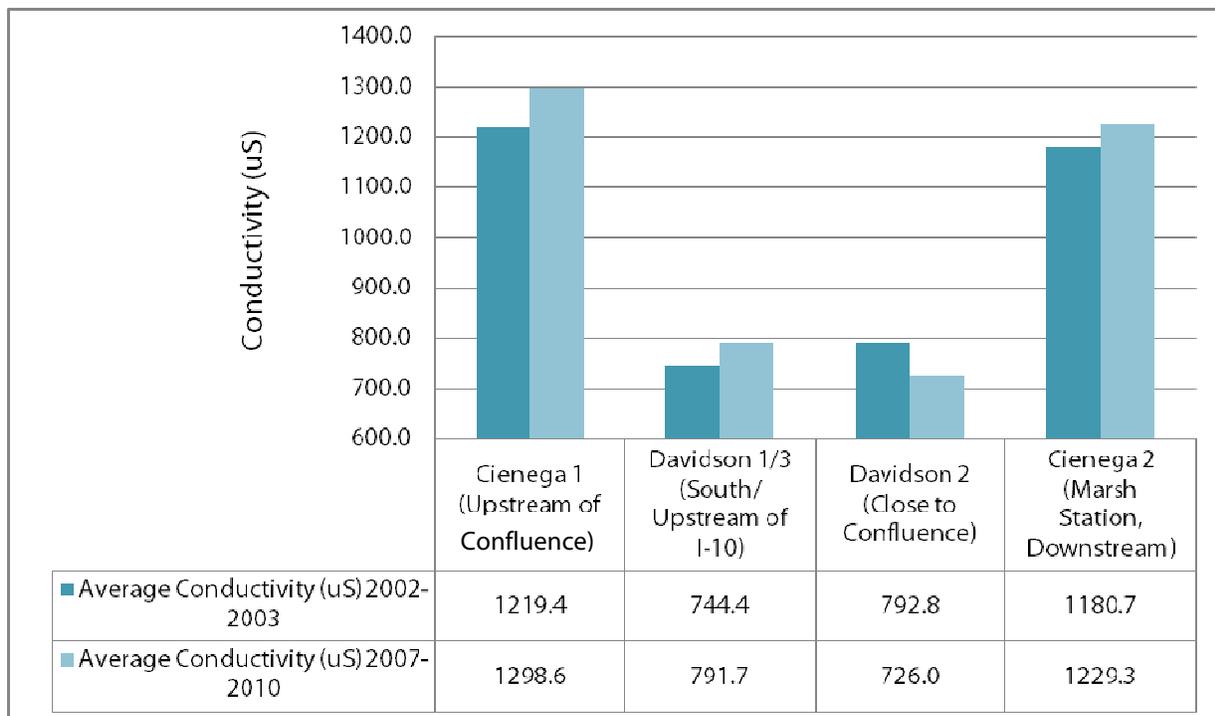


Figure 15. Cienega Watershed – Baseline Average pH (2002 – 2010)

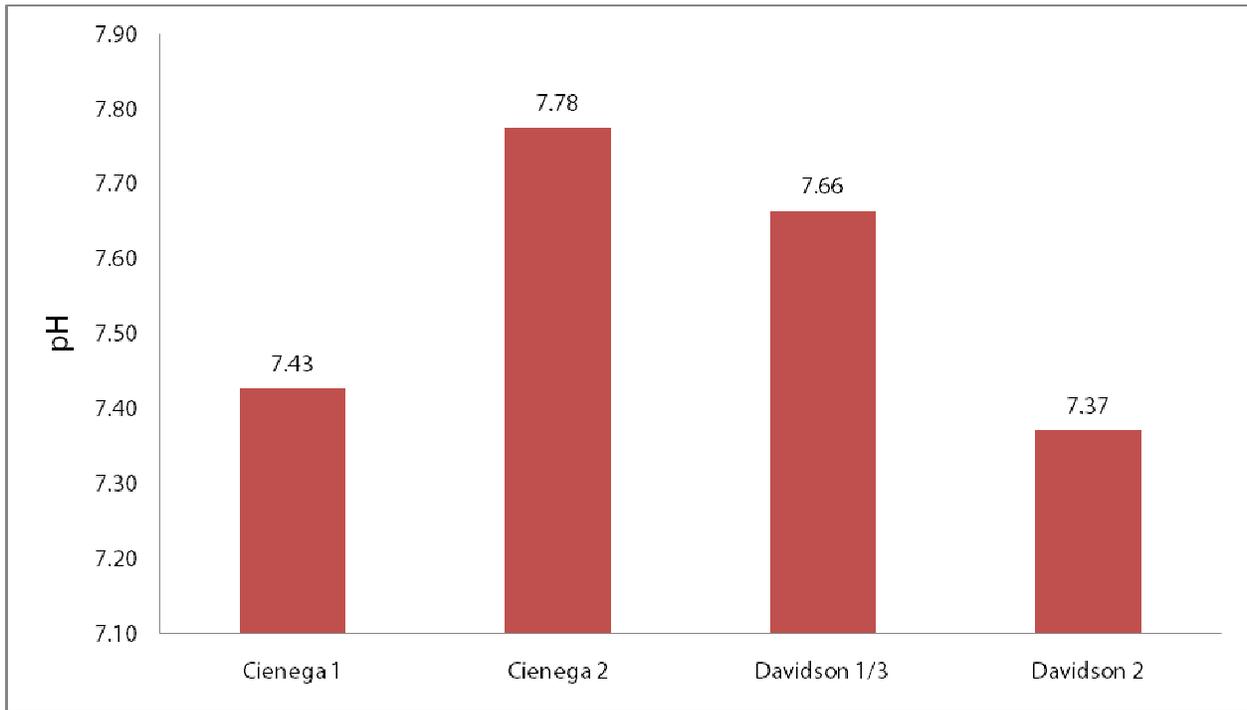
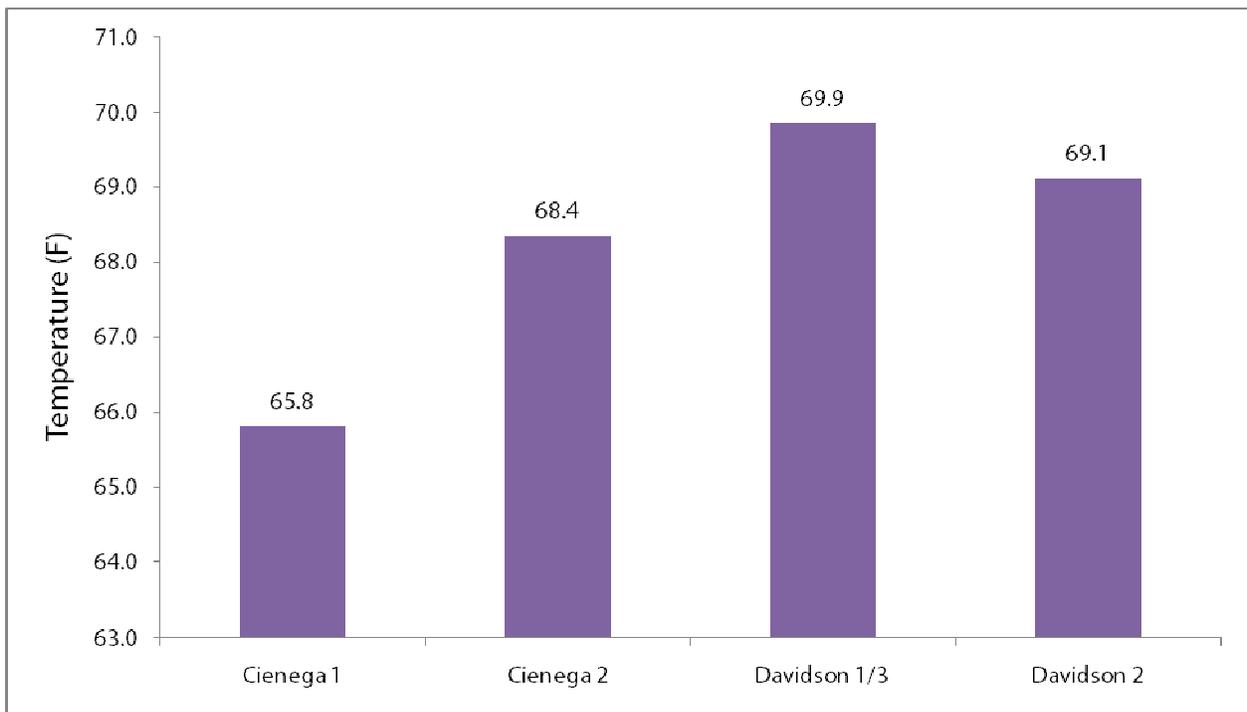


Figure 16. Cienega Watershed – Baseline Average Temperature per Site (2002 -2010)



Repeat Photography

Repeat photography is a valuable tool for assessing the change along the creek and for sharing information with others. In 2006, PAG established eight repeat photography areas and methodology for documentation and has modified the methods as needed. PAG continued photographing established photo areas in FY 09-10 on a quarterly basis, or more often if extreme conditions were encountered while in the field during monthly hydrologic monitoring. Many photo locations include several different repeat photographs so that different view directions can be documented.

Photo sites were initially selected in 2006 by reviewing a collection of photos with a history of recorded site conditions and by adding sites as needed in order to capture dynamic conditions, or to get a better distribution throughout the creek. The GPS site locations are shown in Table 6 on the following page. Care is taken to photograph at the same location each time, adjusting the frame slightly if needed to accommodate conditions. Photos are stored digitally at PAG and, for record-keeping, photos are named according to a photo site number, description and view direction, and filed by date.

In FY 08-09, PAG created an initial review of these photo sites to assess the methodology of the program and see if there is evidence of site morphology, flow or vegetation change recorded within the images of this large set of baseline data. The following areas were assessed in FY 08-09:

- Vegetative changes near Del Lago Dam
- Scour pool below Del Lago Dam
- Canopy cover and sedimentation at Jungle Road

Review of repeat photography shows that site changes that might go unnoticed in the field are often revealed by comparing historical photos. PAG's photo catalogue now contains numerous photo sites distributed throughout the creek. This baseline data is valuable because of the unpredictability of geomorphic alterations along the creek. The photographs have also been used in newsletters, presentations, data requests and other forms of communication to demonstrate seasonal change, drought and erosion. PAG has created and placed the following virtual tours of Cienega Creek on-line.

- Headcut virtual field trip
- 3D Photosynth view of Marsh Station

For this FY 09-10 report, photos were selected from two sites, to demonstrate the very visible scour and sedimentation at these locations (Figures 17 and 18).

Table 6. Cienega Walk-Through Photo Points

Photo Site ID	Photo Name	Description
#1	Jungle Road - A	Stand on road in middle of channel. <i>View Downstream.</i>
	Jungle Road - B	Again - Stand on road in middle of channel. <i>View Upstream.</i>
#2	Jungle Tunnel	Stand downstream of beginning of flow (by tunnel). Capture some of banks of tributary. <i>View Downstream.</i>
#5	Upstream of Tilted Beds	Stand 30 paces from barbed wire fence. <i>View Upstream.</i>
#3	Tilted Beds A	Measuring site in foreground. <i>View Downstream.</i>
#4	Tilted Beds B	Standing atop sandstone outcrop Viewing bucket measuring site. <i>View Upstream.</i>
Bend	Headcut original channel in horseshoe bend	Stand a ways upstream of RR Wash. <i>View Downstream.</i>
HCa	Head Cut - A	At Major headcut plunge pool where headcuts split, slightly upstream of pool, on bank. <i>View Downstream.</i>
HCb	Head Cut - B	At Major headcut plunge pool where headcuts split, standing slightly downstream of pool, in headcut. <i>View Upstream.</i>
#8	Confluence - Upstream from railroad bridge	Downstream of confluence of Cienega Creek and Davidson Creek. <i>View Upstream. Take another to include bedrock, standing more downstream, depending on conditions.</i>
Dav	Davidson - Deer Grass - A	Up Davidson Canyon to most extreme possibility of beginning of flow. <i>View Upstream.</i>
	Davidson - Deer Grass - B	Same as above, but <i>View Downstream.</i>
#9	Sharp bend in creek upstream in Davidson Canyon	Walk upstream from confluence to end of flow, <i>View Downstream.</i>
#10	Just downstream from sharp bend in Davidson Canyon	Just downstream from Point #9, take picture with end of flow included - <i>Turn around to View Upstream.</i>
#7	Upstream from Marsh Station	Through the railroad bridge (with bridge support structure in photo). Vertical shot. <i>View Upstream. Take extra photos if you need to see stream beds and banks closer up (less bridge).</i>
#6a	Marsh Station - A	Bedrock on left, with bridge in picture. Standing downstream of flow measurement site. <i>View Downstream.</i>
#6b	Marsh Station - B	Flow measurement site in photo. <i>View Upstream.</i>
Sediment Plug	Sediment Plug	Stand downstream of stream bend where it is cutting into sediment (duck spot). Capture wide new banks. <i>View Upstream.</i>
#11a	SP 1006 (Southern Pacific mile marker) - A	Stand downstream from beginning of flow with hill present ahead on right (may not be visible). <i>View Upstream.</i>
#11b	SP 1006 (Southern Pacific mile marker) - B	Stand upstream from beginning of flow with hill present ahead on left (may not be visible). <i>View Downstream.</i>
#12a	Del Lago Dam - A	Focus on dam. Stand a bit upstream on N side of creek. <i>View Downstream.</i> Make sure you can see the distance of flow over dam or get another shot.
#12b	Del Lago Dam - B	Focus on dam. Stand a bit downstream on N side of creek. <i>View Upstream.</i>
#12c	Del Lago Dam - C	View across dam from south bank. Capture flow over dam and the pools.

Figure 17. Photo Documentation of Erosion at Tilted Beds, Cienega Creek



1

This series of photographs shows repeat photography at photo site #5, upstream from Tilted Beds, facing upstream. This sequence shows how the creek experiences alternating scouring and sedimentation over time, as well different scour patterns. For example, the Sep. 2009 photograph shows an incised streambed, but by June 2010 that sediment had accumulated and eliminated the downcut channel bed.



2

During the time period shown here, some water was observed on the streambed surface, but there was never sufficient water to create measurable baseflow. Along this reach, occasional flood events scoured the surface, forming pools. Scour events tended to form after dry periods, as shown here.



3



5



4



6



7



8

Figure 18. Photo Documentation of Streamflow Volume Changes at Marsh Station, Cienega Creek

These photos are taken at the Marsh Station site, looking upstream to the streamflow measuring location. They highlight the dramatic reduction of flow in September 2009, which was the driest September since the drought began in 2003. In general, September streamflow volumes are higher than those documented in June because of monsoon rainfall, however, Sep. flows were smaller than June flows in 2009. The photos also illustrate that ranges of streamflow volume of flow can each take many forms.

1



Sep. 2008 (1.71 cfs)

2



June 2009 (0.21 cfs)

3



Sep. 2009 (0.08 cfs)

4



June 2010 (0.18 cfs)

5



Sep. 2010 (0.34 cfs)

Additional Related Monitoring

Extent of Flow Past Del Lago Dam

As a special request from PCRFC in 2007, PAG documented the length of flow past Del Lago Dam during FY 09-10. The observations focused on the presence of pools, fish, flow over the dam/flume and length of flow past the dam. Maintenance was performed on the flume and the valve was left open for several months in the summer of 2008, which provides the opportunity to evaluate the extent of flow and the impact of released flows on groundwater levels. That summer, the flow reached a maximum extent of 2,200 feet downstream of the dam. The flow extent diminished within two months after the flume door was closed. At a well site located at the bottom extent of the flow (PS -1), groundwater levels rose to 29.42 feet below land surface when water was released in the summer of 2008, whereas the average depth is typically ranges from 46 to 50 feet below land surface. Additional information on groundwater levels associated with flow is discussed in the groundwater section of this report.

Headcut Study

Headcutting in the Cienega Creek watershed is a dramatic demonstration of sediment fluctuation within the stream system. The headcut at the railroad horseshoe area was studied through a two-year Arizona Water Protection Fund Grant (AWPF Grant No. 07-144). PAG monitored groundwater levels through two piezometers, measured headcut entrenchment, conducted repeat photography, monitored two streamflow sites and assessed habitat through riffle/pool distribution. Reports to AWPF were completed in 2010¹.

Through a habitat survey, hydrologic monitoring and a geomorphic survey, PAG was able to evaluate stream system changes with the advancement of erosion. Over the two-year study period, the headcut nick point advanced over 2,000 feet upstream and the channel eroded down to 12 feet deep. Headcutting affected many aspects of the creek, including the slope of the water table, the expression of surface flow, the distribution of sediment substrates and the density of vegetation cover.

Depending on the value attributed to trade-offs for certain habitat types, changes in the creek habitat may be viewed as either positive or negative. The immediate results show that streamflow is restored in the headcut region and may last until (and if) the area experiences another wave of sediment accumulation. The trade-off for increased surface flow is loss of local shallow aquifer storage and possibly faster movement of flow out of the system. Loss of vegetation increases temperature and evaporation, decreases infiltration and speeds flood flows. When looking at the long-term, the current older growth tree-fall is reducing vegetative overstory, which will take 30 years to fill back in by the next generation of trees. In the shorter term, it appears that this erosion process will restore fish habitat in the active headcutting area, which has an approximately 10-year life span in our study area.

Because this type of investigation had not been previously conducted in an arid environment, where the typical stream has segmented perennial flow and intermittent ephemeral flow, there was added scientific merit to the project. The surface flow is dependent upon the water table gradient and by sediment aggradation and erosion. The study shows that large rain events, which follow long dry spells (typical of our region), have the greatest ability to create large sediment transit. In addition, this study shows that the timing of the transition of sediments is correlated to the gradient of the water table. During the dry pre-monsoon months, the extra wedge of de-watered alluvium in the streambed, created by the steeper water table slope, likely contributed to collapsed sediment structure and wetland vegetation die-off. Both of these changes appear to be loosening the sediments thereby directly contributing to the degree of erosion during subsequent monsoon floods.

FOOTNOTE:

1. *Pima Association of Governments, Evaluation of Riparian Habitat and Headcutting Along Lower Cienega Creek, Arizona Water Protection Fund Grant #07-144: March 2010*

PAG has established unique field methods for this system. This project has increased public awareness of management issues for this valued resource near the Tucson urban area. Due to the delicate nature of the creek preserve, PAG cannot make a recommendation to create in-creek sediment stabilization, although efforts in tributaries and uplands may be beneficial.

Figure 19. Photo of Depth of Erosion in Active Headcutting Study Area



This photo features the headcut at the "Railroad Horseshoe turn" where a second channel (behind the person on the upper level) branches of the main channel (person in the foreground).

Wildlife Observations

PAG regularly documents wildlife observations and habitat characteristics during field work in Cienega Creek. Observations of flora and fauna below were noted during quarterly walk-throughs and during the headcut habitat survey in March 2008 and March 2009. The native threatened and endangered fish and frog species observed by PAG in pools and other flowing reaches consisted of Gila Topminnow and Gila Chub. Lowland Leopard Frogs were present, whereas PAG did not see or hear Bullfrogs (an invasive species) within the creek. Longfin Dace is the most abundant native fish in lower Cienega Creek and though Topminnow is less dominant, it is commonly seen in most reaches. Pool habitats were present at various locations along Cienega Creek during each quarterly walk-through this year. PAG sees mud turtles less frequently, but it is not uncommon to come across one each year. PAG also commonly sees coatimundi, javelina, deer, hawks, barn owls, heron and reptiles and less commonly, Gila Monster. In the past few years, PAG has also seen mountain lion and tracks of bear and bobcat, but none were sighted this year.

As part of the habitat survey conducted for the headcut study, PAG found that the dominant native vegetation includes an overstory of Cottonwood, Goodding Willow, Mesquite and Ash, and an understory of Coyote Willow, Desert Broom, Deer Grass, Cattail, Bulrush, Horsetail and Canada Wildrye. There are only a few Sycamore trees along the creek. Invasive and exotic vegetation species commonly seen along lower Cienega Creek include Johnson Grass, Rabbitsfoot Grass, Tamarisk and Buffelgrass. PAG has not seen the Huachuca Water Umbel, the endangered plant species that is found in the upper watershed in Las Cienegas National Conservation Area. In order to present these findings to the public, PAG has created an informal guide for common species in the Preserve, which will be published on our Web site.

In order to communicate habitat and wildlife information, PAG reports incidental observations of species of concern on Pima County properties to the Office of Conservation Science with the goal to record observations of species that are part of the forthcoming U.S. Fish and Wildlife Service (USF&WS) Section 10 permit. Coordinates for location and species data from this effort is entered into an intranet database at Pima County and, over time, these data will become an invaluable resource for monitoring changes in the location of resources as well as providing a tool for current conservation planning efforts such as development of site-specific management plans. Threatened or candidate species that could potentially be present during our monitoring at Lower Cienega Creek include Gila Chub, Gila Topminnow, Northern Mexican Garter Snake, Southwestern Willow Flycatcher, Lesser Long-Nosed Bat, Sonoran Desert Tortoise, Chiricahua Leopard Frog and Huachuca Water Umbel. PAG has also been requested to record the presence of Longfin Dace, Sonora Mud Turtles and Lowland Leopard Frogs for this effort, as well as invasive species such as bullfrogs and buffelgrass for preserve management.

Drought Watch

In 2008, PAG began contributing Cienega monitoring data to the Local Drought Impact Group. On a quarterly basis, PAG uploads monthly reports on the impact and trends of drought on lower Cienega Creek to the statewide reporting Arizona Drought Watch Web site: <http://azdroughtwatch.org>. For groundwater and streamflow, PAG reports the presence of drought impacts and whether the trend is 'better' or 'worse' in severity. Flow extent data are reported within the quarter they are collected. Marsh Station serves as the streamflow site. Two wells (Cienega and Jungle) are used for groundwater analysis for this reporting system. These wells were selected because they have similar response times to precipitation, they are consistently accessible and they have a set of historic monthly data available. Data from the two well sites are averaged for the analysis.

To determine whether there are drought impacts, PAG compares the monthly data to the water levels seen in pre-drought years. PAG considers 2001 through the present to be the drought years and 1994 through 2002 the pre-drought years. To assess the trend of these impacts, PAG compares to data one year prior instead of one month prior, to account for seasonal changes. For example, during our monthly monitoring, if stream volume has decreased, flow extent has decreased or groundwater levels become lower when compared to the level that it was at one year prior, PAG submits a record of worsening trend.

PAG data clearly shows the presence of continued drought impacts. The gradual drying trend in Cienega flow lengths since 1984 (Table 5) is probably due in part to the current drought, but PAG cannot completely rule out all other contributing factors, such as water withdrawals from nearby wells or upstream land uses. The largest impacts of drought in our records were found during FY 04-05, although in September 2009, the flowing length was the lowest extent on record for September. During the last two monitoring years, PAG observed major declines. Starting with good winter rains that helped the first half of FY 08-09, the drought trend improved most fall and winter months. The trend worsened from March 2009 through January 2010, especially during the summer months due to

the lack of regular precipitation in the monsoon season. In FY 09-10, Cienega groundwater levels in our 2 drought monitoring wells averaged 4.67 feet lower than the pre-drought average, and averaged 4.15 feet lower than the previous fiscal year. Streamflow in FY 09-10 averaged 27.5% lower than pre-drought flow. Short term drought severity improved from February through June 2010, with flows increasing 43% to 86% compared to last year.

Outreach and Coordination

Public Outreach

PAG continues to raise public awareness about the unique habitat, wildlife, and water resources of Cienega Creek. PAG has incorporated Cienega information into outreach materials and Web site. During FY 09-10 PAG presented at the September 2010 annual Arizona Hydrological Society Symposium and ran a field trip to the headcut at Cienega Creek. Drought information is presented annually to the Cienega Corridor Conservation Council (4Cs). PAG also coordinated speakers from Pima County Local Drought Impact Group and the Climate Assessment for the Southwest with the Cienega Watershed Partnership for a special meeting on drought status and reporting systems in February 2010.

Coordination

PAG continues to connect with other agencies and professionals to facilitate, coordinate and support collaborative projects in the region. Information exchange and coordination take place in part through participation in the 4Cs and the Cienega Watershed Partnership (CWP). Toward that end, PAG coordinates with the Bureau of Land Management (BLM) and The Nature Conservancy (TNC) on methods of surface flow mapping to ensure that our hydrologic monitoring programs are consistent with those of the upper reaches of Cienega Creek within the Las Cienegas National Conservation Area. To organize a single week for Arizona rivers mapping, PAG also coordinates with Arizona Non-point Education for Municipal Officers (NEMO), who maps the Gila and Agua Fria Rivers; with TNC, Community Watershed Alliance, BLM, and CONANP (Comisión Nacional de Areas Naturales Protegidas), who map the San Pedro River; and with TNC, who maps Sonoita Creek.

Outside agency staff and other interested individuals are always invited to accompany PAG staff on quarterly walk-throughs to provide them an opportunity to learn about Cienega Creek and become more familiar with some of the management issues of the Preserve and the surrounding region. The invited agencies include PCRFC, PCNRP&R, Arizona Game and Fish Department, Arizona Department of Environmental Quality, USF&WS, TNC, Sonoran Institute, University of Arizona, CWP, Arizona Department of Water Resources, Sky Island Alliance, Empire-Fagan Coalition, the Sustainability of semi-Arid Hydrology and Riparian Areas center, Tucson Audubon Society, NEMO, USDA Agricultural Research Center, Rincon Institute, Watershed Management Group, Colossal Cave Park, Tucson Electric Power, Arizona State University, Congresswoman Gabrielle Gifford's Office and the Master Watershed Stewards program.

Conclusions and Recommendations

Cienega Creek is a unique Sonoran Desert low-elevation perennial stream with critical water, recreation and wildlife resources in southeastern Arizona. Since the mid 1980s, PAG has conducted research to firmly establish baseline hydrologic conditions for comparison purposes, in the event that future groundwater development or land use changes occur in the vicinity of the Creek. Originally focusing solely on groundwater and streamflow monitoring over the years, PAG's work has evolved into a multifaceted monitoring program that includes many more aspects of the Creek system, thus becoming an important part of regional and statewide drought assessment.

Fiscal Year 2009-2010 monitoring indicated progressively severe drought in the Cienega Creek watershed. Annual average streamflows decreased and groundwater levels dropped at all wells during this year as compared to the previous year. In addition, many normally flowing sites exhibited no ephemeral baseflow. Most notable during this year was the lack of significant precipitation during the summer monsoon season. As a result, groundwater levels did not rebound in typical fashion and the streamflows did not increase, giving us the lowest September flow length in our historical record. Groundwater levels appeared to be most stable in the Pantano Jungle and Cienega well areas, which are characterized by bedrock-bound shallow groundwater zones, associated with gaining stream reaches with relatively stable perennial flows.

A significant contribution to the FY 09-10 PAG program was investigation of a large erosional headcut in the horseshoe bend region of Cienega Creek¹. In-stream groundwater monitoring, structural habitat, geomorphology studies and streamflow documentation allowed understanding regarding sediment transport and habitat change associated with headcutting. In general, streambed incision, due to headcutting, resulted in increased flow extent where the ground surface intersected the groundwater table. These stream reaches provided good fish habitat partly because of their varied pool/riffle flow regimes. However, these areas also showed a dramatic loss of top-story established tree canopy, which will not be re-established for many years. This project also gave us unique information correlating shallow aquifer dewatering with unsettled sediments and vegetation die-off upstream of the headcut nick point. This helps to explain why extreme erosional incidents occur when floods follow extremely dry periods.

PAG's role connecting those that are passionately interested in, or working within, either the Cienega Creek or neighboring riparian systems has expanded in recent years. Because of its long-term and consistent monitoring program, PAG provides critical input to the Arizona Drought Watch Program regarding the status of drought in our region. PAG's connections with other agencies and professionals to facilitate, coordinate and support collaborative projects in the region have been very well received by others. Our photographic documentation helps communicate how the system is transforming over the years, and our wildlife sightings, habitat change observations and water quality analyses are all important tools in monitoring the health of the aquatic and riparian resource.

PAG recommends continued investigation into measures that will maintain or restore native riparian vegetation and habitat, stream geomorphology, channel characteristics and floodplain functions. New exciting work is being done in upland hydrology with the development of natural erosion control structures in Las Ciénegas through the BLM, Bill Zeedyk, the Sky Island Alliance and the Cienega Watershed Partnership. By continuing to participate with organizations that work in preserving the Cienega Watershed and by providing information and promoting awareness of the resource, PAG hopes to continue aiding PCRFC and PCNRP&R in their management of the Cienega Creek Natural Preserve. Continued groundwater and surface water monitoring, water quality analysis, and habitat and wildlife documentation are critical tools toward achieving integrated resource management for the system.

FOOTNOTE:

1. Pima Association of Governments, Evaluation of Riparian Habitat and Headcutting Along Lower Cienega Creek, Arizona Water Protection Fund Grant #07-144: March 2010



MEMORANDUM

TO: Suzanne Shields, P.E., Director,
Pima County Regional Flood Control District

CC: Thomas Helfrich, Frank Postillion, David Scalero
Pima County Regional Flood Control District

Kerry Baldwin and Amy Loughner
Pima County Natural Resources Parks and Recreation

Julia Fonseca and Brian Powell
Pima County Office of Sustainability and Conservation

FROM: Claire Zucker, Director
Sustainable Environment Program

Mead Mier, Senior Watershed Planner
Pima Association of Governments

SUBJECT: **Cienega Creek Natural Preserve Surface Water and Groundwater Monitoring
Annual Report for the 2009-2010 Fiscal Year**

DATE: February 2012

Please find the enclosed Fiscal Year 2009-2010 technical report for the Cienega Creek Natural Preserve Monitoring Project. This report summarizes PAG's groundwater and surface water monitoring between July 2009 and June 2010.

If you have any questions and/or would like any additional information, please feel free to call me at 792-1093.

Pima County's Cienega Creek Natural Preserve

Surface Water and Groundwater Monitoring Project – PAG Annual Report

Fiscal Year 2009 - 2010



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



Pima Association of Governments

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Thank you to Pima County for its long-term support of the Cienega Creek monitoring program as a part of PAG's annual work plan. We greatly appreciate the following Pima County staff for supporting the monitoring, initiating program elements as needed, sharing data, providing input and coordinating with us: David Scalero, Frank Postillion and Tom Helfrich, Pima County Regional Flood Control District; Julia Fonseca and Brian Powell, Pima County Office of Conservation and Sustainability; and Don Carter and Iris Rodden, Pima County Natural Resources, Parks and Recreation.

Thank you to Diane Hanna, one of the Preserve caretakers, for local updates of creek conditions and for providing past well data and Brian Telfrey (Empirita Ranch) for providing past water level data. We greatly appreciate the efforts of Arizona Department of Water Resources, for coordinating and managing data for the Pantano 1 and 2 wells through GWSI. We also appreciate Karen Simms (Bureau of Land Management at Las Cienegas) for coordinating with us for June wet / dry mapping efforts across Arizona.

Thank you for coordination efforts to the Cienega Watershed Partnership and Cienega Corridor Conservation Council: Netzin Steklis, Dennis Caldwell, Jeff Williamson, Sheila Bowen, Trevor Hare (Sky Island Alliance), Martie Maierhauser and Bill Savery (Colossal Cave Mountain Park).

We appreciate all the volunteers who joined us for wet/dry monitoring this year: Raquel Haro (Pima County intern), Bill Ball and Richard Callahan (Master Watershed Stewards), Frank Postillion and David Scalero (PCRFCDD), Doug Duncan (USFWS), Erik Glenn (UA Cooperative Extension office), Don Carter and Iris Rodden (PCNRPR), Julia Fonseca and Brian Powell (Pima County Office of Conservation and Sustainability), Charlotte Cook and Elizabeth Webb (Empire-Fagan Coalition), Adrien Caldwell, James Blakely, and David Siebert.

Finally, our current program would not be possible without the work of previous PAG employees who helped design and refine the monitoring program and for conducting monitoring over the years including, Michael Block, Greg Hess and Staffan Schorr.

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Introduction

Cienega Creek is an important water, recreation and wildlife resource in the Santa Cruz River watershed. It is one of the few low-elevation streams in Pima County that exhibit significant perennial flow. Perennial reaches of Cienega Creek support native fish and the surrounding riparian vegetation provides habitat for a diversity of wildlife. In recognition of its value to the state of Arizona, the reach of Cienega Creek downstream from Interstate 10 to the Del Lago Dam has been designated by the Arizona Department of Environmental Quality (ADEQ) as an "Outstanding Water," (R18-11-112) which means that site-specific water quality standards are established to maintain and protect the existing water quality. The certificate of in-stream flow rights was granted by the Arizona Department of Water Resources (ADWR) to Pima County Regional Flood Control District in December 1993 (No. 89090.0000). Both Cienega and Davidson Canyon have priority aquatic and riparian resources as specified in the Sonoran Desert Conservation Plan. This report describes work completed by Pima Association of Governments (PAG) as part of its 2009-2010 Overall Work Program, which includes monitoring in lower Cienega Creek and Davidson Canyon.

The purpose of PAG's monitoring program is to establish baseline hydrologic conditions for comparison purposes, in the event that future groundwater development or land use changes occur in the vicinity of the creek. Monthly monitoring of groundwater levels, streamflow extent and stream discharge in the preserve are conducted so that long-term trends and conditions are documented. This monitoring is consistent with the management plan for the preserve in which the goals include to maintain in-stream flows, preserve tree-sustaining shallow groundwater and preserve natives. PAG has monitored the hydrology in the Cienega Creek Natural Preserve (preserve) since 1989, in coordination with the Pima County Regional Flood Control District (PCRFCD). This report contains data collected between July 1, 2009 and June 31, 2010 (the fiscal year, i.e. monitoring year) on streamflow volume, groundwater levels, streamflow length (through the extent of the Preserve), water chemistry and photography. It also includes additional observations and studies, such as a summary of species of concern, an analysis of erosion impacts in one of the major head-cutting areas and drought reporting. Data tables and figures in this report focus on results from the 2009-2010 monitoring year, but they also show some data from previous years for comparison purposes.

The Cienega Creek Natural Preserve, which is owned by PCRFCD and co-managed by PCRFCD and Pima County Natural Resources Parks and Recreation (PCNRP&R), includes lower Cienega Creek and portions of lower Davidson Canyon. For ease of reading, the following geographically distinct areas are referred to in these terms throughout the report.

- Cienega Creek
This area is defined as reach of lower Cienega Creek between Interstate 10 and the diversion dam east of Vail, Arizona. This area is the main focus of PAG's hydrologic monitoring program.
- Cienega Creek Natural Preserve
This area includes lower Cienega Creek, Empirita Ranch south of I-10, and monitoring sites in lower Davidson Canyon.
- Cienega Watershed
This area includes the Preserve area and monitoring sites in upper Davidson Canyon (not in the Preserve, south of I-10)
- Upper Cienega Creek
The report does not include upper Cienega Creek which includes the Las Ciénegas Natural Conservation Area, managed by the U.S. Bureau of Land Management (BLM). Las Ciénegas is where the headwaters begin and flow north.

The locations of all of the monitoring sites are shown in Figures 1A and 1B. During FY 09-10, monitoring methods and locations remained essentially the same as in past years, with any exceptions for this year explained in this report. The specific methodology for each aspect of monitoring is described within its corresponding section. PAG has further documentation for protocols, forms and metadata available in-house, as well as reports from previous years available in the PAG on-line library.

Figure 1A. PAG Monitoring Site Locations in the Cienega Creek Watershed

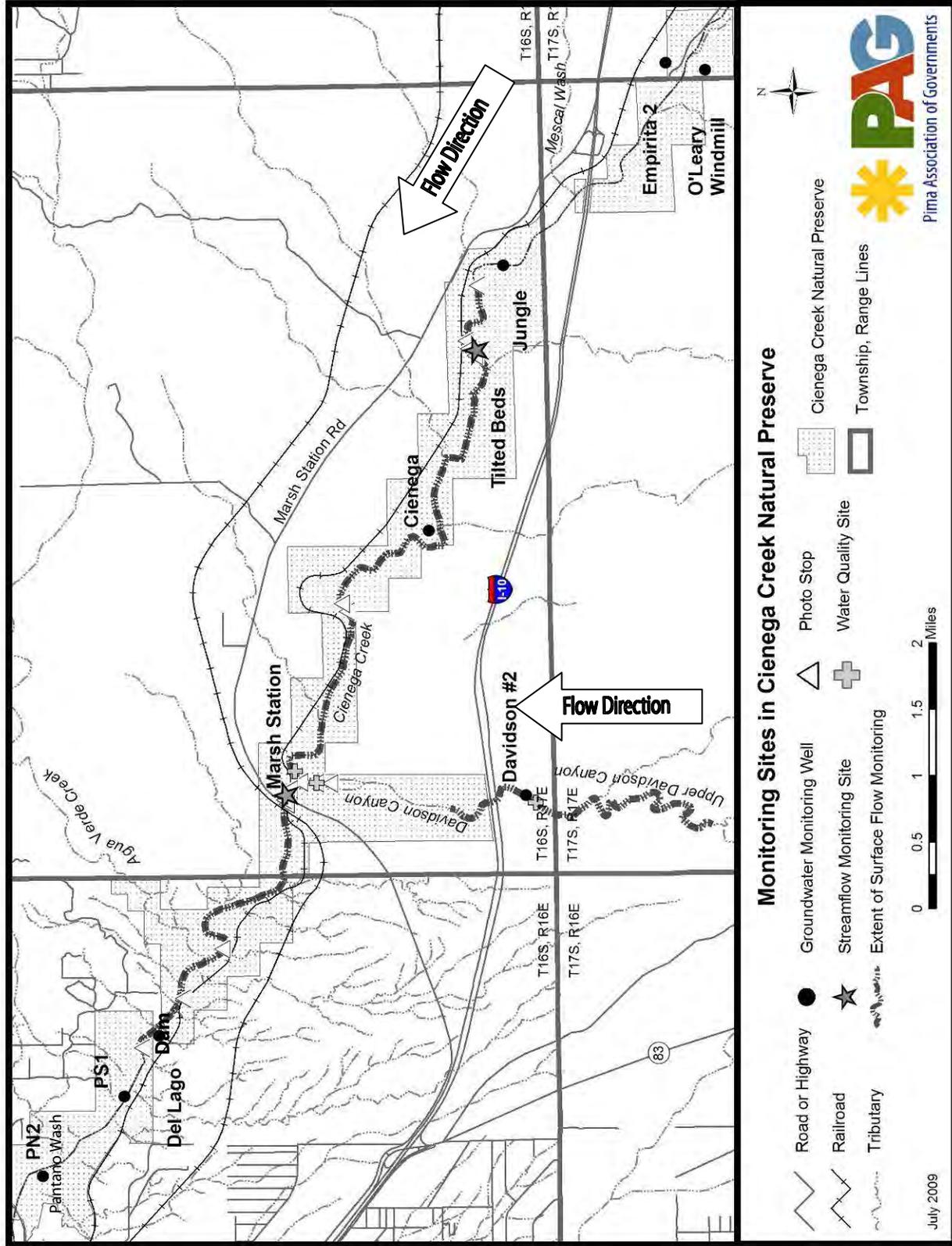


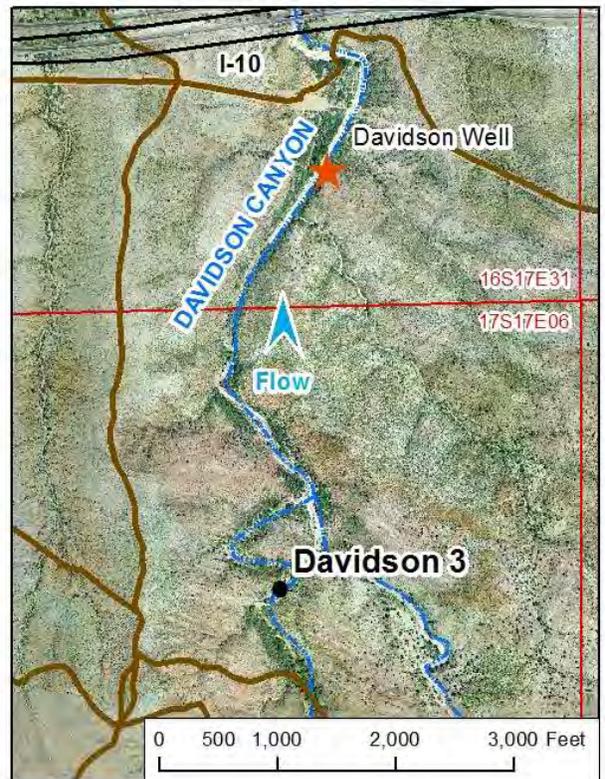
Figure 1B. PAG Water Quality Monitoring Site Locations



Water Quality Sampling Sites

Legend

- Water Quality Sample Site
- ★ Monitoring Sites
- Ephemeral Flow
- Perennial Flow
- Streets
- Dirt roads
- Railroad



Streamflow Volume

Methods

In Fiscal Year 2009-2010, PAG took monthly streamflow volume measurements at two sites using a USGS Pygmy Flow Meter and calculated the discharge (Q) in cubic feet per second (CFS). The sites are Marsh Station Road Bridge, downstream from the Cienega/Davidson confluence, and Tilted Beds, several miles upstream from Marsh Station (Figure 1A).

PAG monitors the streamflow during baseflow conditions, as required in the methodology of the program. Baseflows are produced by discharges from the shallow aquifer into the stream channel without the direct influence of surface runoff. If a significant rainfall event occurs within three days prior to a scheduled field event, the sampling is postponed until drier conditions prevail and runoff is thought to no longer have a direct influence on streamflow in the canyon. Baseflow is determined through County gages on the PC ALERT Web site, <http://alert.rfcd.pima.gov/scripts/pima.pl>, including rain gage numbers 4280, 4310, 4220 and 4250, and stream gage numbers 4283 (Cienega at I-10), 4313 (Davidson Canyon) and 4253 (Pantano at Vail). Field staff does not conduct monitoring under hazardous conditions, such as during flood flows or lightning storms.

Based on standard guidelines, streamflow measurements are taken at a location along the stream where the channel is relatively straight and streamflow is fairly uniform. When possible, points of converging and diverging flow paths are avoided. The stream form changes with each monthly visit and so the site location varies by up to 30 feet.

Results

FY 2009-2010 Results

The range in seasonal fluctuation was notably smaller in this monitoring year. In FY 09-10, streamflow at the Marsh Station site ranged from a low of 0.08 cfs (in September 2009) to a high of 1.07 cfs (in March 2010) (Table 1). This is a range of 0.99 cfs, whereas the previous monitoring year fluctuated by 1.78 cfs.

Tilted Beds was dry during FY 09-10, with the exception of January 2010, when isolated patches of water with immeasurable movement were observed (Table 1). Tilted Beds has a pattern of ephemeral flow for 2-3 years, followed by absence of flow for 2-3 years (Figure 3). The site flows generally during the winter months. However, from 2007 to 2009, Tilted Beds exhibited nearly consistent flow throughout the year. This site's flow may be ephemeral because it is more impacted by sedimentation and erosion processes than the Marsh Station site.

Historical Trends

Annual average streamflow remained lower than last year's levels at the streamflow sites. Streamflow data for this fiscal year are shown in Table 1, while Figure 2 graphically presents the streamflow trends for the past two fiscal years. To provide a longer term perspective on flow trends, Figure 3 shows discharge data from 1993 to the present.

Since monitoring began in 1993, annual average flow has declined over time. Annually averaged flow has fluctuated up and down within the long-term downward trend of streamflow volume at our perennial streamflow measuring site, Marsh Station (Figure 4). The two upward swings in annual average flow became lower each time (around 2001 and around 2008). Low periods of flow similarly became lower (during 1996-2000, 2002- 2006, and 2010) each period. The annual average streamflow at Marsh Station was lower this monitoring year than the last by 0.77 cfs (Table 1).

Within each monitoring year, there are normally seasonal peaks with winter rains and summer monsoon rains. Seasonal patterns can be seen in Figure 3. The downward trend has cyclical rises in the wet seasons of winter storms and summer monsoon rains. From 1993-2004, the highest seasonal peak usually accompanied winter rains. In the drought years of 2001-2004, winter rains sustained flow levels. From 2005-2009, the pattern switched and summer monsoon flows were higher than winter flows. Thus, for the less severe drought period of 2005-2009, it was the monsoons that were critical in bringing up the average flow levels (Figure 4). Fiscal year 09-10 was starkly unique in that there was no summer peak (Figure 2). This corresponds to the deficiency of monsoon storms and resulted in the record lowest annual average flow. The differences in the two seasonal flow periods would benefit from further analysis because they have profoundly different influences on the ecology of the stream.

Table 1. Monthly Streamflow Volumes (July 2009 - June 2010)

DATE	FLOW (cfs) Marsh Station	FLOW (cfs) Tilted Beds
Monthly Monitoring Data		
July 2009	0.290	0.00
August 2009	0.120	0.00
September 2009	0.080	0.00
October 2009	0.150	0.00
November 2009	0.130	0.00
December 2009	0.270	0.00
January 2010	0.540	0*
February 2010	0.830	0.00
March 2010	1.070	0.00
April 2010	0.670	0.00
May 2010	0.350	0.00
June 2010	0.180	0.00
Recent Annual Mean Flows		
2006-2007 AVERAGE	1.06	0.00
2007-2008 AVERAGE	0.99	0.07
2008-2009 AVERAGE	1.16	0.09
2009-2010 AVERAGE	0.39	0.00
Relative Flow Per Specified Period		
06-07 to 07-08 CHANGE ⁽¹⁾	- 0.07	+ 0.07
07-08 to 08-09 CHANGE ⁽¹⁾	+ 0.17	+ 0.02
08-09 to 09-10 CHANGE ⁽¹⁾	- 0.77	- 0.09

Table Notes

PAG measured all flows with a USGS Pygmy Flow Meter.

* = Slow water movement is present, but flow is not measurable with the Pygmy meter

1 = "CHANGE" is defined as the difference between annual averages

"+" = Increase in discharge

"-" = Decrease in discharge

Figure 2. Monthly Streamflow Volume at Tilted Beds and Marsh Station Sites (July 2008 - June 2010)

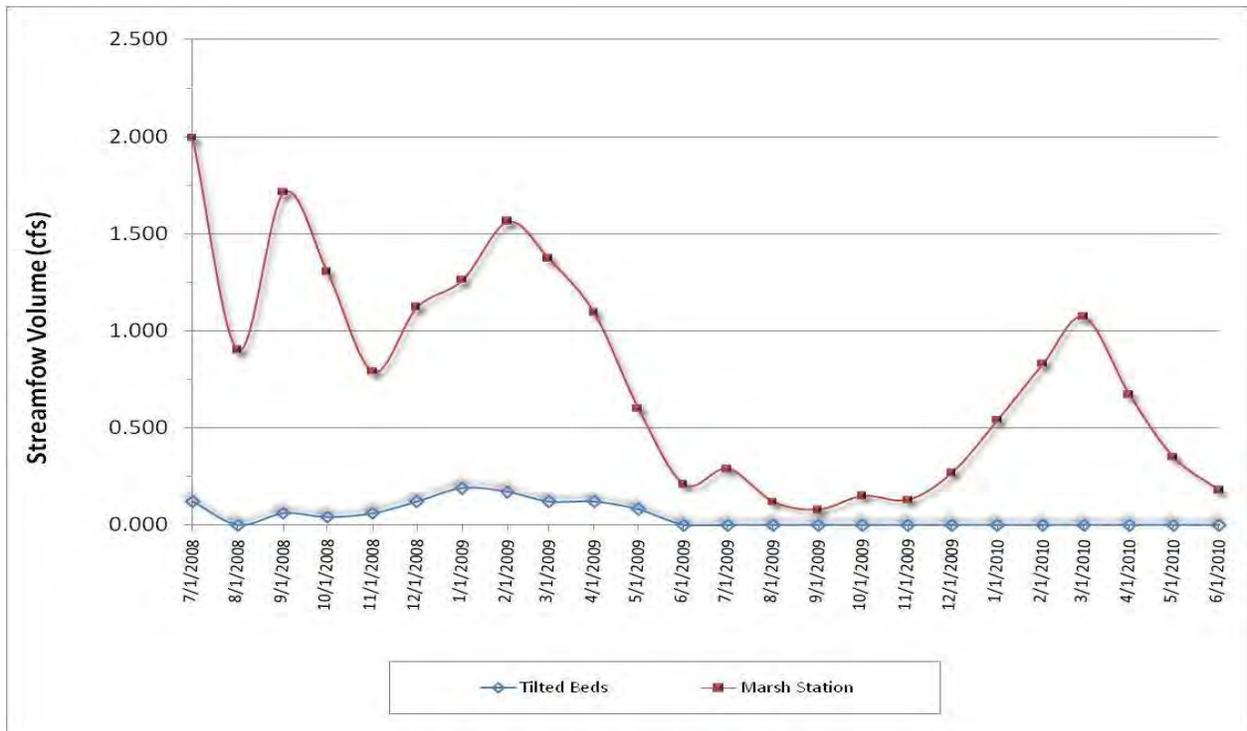


Figure 3. Monthly Streamflow Volume at Tilted Beds and Marsh Station Sites (1993 – 2010)

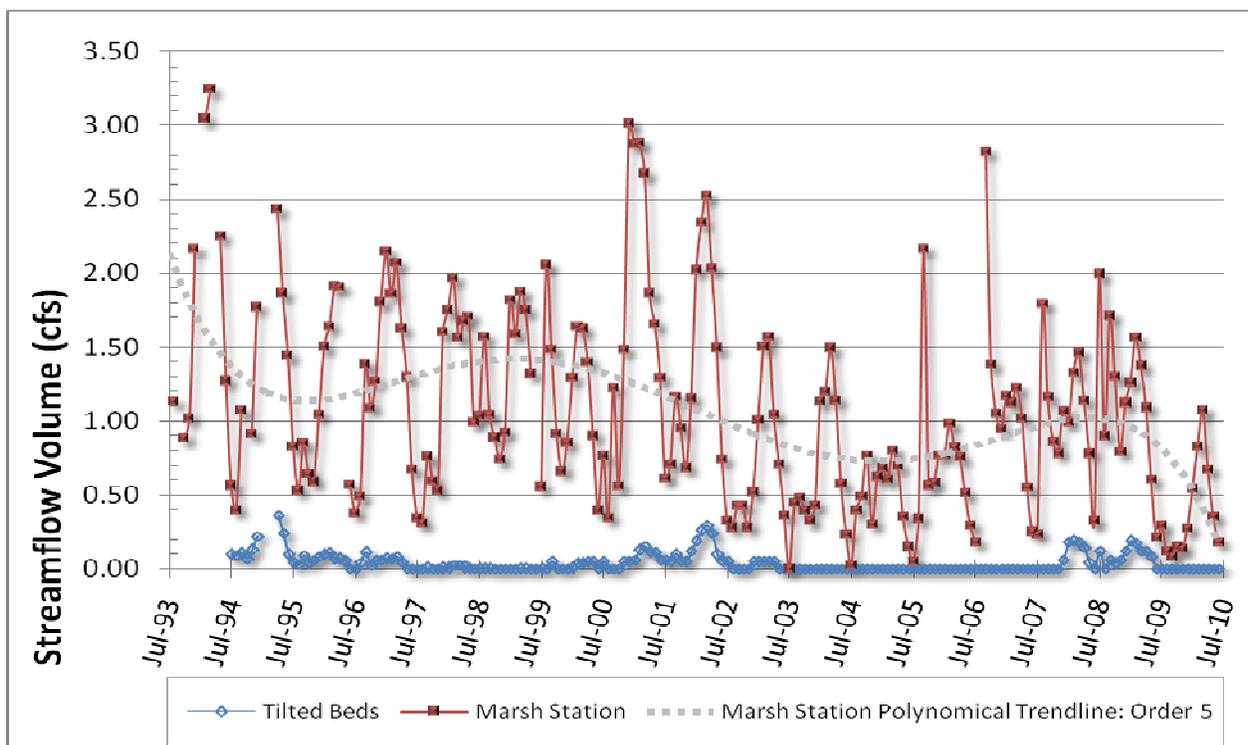
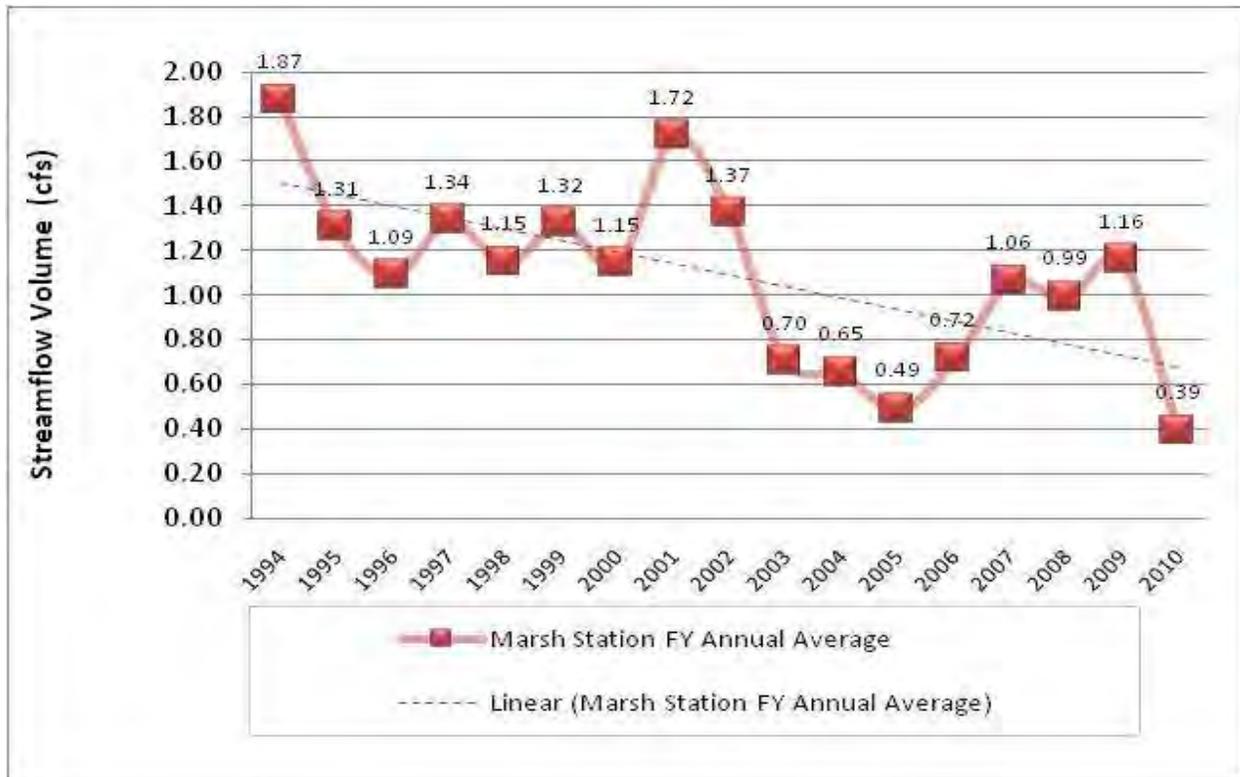


Figure 4. Annual Mean Streamflow Volume Trends at Marsh Station (FY 93-94 to FY 09-10)



Groundwater Levels

Methods

Depths to groundwater were measured at eight wells with either a Solinst Water Level Meter or with *in situ* transducers. The wells are distributed throughout the preserve length and are named (Figure 1A). On a monthly basis, PAG monitored the Jungle, Cienega, Del Lago 1 and Empirita 2 (when accessible) well sites. Davidson 2 continued to be monitored on a quarterly schedule. The PS-1 and PN-2 wells were monitored four times a day by ADWR transducers. If any monitor dates fell outside of this schedule, it is noted in Table 2. Because the O'Leary well had a pump installed in June 2007, which influenced subsequent water levels, it has been removed from the monitoring program and calculations.

Results

Long-Term Trends

Trends in groundwater levels follow trends of streamflow closely. Recent mean annual changes are displayed in Figure 5 and Table 3, while Figure 6 exhibits the long-term trends, showing water level data from 1994 to the present. In FY 09-10, annual mean water levels dropped appreciably at all wells, reaching one of the most severe drought stages on our records because of the lack of summer monsoons. With the exception of June 2006 to June 2009, when water levels increased, yearly declines in groundwater levels were exhibited since 1994, with a rise in 2001. In 2002, drought began to appreciably impact the Cienega Creek Natural Preserve. In the two years prior to this monitoring year, water levels rose at some wells and fell at others, creating an average of slightly increased water levels in FY 06-07 and FY 08-09, but they never averaged above pre-drought levels. More information on trends, including measurements of declines, is also available in the drought section of this report in which two wells with consistent records are compared to create means. Due to inaccessibility of the other wells, inconsistency of records prevents comparison means of all well levels through time.

Seasonal Patterns

Figure 7 presents seasonal fluctuations in water level data for this monitoring year and the previous fiscal year. Seasonal trends were observable at most monitoring wells, although FY 09-10 showed an atypical pattern. Typically, groundwater levels rose most dramatically in August and September, with additional smaller increases in January at most wells. Due to a lack of summer rains, there was no post-monsoon peak in FY 09-10. The degree of seasonal fluctuation at each well depended on the amount of precipitation, the proximity to the creek and the geology. The Jungle and Cienega wells experienced gradual seasonal changes, whereas the wells downstream of Del Lago dam (PS-1 and PN-2) have the largest seasonal response. The Del Lago well was unique in that it expressed large seasonal change in years in which groundwater levels were higher and yet had stable water levels with minimal seasonal responses throughout the low water years of 2003-2006, as well as with the absence of the monsoon in 2009. As is the case with the Jungle and Cienega wells, the groundwater levels seemed to fluctuate less where the underlying bedrock and topography create shallower groundwater zones and where there are more stable perennial flows within gaining stream reaches.

Streamflow Near Wells

By observing flow presence in the stream adjacent to each of the well sites, PAG observed the groundwater level associated with surface flow at each site. The streamflow presence near the Cienega well site appears to correspond to a depth to water at the well of less than 13 feet, near the Jungle well site when the depth is less than 30 feet and near the Davidson well site when the depth is around 12 feet. At one site, Empirita, PAG has not seen flow, so the associated shallow groundwater level is not known. Del Lago is the sole site that has perennial flow and no groundwater levels associated with surface flow in our records.

More sites exhibited no baseflow this monitoring year than last year. None of the groundwater levels associated with flow was reached in FY 09-10 at the Cienega, Jungle and Davidson sites. In contrast, in FY 08-09, streamflow was present at most well sites from July through September (Table 2). The flow at PS-1 and PN-2 in March 2010 was due to surface flow released at the dam and was not due to groundwater surfacing above the sediment. Those groundwater levels do not regularly cause flow sightings at these sites.

Table 2. Depth to Groundwater and Streamflow Presence at Cienega Creek Natural Preserve Monitor Well Sites

Monthly Monitoring in Fiscal Year: July 2009 – June 2010

DATE	DEL LAGO-1		CIENEGA		JUNGLE		EMPIRITA-2 ⁽³⁾		DAVIDSON-2 ⁽¹⁾		PS-1 ⁽²⁾		PN-2 ⁽²⁾	
	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth	DTW	Flow depth
7/14/09	71.9	y, .20 ft	18.9	n	33.1	n	81.4	n			57.1	n	193.4	n
8/18/09	75.9	y, .19 ft	19.8	n	34.2	n	81.7	n			54.7	n	197.4	n
9/17/09	76.3	y, .15 ft	20.1	n	34.8	n	82.0	n	21.4	n	56.9	n	200.8	n
10/14/09	77.5	y, .13 ft	20.6	n	35.5	n	82.3	n			58.2	n	203.5	n
11/12/09	77.6	y, .17 ft	20.7	n	35.8	n	82.7	n			59.5	n	206.2	n
12/21/09	77.6	y, .21 ft	19.4	n	35.8	n	83.2	n	25.4	n	60.4	n	209.8	n
1/26/10	76.4	y, .11 ft	16.9	n	35.6	n	83.6	n			60.4	n	212.8	n
2/19/10	75.9	y, .18 ft	15.5	n	35.7	n	83.8	n			59.6	n	214.7	n
3/11/10	65.2	y, .53 ft	15.1	n	35.7	n	84.0	n	24.6	n	38.5	y, .72 ft	215.8	y, .45 ft
4/20/10	70.1	y, .20 ft	15.8	n	36.2	n	85.2	n			47.4	n	187.1	n
5/18/10	75.6	y, .22 ft	17.0	n	36.7	n		n			52.0	n	186.7	n
6/11/10	76.6	y, .18 ft	18.7	n	37.9	n	86.7	n	26.1	n	54.3	n	188.0	n

Note: All depths are feet below land surface. Streamflow is observed in the closest streambed location: “y” = streamflow was present, “n” = no streamflow was present. Streamflow presence is accompanied by maximum stream depth data.

*Due to fluctuation in well water depth levels from pumping, PAG is no longer monitoring the O’Leary well.

⁽¹⁾ Measured quarterly

⁽²⁾ Monitored by ADWR

⁽³⁾ Inconsistently accessible

Figure 5. Annual Change in Average Depth to Water

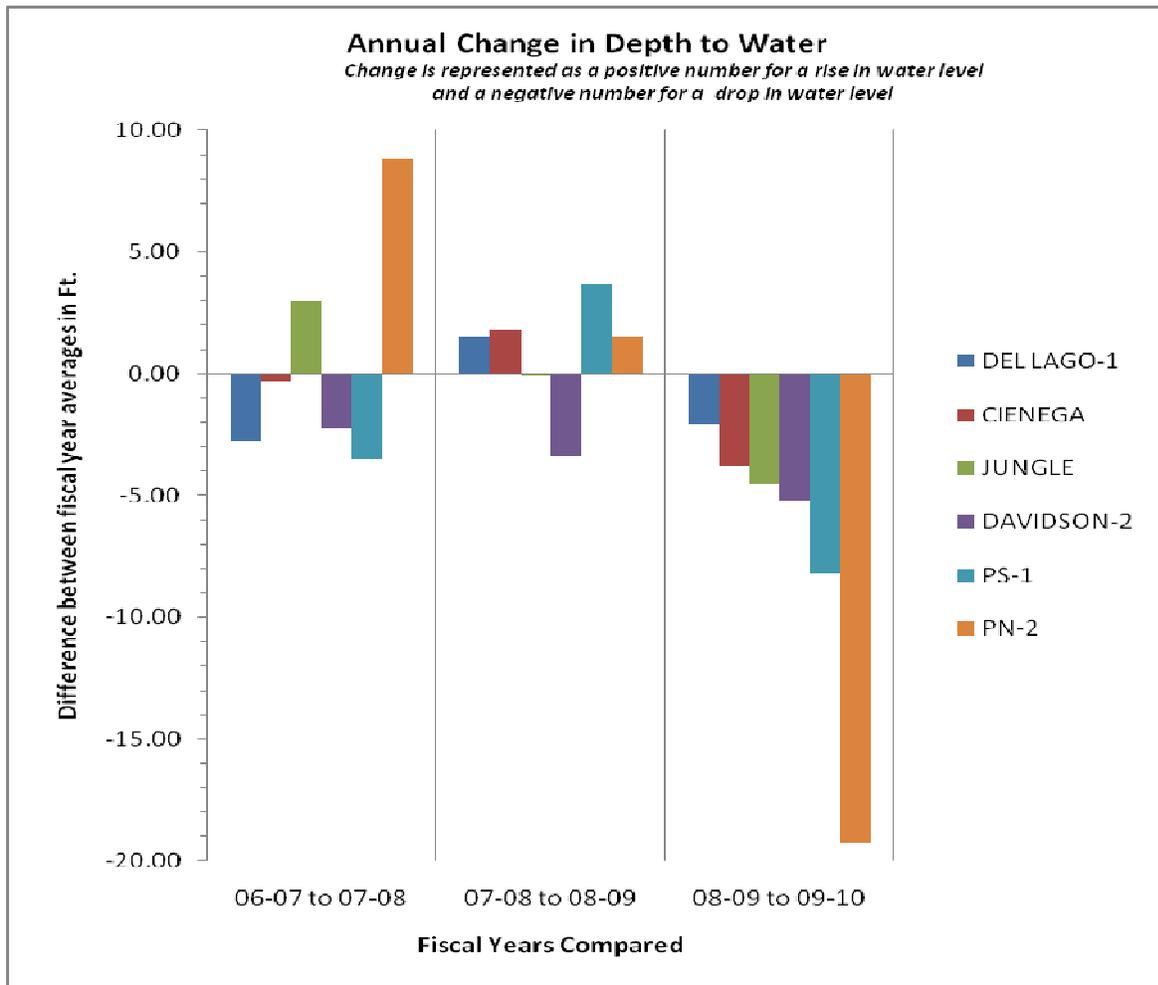


Table 3. Annual Average Depth to Water

DATE	Annual Average Depth to Water (ft.)				Annual Change (ft.)		
	06-07	07-08	08-09	09-10	06-07 to 07-08	07-08 to 08-09	08-09 to 09-10
DEL LAGO-1	69.47	72.21	70.68	74.71	-2.74	1.53	-2.07
CIENEGA	15.95	16.27	14.45	18.20	-0.32	1.82	-3.76
JUNGLE	33.99	30.98	31.02	35.56	3.01	-0.04	-4.54
DAVIDSON-2	20.30	22.55	19.17	24.37	-2.25	-3.38	-5.20
PS-1	46.88	50.38	46.71	54.91	-3.50	3.67	-8.20
PN-2	192.50	183.65	182.10	201.36	8.85	1.55	-19.26
Average	63.18	62.67	60.69	68.19	0.51	0.86	-7.17

Note:

All depths are feet below land surface.

Davidson is measured quarterly.

PS-1 and PN-2 are monitored by ADWR.

Empirita-2 and O'Leary were inconsistently available, so they are not included.

Figure 6A. Cienega Creek Natural Preserve Monthly Depth to Groundwater (June 1994 - June 2010)

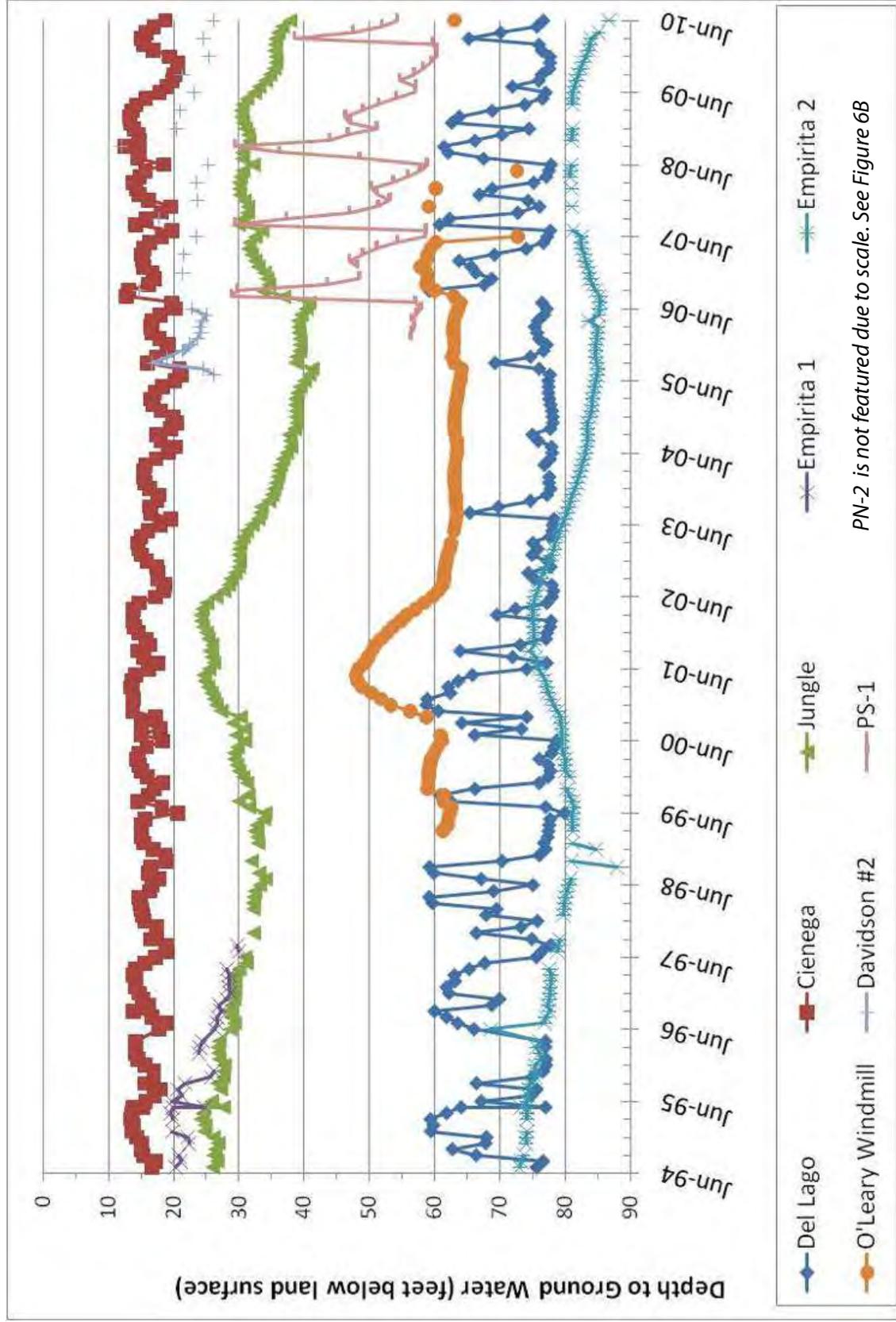


Figure 6B. PN-2 Monthly Depth to Groundwater (June 2006 - June 2010)

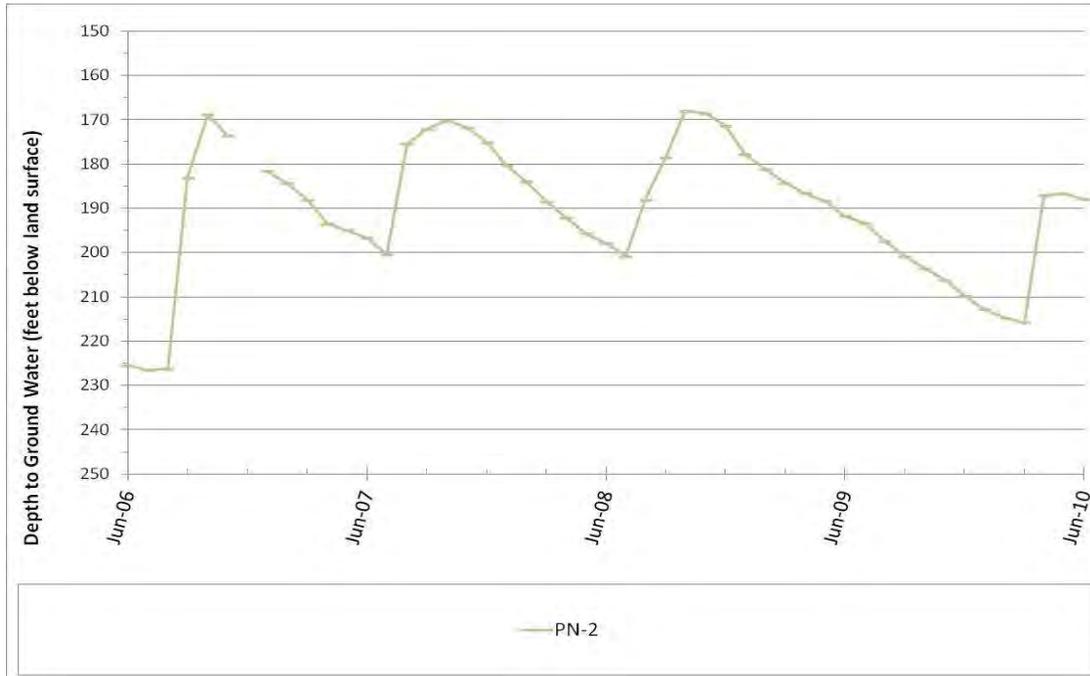
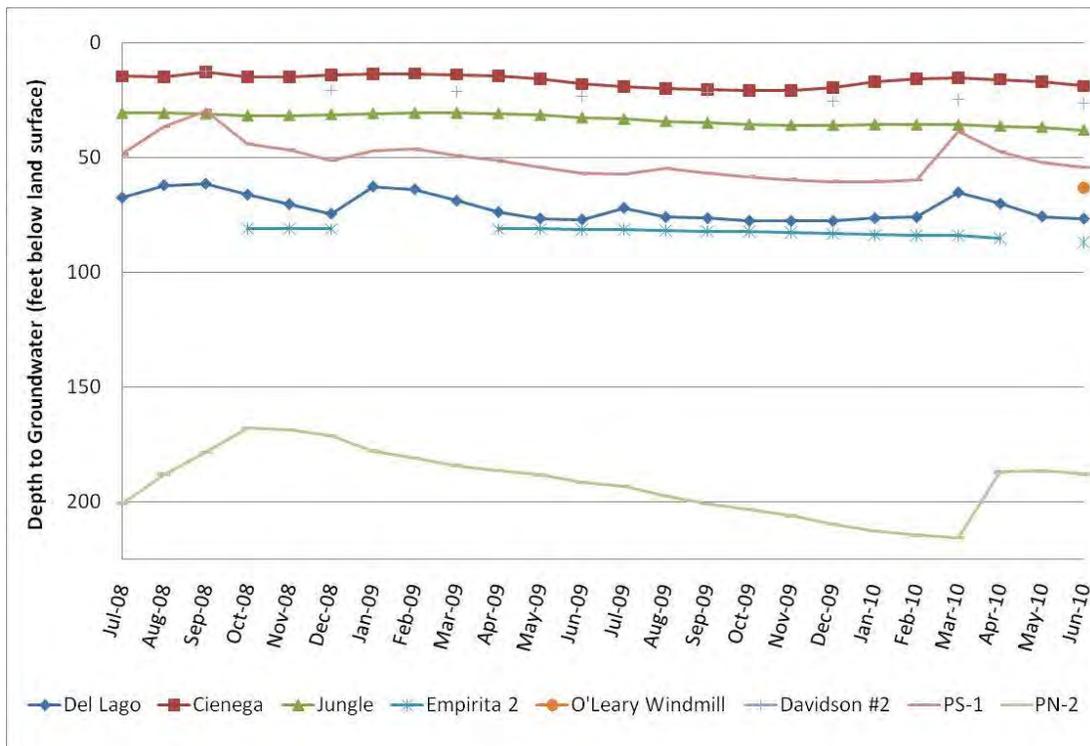


Figure 7. Cienega Creek Natural Preserve Monthly Depth to Groundwater (July 2008 - June 2010)



Data are not available for some months due to inaccessibility.

Extent of Surface Flow (Wet/Dry Mapping Walk-Throughs)

Methods

The extent of surface flow was mapped by walking the length of the creek channels and marking the location of the flows. For this report, the length of flow is referred to, the topic is the distance of stream that has flow extent, not the span of time that it is flowing. Annual wet/dry mapping was conducted during our driest month of June, between 1999 and 2001; the current quarterly schedule for the wet/dry program began during the FY 01-02 monitoring year. Quarterly mapping is conducted during the months of September, December, March and June. Cienega Creek walk-throughs begin at the ephemeral reach at Jungle Road and continue to the Pantano (Del Lago/Vail Water) diversion dam, a distance of about 8 miles (Figure 1A). Lower Davidson Canyon walk-throughs have been conducted near its confluence with Cienega Creek since FY 01-02 and in upper Davidson Canyon, south of Interstate 10 on the County's Bar V property, since FY 05-06.

The mapped extent of streamflow is processed using GIS. From 1999 to 2008, wet/dry mapping was completed on hardcopy aerial photography maps in the field and was subsequently hand digitized in GIS (ArcMap) to clip a creek shapefile line into corresponding flowing segments. In FY 07-08, PAG began using a GPS (Trimble) Unit to mark points at the beginning and end of intermittent flow. PAG continues to use GIS to clip the same Cienega streamflow shapefile line, which follows the general incision of the creek, but does not necessarily follow the small meanders, since the particular stream course changes over time. This shapefile template is from the Pima County Land Information System and was created at a 1:200,000 scale. The mapping results are shown in Figure 8 and Figure 11.

The length of surface flow for each quarterly walk-through is calculated by totaling the extent of each flowing segment. As is consistent with historical records, PAG considers the total length of creek channel within the preserve to be 9.5 miles. This includes the section of creek that begins at the I-10 crossing and flows north-west to the dam, but PAG does not walk the first 1.5 miles since it is known to be dry. All flow lengths within the Preserve, including lower Davidson Canyon, are included in the total sum of flow length. Located outside the Preserve, the sum of flow length for upper Davidson Canyon (Figure 1A) is calculated and presented separately.

Results

Historical and Current Cienega Flow Extent:

These data are evaluated for trends of average annual total distance of the surface flow length, seasonal variation, intermittency of segments and minimal perennial flow trends.

The annual average total distance of surface flow extent in the Cienega Creek Preserve since 1975 has decreased over time (Figure 10). It decreased from 7.7 miles, the average flow length from 1975 to 1992, to 4.1 miles on average since 2001. Using this flow extent data plus groundwater levels, streamflow volume and precipitation data, PAG considers the time period since 2001 to be a drought period. In the short term (Figure 9), the annual average flow extent was 3.3 miles in length during FY 09-10, a decrease of 61% from last year.

The documentation of seasonal variation helps to identify ephemeral and perennial reaches. Seasonal variation is evaluated for each year by taking the difference between the quarters with the longest and shortest total flow extents. The largest change in flow extent generally occurs as a decline between the months of March and June, which coincides with the time period when evapo-transpiration rates increase, precipitation is minimal and recharge rates decrease (Figure 8 and Table 4). With drought, increased seasonal variation of surface flow length was observed (Figure 10). The

difference between the high and low seasons' averages 3.0 miles since 2001. Prior to 1993, the difference between seasons' flow lengths ranged between 0.0 to 1.7 miles.

Mapping streamflow during the driest part of the year conservatively identifies the perennial reaches in the Preserve. As seen in Figure 8, the total flow extent in the Preserve is consistently lowest pre-monsoon, in June. Summer flow extents have declined substantially since the 1980s (Table 5, Figure 12). In July 1984, the creek flowed continuously from I-10 to the Pantano Dam, a distance of 9.5 miles (Montgomery & Associates 1993). In contrast, the average percentage of wet (i.e. flowing) creek length in the same area in June since 1999 has been 28 percent. Since 1999, the summers of 2004 and 2005 were a low point followed by a rise in flow in 2007, 2008 and 2009 (Figure 9). With a decrease in summer flow this June 2010, the creek flowed for 2.38 miles in total, composing 25 percent of the monitored preserve length (Figure 11). This was 0.3 miles less than the average since 1999. In addition to shorter total flow extent, drier years and drier seasons also generally have shorter length stream reaches, as seen in Figure 8 and Table 4.

The month with the longest total flow extent is usually either March or September (Figure 8 and Table 4). This analysis finds that a rise in annual average flow extent coincides with the longest extent occurring in September. These lengthier September extents are a result of the monsoon precipitation, which decreases drought impacts when looked at as an annual average of flow. This is consistent with this year's findings and is true for both streamflow volume and flow extent, since March had the greatest flow length and drought impacts have increased. In addition to September 2009 not exhibiting the greatest flow extent this year, for the first time on record, September had lower flow than June. September 2009 had 52% of the average September flow length. September 2009 was especially unique because it had the lowest September flow length on record, which was most likely due to a lack of monsoon rainfall in 2009. PAG had previously noted that 2004 was the lowest of the drought years, but September 2009 flow was 0.5 miles less than September 2004. However, average annual flow length in FY 04-05 was 0.7 miles shorter than in FY 09-10 and still ranks as the peak drought year.

Lower Davidson Canyon Flow Extent:

Since 2001, when mapping began in lower Davidson Canyon near the confluence with Cienega Creek, the extent of surface flow has considerably varied both annually and seasonally. Every other year, the reach alternates between near year-round flow and near year-round dryness. In FY 09-10 lower Davidson Canyon had no flow in any of the monitoring quarters (Table 4). In FY 08-09, lower Davidson Canyon had flowing extents for three quarters of the year. In FY 07-08, the reach only flowed during a single quarter, measured in September; FY 06-07 had flow year-round; and FY 05-06 had no flow year-round.

Upper Davidson Canyon Flow Extent:

The flowing reaches of upper Davidson Canyon are located at a spring next to a bedrock outcrop south of the I-10 crossing (as seen on the map in Figure 8). This is the fifth year that these surface flows were systematically mapped, but the streamflows along this reach were also noted during earlier PAG studies. Pools of considerable size, between one to three feet deep, remain along this channel, but no fish have been sighted since the summer of 2005. The only flowing quarter in Davidson Canyon in FY 09-10 was in September 2009 when it flowed for 0.58 miles (Table 4). Since monitoring began in Upper Davidson Canyon, September has been the peak flow extent, followed by progressively lower flows each quarter through the monitoring year. In FY 09-10, PAG observed the lowest September flow on our short record, followed by the first observation of consecutive quarters of no flow. June 2008 was the only other quarter where no flow was seen since monitoring began on this reach in September 2005.

Table 4. Cienega Creek, Lower Davidson Canyon and Upper Davidson Canyon, Quarterly Data for Lengths of Each Flowing Segment (Sep. 2009 - June 2010)

Flowing Reach	Length of Flowing Reach (feet)			
	September	December	March	June
	9/17/2009	12/7/2009	3/35/10	6/17/2010
Cienega Creek Reach A	245	6125	8262	182
Cienega Creek Reach B	209	3819	3498	224
Cienega Creek Reach C	3121	5931	927	26
Cienega Creek Reach D	3898	1135	175	85
Cienega Creek Reach E	1604		5715	108
Cienega Creek Reach F	578		6360	1218
Cienega Creek Reach G	658		4648	1366
Cienega Creek Reach H			328	4731
Cienega Creek Reach I			57	3016
Cienega Creek Reach J				1589
Lower Davidson Canyon Reach A	0	0	0	0
TOTAL (ft)	10313	17010	29970	12545
(miles)	1.95	3.22	5.68	2.38
Upper Davidson Canyon Reach A	19	0	0	0
Upper Davidson Canyon Reach B	888			
Upper Davidson Canyon Reach C	260			
Upper Davidson Canyon Reach D	1877			
TOTAL (ft)	3044	0	0	0
(miles)	0.58	0.00	0.00	0.00

Reaches are not numbered in sequence; they are not associated with any one fixed portion on the creek. A lower total number of reaches generally indicates less interrupted flow.

Upper Davidson Canyon reaches are mapped on different dates than Cienega Creek and lower Davidson Canyon reaches due to the length of time required to complete both creeks.

Table 5. Cienega Creek and Upper Davidson Canyon, Summer Months' Total Length of Flow Extent, (1984 -2010)

Year	Length of Cienega Creek	Length of Upper Davidson	Source	
Jul-84	50,000 ft. (9.5 miles)	No data	Errol L. Montgomery & Associates, Inc.	
May-85	50,000 ft. (9.5 miles)			
May-86	43,140 ft. (8.2 miles)			
May-87	43,200 ft. (8.2 miles)			
May-88	41,500 ft. (7.9 miles)			
May-89	34,640 ft. (6.6 miles)			
May-90	37,400 ft. (7.1 miles)			
May-91	42,160 ft. (8.0 miles)			
May-92	37,740 ft. (7.1 miles)			
<i>No data 1993-1998</i>				
Jun-99	14,290 ft. (2.7 miles)	No data	PAG	
Jun-00	14,590 ft. (2.8 miles)			
Jun-01	24,950 ft. (4.7 miles)			
Jun-02	17,220 ft. (3.3 miles)			
Jun-03	10,630 ft. (2.0 miles)			
Jun-04	8,145 ft. (1.5 miles)			
Jun-05	7,865 ft. (1.5 miles)			
Jun-06	12,025 ft. (2.3 miles)			170 ft. (.03 miles)
Jun-07	15,860 ft. (3.0 miles)			483 ft. (.09 miles)
Jun-08	14,831 ft. (2.8 miles)			0 ft. (0 miles)
Jun-09	16,127 ft. (3.1 miles)	1,187 ft (.22 miles)		
Jun-10	12,566 ft. (2.4 miles)	0 ft (0 miles)		

The length of the Cienega Creek channel from Interstate 10 to the Pantano Dam equals 50,000 ft. (9.5 miles) and includes 1,100 ft. (0.21 miles) of Lower Davidson near the confluence with Cienega in this calculation. Upper Davidson includes 22,700 ft. of creek channel (4.3 miles) from the spring south of the I-10 crossing down to the beginning of the Lower Davidson Reach. Data were collected by Errol L. Montgomery & Associates from 1984 to 1993. Data were not collected from 1993 through 1998.

Figure 8. Maps of Cienega Creek and Davidson Canyon, Quarterly Flow Extent (Sep. 2009 - June 2010)

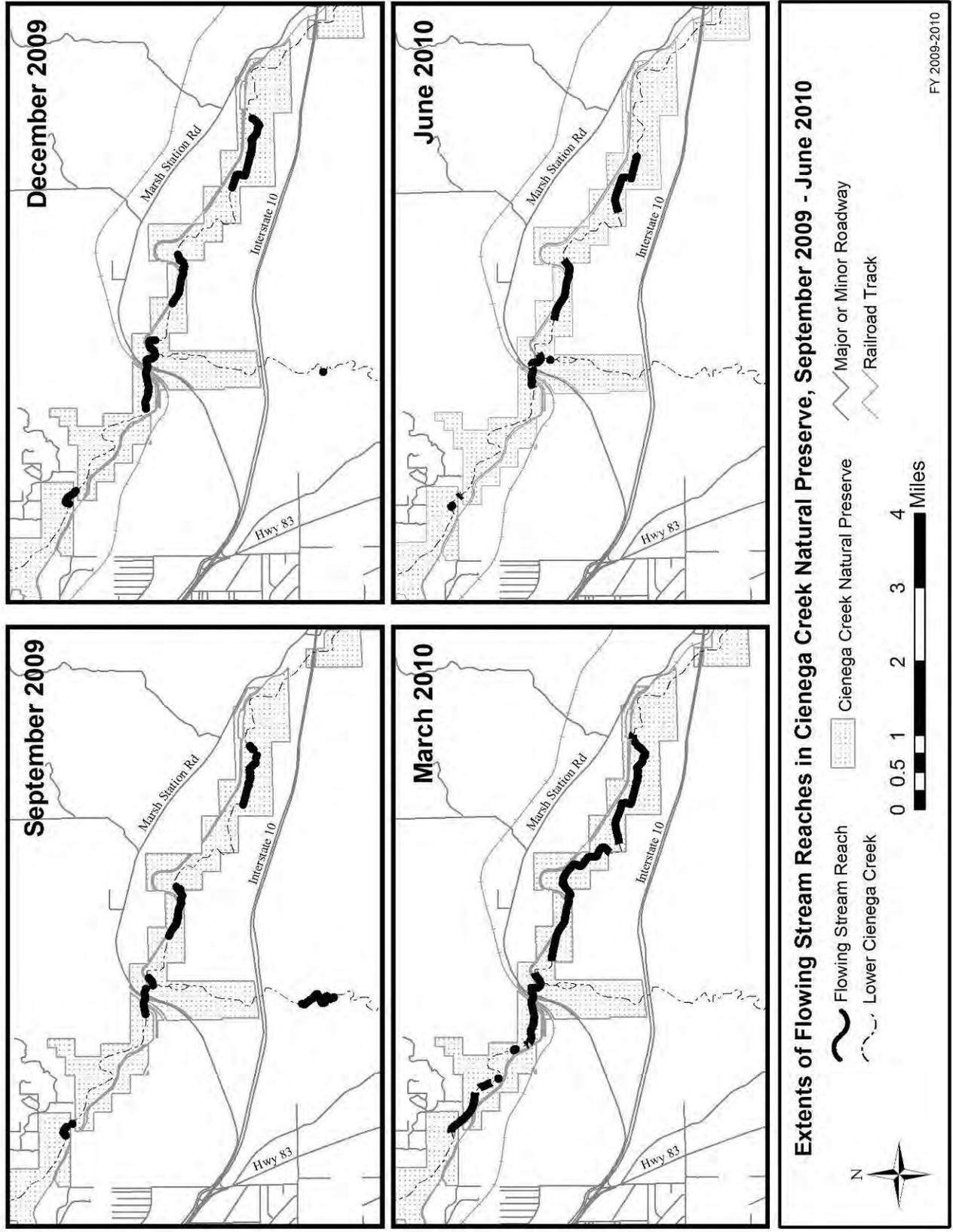


Figure 9. Cienega Creek Quarterly Flow Extent, 1999 to 2010

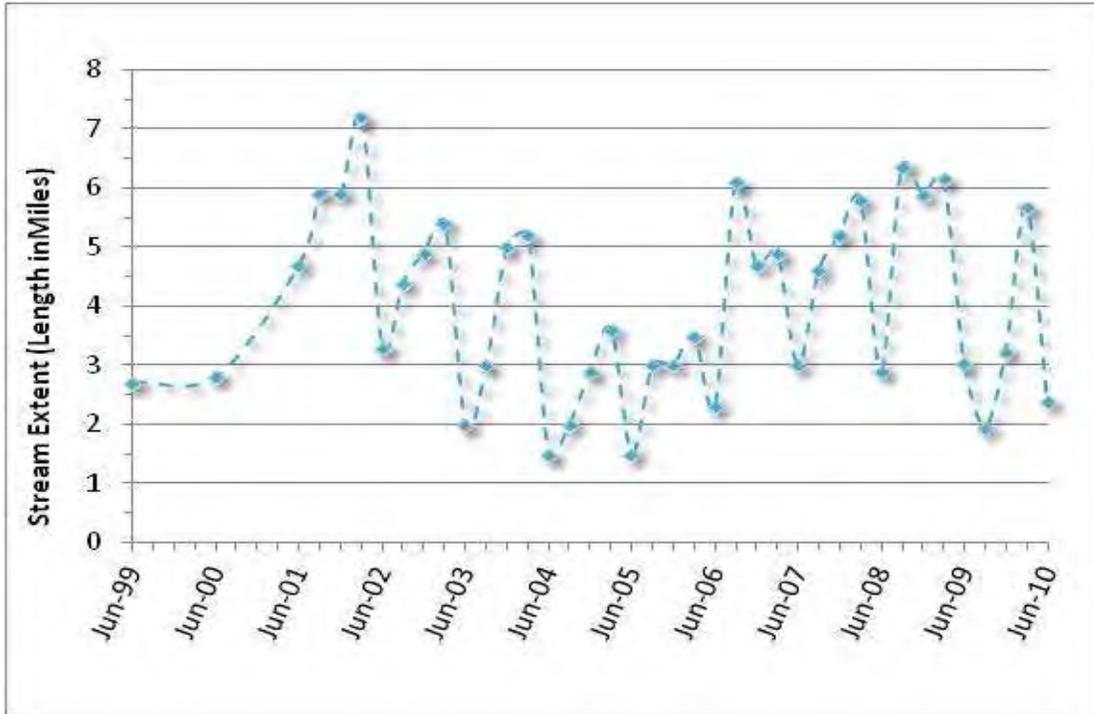
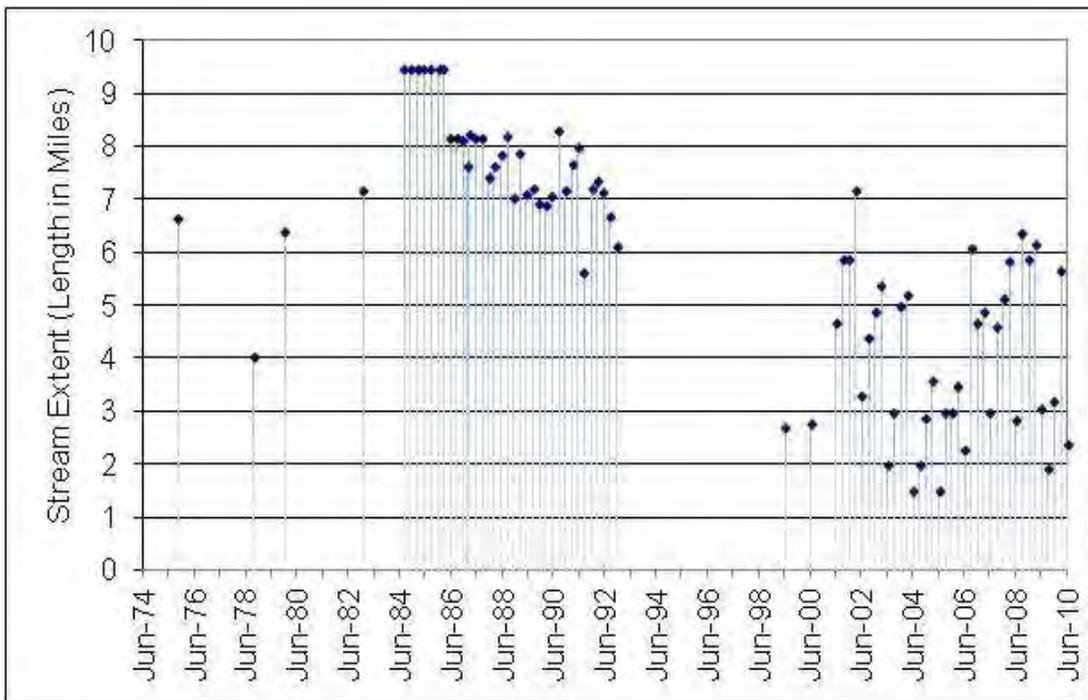


Figure 10. Cienega Creek Flow Extent, 1975 to 2010



Data prior to 1993 is from Errol L. Montgomery & Associates, (Montgomery & Associates 1993). Prior to 1984, and between 1999-2000, flow extent was measured was not consistently. Extent length was measured in October 1974, September 1978, December of 1979 and 1982, and June of 1999 and 2000, typically drier months. Length was not measured from 1993-1998. Akko other measurements were taken quarterly.

Figure 11. Map of Cienega Creek's June Flowing Reaches with Wet/Dry Pie Charts, 1999 to 2010

Cienega Creek Annual Wet/Dry Status in June

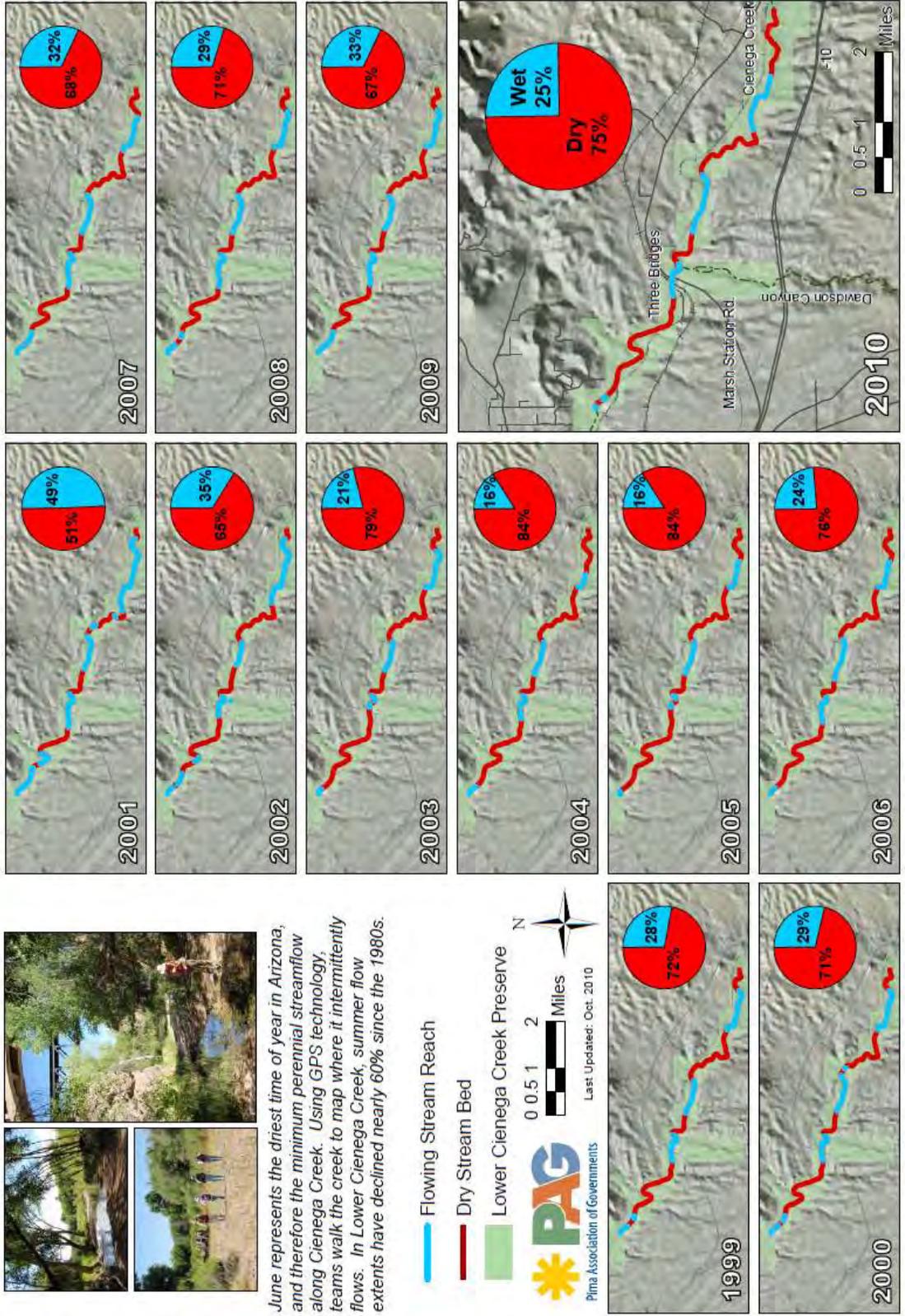
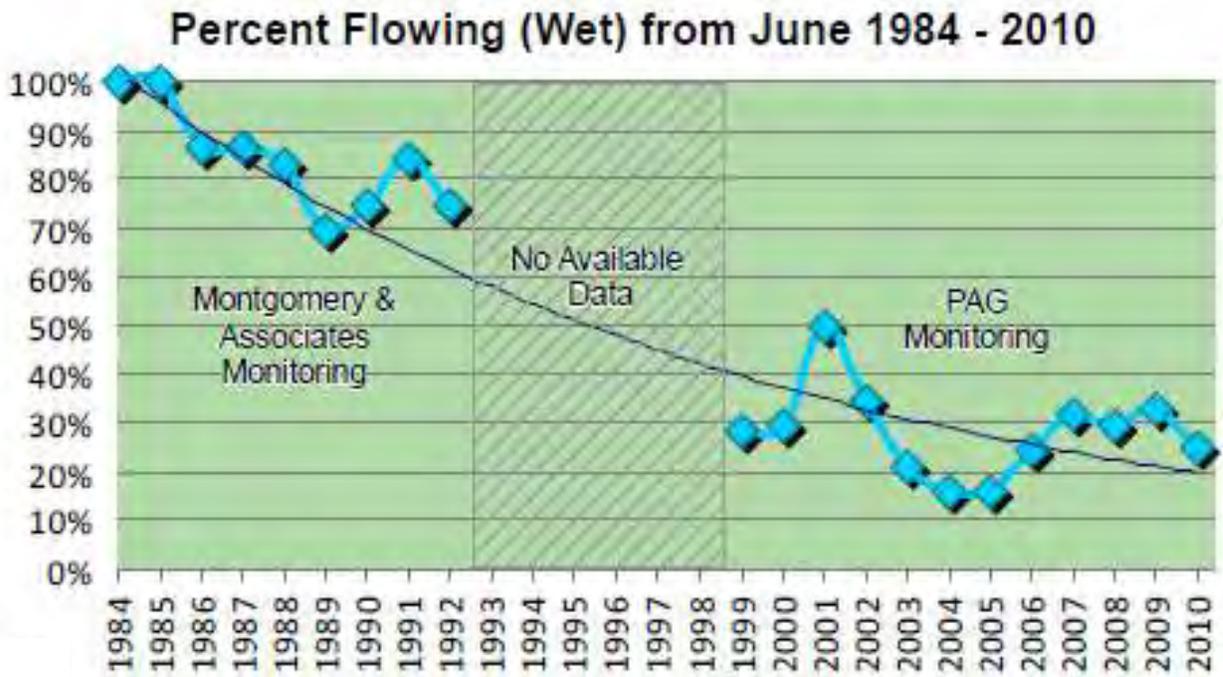


Figure 12. Graph of Percent of Creek Length Flowing in June: Perennial Flow



Water Chemistry

Methods

In January 2007, PAG began regular water quality monitoring at four monitoring sites that had also been monitored in past PAG studies. ADEQ's inclusion of Davidson Canyon as an Outstanding Arizona Water was the impetus for resuming the water quality monitoring in 2007. This monitoring will serve as additional baseline data, should the creek become impacted by upstream copper or limestone mining.

The locations of the monitoring sites for water chemistry are displayed in Figure 1B. Current monitoring stations, Davidson 3 and Davidson 2 are both located in Davidson Canyon upstream from its confluence with Cienega Creek, and both exhibit ephemeral flow conditions. Davidson 3 replaced Davidson 1 after it went dry. Cienega 1, located just upstream of the confluence with Davidson Canyon is a perennial site. Cienega 2, located downstream from the confluence at Marsh Station Bridge, is also a perennial streamflow monitoring site. ADEQ has over 10 years of historical water quality data from the Marsh Station monitoring location.

Various water quality field parameters were measured by PAG staff during walk-throughs at the four water quality sites. In addition, Cienega 2 field parameters were measured during monthly streamflow monitoring. PAG uses an Ultrameter to measure field parameters consisting of Total Dissolved Solids, temperature, conductivity and pH. At two sites, samples are collected and processed twice a year, in March and September. Sampling analytes include alkalinity, anions, TDS, metals, hardness, Nitrate, Nitrite, turbidity and Cyanide. A complete list of analytes included in sampling is not included in this report but is available upon request. One sampling site is Cienega 1 and the other sites vary depending on availability of flow. Davidson 3 is the preferred second sampling site, but if that spring is dry, PAG samples in Cienega Creek below Davidson's confluence (at Cienega 2) to measure influences of Davidson Canyon.

Prior to the field day, PAG prepares sampling analyte forms and protocols and requests PCRFC and the lab to review the updates and purchasing information. PAG keeps the chain of custody record, field parameter records and streamflow volume data. PCRFC analyzes the sampling results. The water quality Ultrameter is maintained by monthly calibration. Field notes of field parameter measurements and sampling include date and time, a description of the weather, the names of the field crew, the site name and any calibration observations. Water quality measurements are only gathered during baseflow conditions when clear, non-storm runoff water is flowing in the creek. Samples and readings are not collected from standing water, eddies or sections with immeasurable flow. Samples are collected using gloves; samples are filled so that no air is sealed into the bottle; samples are stored on ice and return to the lab in a timely manner so that analytes can be processed within 24 hours. Streamflow volume is measured to accompany all sampling efforts.

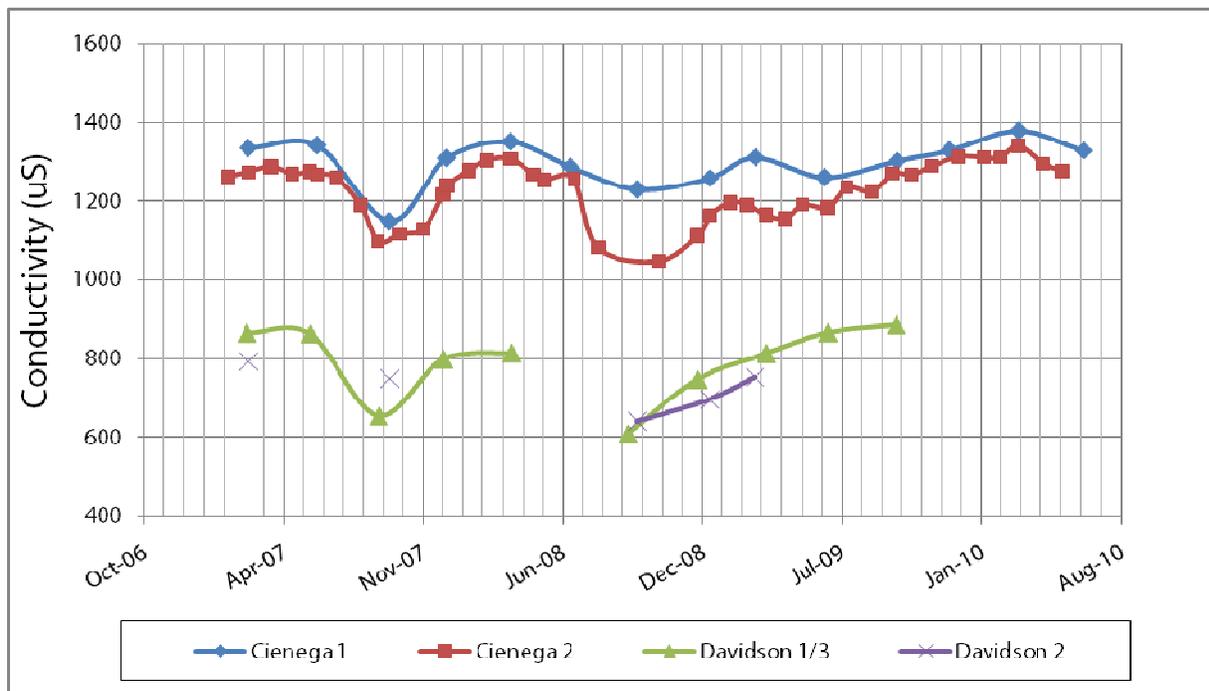
Results

Our data shows seasonal and geographic variations in water chemistry, but does not indicate any significant long-term trends. Seasonally, conductivity and total dissolved solids drops in the fall. Conductivity fluctuates by about 200 μS within a year (Figure 13). This trend was not observed in 2009, possibly due to abnormally low precipitation. The average conductivity of the Davidson Canyon sites is lower than the Cienega sites. The contribution of Davidson Canyon to baseflows in Cienega Creek may lower the conductivity at the Cienega Creek downstream from the Davidson confluence (Cienega 2). The long-term trend (Figure 14) shows that over the last nine years, conductivity increased slightly at all sites, except for a slight decrease at Davidson 2. The pH was highest at Davidson 1/Davidson 3 and at Cienega 2 (Figure 15). The temperature was lowest at Cienega 1 (Figure 16).

Further sampling and water chemistry data is available from the following sources:

- Errol L. Montgomery & Assoc. (EMA) in June 2008 at Cienega 1, Davidson 2 and Davidson 3 and in October 2008 at Cienega 1, Davidson 2 and Tilted Beds
- PAG sampling results (Test America Lab Work) taken at Davidson 3 in September 2008 and September 2009. Samples were taken at Cienega 1 and Cienega 2 in March 2010, above and below the Davidson confluence because the Davidson sites were dry at that time.
- Water Quality Studies Within The Cienega Creek Natural Preserve: Prepared by: David Scalero, Principal Hydrologist, and Frank Postillion, Chief Hydrologist, Pima County Regional Flood Control District, Water Resources Division, April 10, 2009 (analysis of EMA and PAG lab-work from 2008)
- PAG Quarterly samples were taken in 2002-2003 and a single sample in 2005 for the Unique Waters Study and more metals were sampled in 2005 for the Davidson Unique Waters Plan.
- PAG 2002-2003 quarterly samples for isotopes, chemistry and constituent sampling in the Davidson Cienega Study

Figure 13. Cienega Watershed – Seasonal Conductivity Fluctuation (January 2007 - June 2010)



Note: Davidson 3 serves as a replacement for the Davidson 1 site since March 2007. Depending on the site, readings were measured every 1-3 months, when sites had available flow. No data was collected from 2004-2006.

Figure 14. Cienega Watershed – Change in Average Conductivity per Site (2002 – 2010)

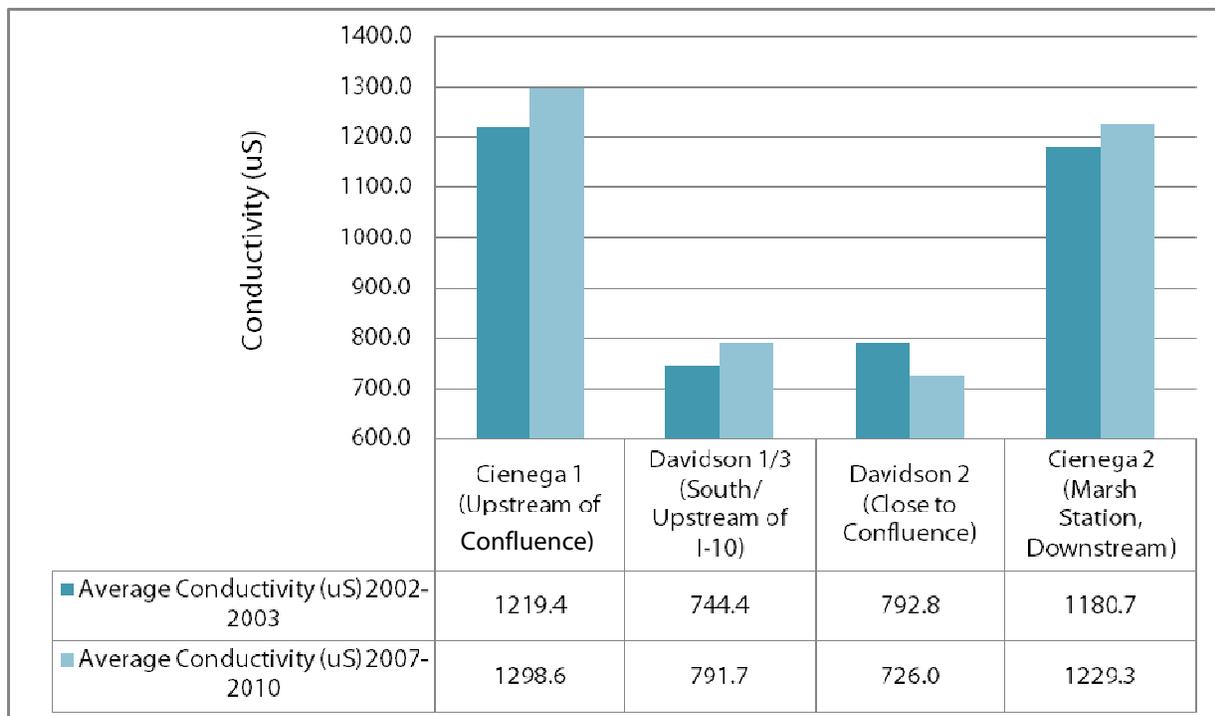


Figure 15. Cienega Watershed – Baseline Average pH (2002 – 2010)

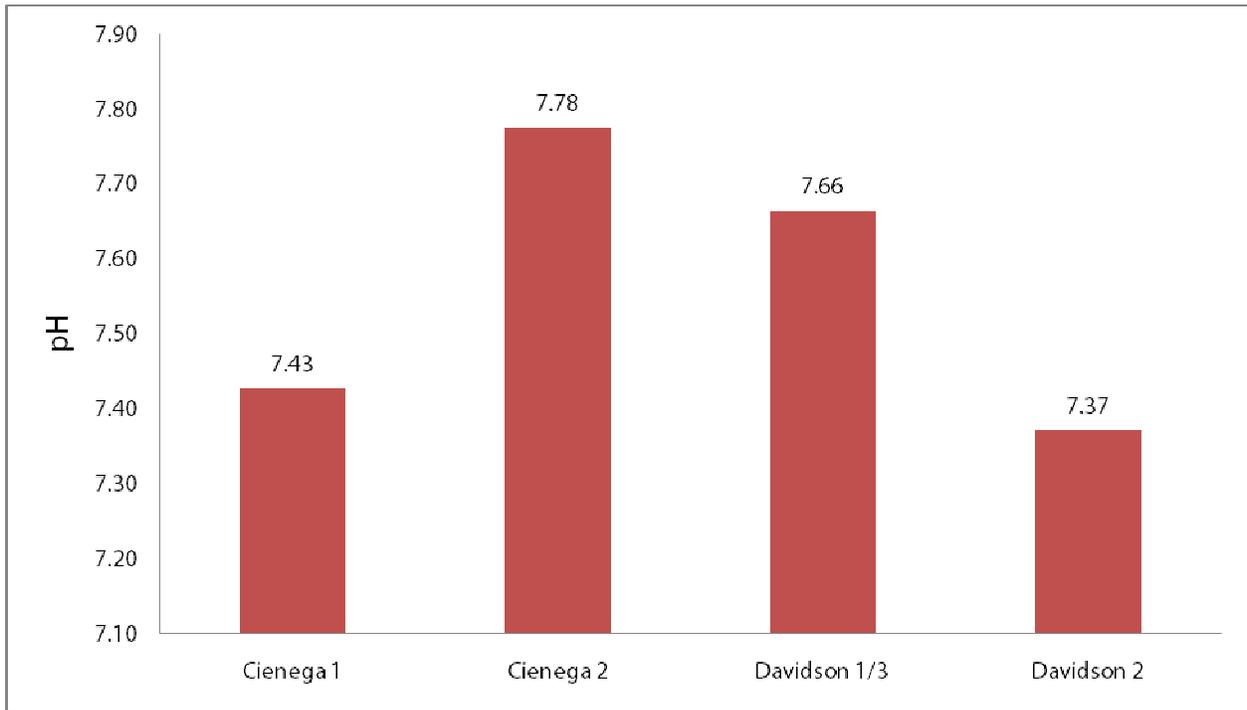
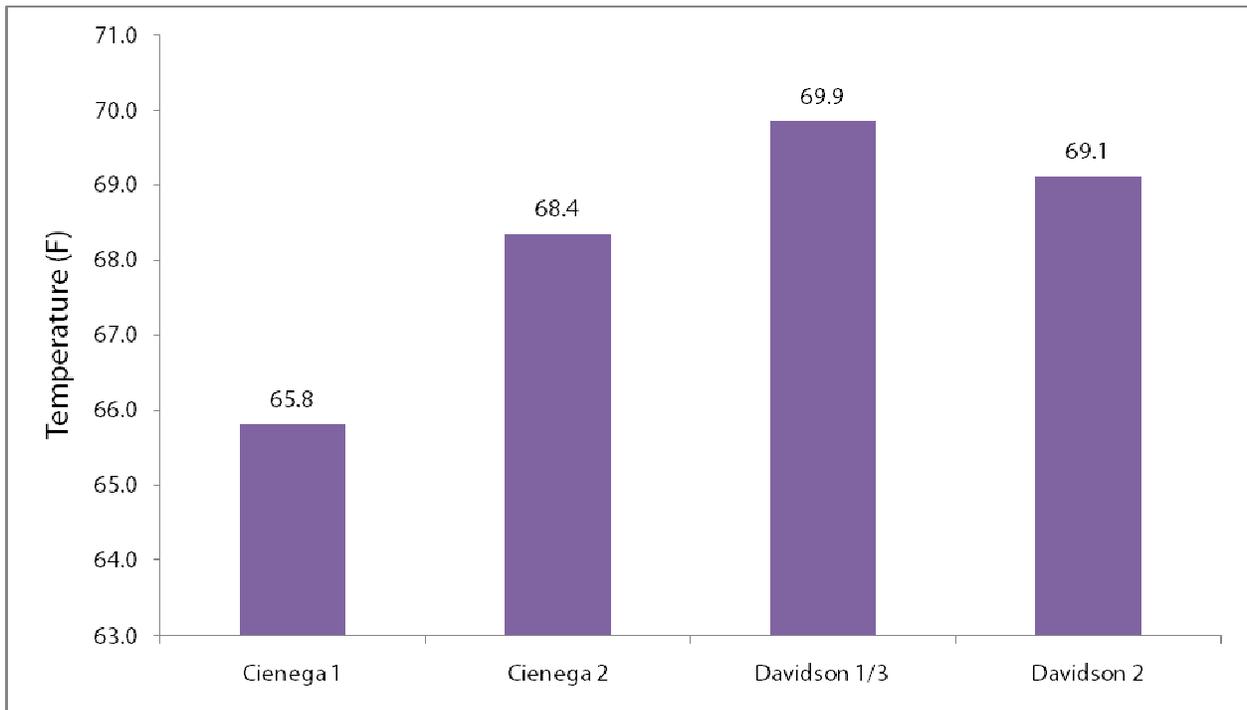


Figure 16. Cienega Watershed – Baseline Average Temperature per Site (2002 -2010)



Repeat Photography

Repeat photography is a valuable tool for assessing the change along the creek and for sharing information with others. In 2006, PAG established eight repeat photography areas and methodology for documentation and has modified the methods as needed. PAG continued photographing established photo areas in FY 09-10 on a quarterly basis, or more often if extreme conditions were encountered while in the field during monthly hydrologic monitoring. Many photo locations include several different repeat photographs so that different view directions can be documented.

Photo sites were initially selected in 2006 by reviewing a collection of photos with a history of recorded site conditions and by adding sites as needed in order to capture dynamic conditions, or to get a better distribution throughout the creek. The GPS site locations are shown in Table 6 on the following page. Care is taken to photograph at the same location each time, adjusting the frame slightly if needed to accommodate conditions. Photos are stored digitally at PAG and, for record-keeping, photos are named according to a photo site number, description and view direction, and filed by date.

In FY 08-09, PAG created an initial review of these photo sites to assess the methodology of the program and see if there is evidence of site morphology, flow or vegetation change recorded within the images of this large set of baseline data. The following areas were assessed in FY 08-09:

- Vegetative changes near Del Lago Dam
- Scour pool below Del Lago Dam
- Canopy cover and sedimentation at Jungle Road

Review of repeat photography shows that site changes that might go unnoticed in the field are often revealed by comparing historical photos. PAG's photo catalogue now contains numerous photo sites distributed throughout the creek. This baseline data is valuable because of the unpredictability of geomorphic alterations along the creek. The photographs have also been used in newsletters, presentations, data requests and other forms of communication to demonstrate seasonal change, drought and erosion. PAG has created and placed the following virtual tours of Cienega Creek on-line.

- Headcut virtual field trip
- 3D Photosynth view of Marsh Station

For this FY 09-10 report, photos were selected from two sites, to demonstrate the very visible scour and sedimentation at these locations (Figures 17 and 18).

Table 6. Cienega Walk-Through Photo Points

Photo Site ID	Photo Name	Description
#1	Jungle Road - A	Stand on road in middle of channel. <i>View Downstream.</i>
	Jungle Road - B	Again - Stand on road in middle of channel. <i>View Upstream.</i>
#2	Jungle Tunnel	Stand downstream of beginning of flow (by tunnel). Capture some of banks of tributary. <i>View Downstream.</i>
#5	Upstream of Tilted Beds	Stand 30 paces from barbed wire fence. <i>View Upstream.</i>
#3	Tilted Beds A	Measuring site in foreground. <i>View Downstream.</i>
#4	Tilted Beds B	Standing atop sandstone outcrop Viewing bucket measuring site. <i>View Upstream.</i>
Bend	Headcut original channel in horseshoe bend	Stand a ways upstream of RR Wash. <i>View Downstream.</i>
HCa	Head Cut - A	At Major headcut plunge pool where headcuts split, slightly upstream of pool, on bank. <i>View Downstream.</i>
HCb	Head Cut - B	At Major headcut plunge pool where headcuts split, standing slightly downstream of pool, in headcut. <i>View Upstream.</i>
#8	Confluence - Upstream from railroad bridge	Downstream of confluence of Cienega Creek and Davidson Creek. <i>View Upstream. Take another to include bedrock, standing more downstream, depending on conditions.</i>
Dav	Davidson - Deer Grass - A	Up Davidson Canyon to most extreme possibility of beginning of flow. <i>View Upstream.</i>
	Davidson - Deer Grass - B	Same as above, but <i>View Downstream.</i>
#9	Sharp bend in creek upstream in Davidson Canyon	Walk upstream from confluence to end of flow, <i>View Downstream.</i>
#10	Just downstream from sharp bend in Davidson Canyon	Just downstream from Point #9, take picture with end of flow included - <i>Turn around to View Upstream.</i>
#7	Upstream from Marsh Station	Through the railroad bridge (with bridge support structure in photo). Vertical shot. <i>View Upstream. Take extra photos if you need to see stream beds and banks closer up (less bridge).</i>
#6a	Marsh Station - A	Bedrock on left, with bridge in picture. Standing downstream of flow measurement site. <i>View Downstream.</i>
#6b	Marsh Station - B	Flow measurement site in photo. <i>View Upstream.</i>
Sediment Plug	Sediment Plug	Stand downstream of stream bend where it is cutting into sediment (duck spot). Capture wide new banks. <i>View Upstream.</i>
#11a	SP 1006 (Southern Pacific mile marker) - A	Stand downstream from beginning of flow with hill present ahead on right (may not be visible). <i>View Upstream.</i>
#11b	SP 1006 (Southern Pacific mile marker) - B	Stand upstream from beginning of flow with hill present ahead on left (may not be visible). <i>View Downstream.</i>
#12a	Del Lago Dam - A	Focus on dam. Stand a bit upstream on N side of creek. <i>View Downstream.</i> Make sure you can see the distance of flow over dam or get another shot.
#12b	Del Lago Dam - B	Focus on dam. Stand a bit downstream on N side of creek. <i>View Upstream.</i>
#12c	Del Lago Dam - C	View across dam from south bank. Capture flow over dam and the pools.

Figure 17. Photo Documentation of Erosion at Tilted Beds, Cienega Creek



1

This series of photographs shows repeat photography at photo site #5, upstream from Tilted Beds, facing upstream. This sequence shows how the creek experiences alternating scouring and sedimentation over time, as well different scour patterns. For example, the Sep. 2009 photograph shows an incised streambed, but by June 2010 that sediment had accumulated and eliminated the downcut channel bed.



2

During the time period shown here, some water was observed on the streambed surface, but there was never sufficient water to create measurable baseflow. Along this reach, occasional flood events scoured the surface, forming pools. Scour events tended to form after dry periods, as shown here.



3



5



4



6



7



8

Figure 18. Photo Documentation of Streamflow Volume Changes at Marsh Station, Cienega Creek

These photos are taken at the Marsh Station site, looking upstream to the streamflow measuring location. They highlight the dramatic reduction of flow in September 2009, which was the driest September since the drought began in 2003. In general, September streamflow volumes are higher than those documented in June because of monsoon rainfall, however, Sep. flows were smaller than June flows in 2009. The photos also illustrate that ranges of streamflow volume of flow can each take many forms.

1



Sep. 2008 (1.71 cfs)

2



June 2009 (0.21 cfs)

3



Sep. 2009 (0.08 cfs)

4



June 2010 (0.18 cfs)

5



Sep. 2010 (0.34 cfs)

Additional Related Monitoring

Extent of Flow Past Del Lago Dam

As a special request from PCRFC in 2007, PAG documented the length of flow past Del Lago Dam during FY 09-10. The observations focused on the presence of pools, fish, flow over the dam/flume and length of flow past the dam. Maintenance was performed on the flume and the valve was left open for several months in the summer of 2008, which provides the opportunity to evaluate the extent of flow and the impact of released flows on groundwater levels. That summer, the flow reached a maximum extent of 2,200 feet downstream of the dam. The flow extent diminished within two months after the flume door was closed. At a well site located at the bottom extent of the flow (PS -1), groundwater levels rose to 29.42 feet below land surface when water was released in the summer of 2008, whereas the average depth is typically ranges from 46 to 50 feet below land surface. Additional information on groundwater levels associated with flow is discussed in the groundwater section of this report.

Headcut Study

Headcutting in the Cienega Creek watershed is a dramatic demonstration of sediment fluctuation within the stream system. The headcut at the railroad horseshoe area was studied through a two-year Arizona Water Protection Fund Grant (AWPF Grant No. 07-144). PAG monitored groundwater levels through two piezometers, measured headcut entrenchment, conducted repeat photography, monitored two streamflow sites and assessed habitat through riffle/pool distribution. Reports to AWPF were completed in 2010¹.

Through a habitat survey, hydrologic monitoring and a geomorphic survey, PAG was able to evaluate stream system changes with the advancement of erosion. Over the two-year study period, the headcut nick point advanced over 2,000 feet upstream and the channel eroded down to 12 feet deep. Headcutting affected many aspects of the creek, including the slope of the water table, the expression of surface flow, the distribution of sediment substrates and the density of vegetation cover.

Depending on the value attributed to trade-offs for certain habitat types, changes in the creek habitat may be viewed as either positive or negative. The immediate results show that streamflow is restored in the headcut region and may last until (and if) the area experiences another wave of sediment accumulation. The trade-off for increased surface flow is loss of local shallow aquifer storage and possibly faster movement of flow out of the system. Loss of vegetation increases temperature and evaporation, decreases infiltration and speeds flood flows. When looking at the long-term, the current older growth tree-fall is reducing vegetative overstory, which will take 30 years to fill back in by the next generation of trees. In the shorter term, it appears that this erosion process will restore fish habitat in the active headcutting area, which has an approximately 10-year life span in our study area.

Because this type of investigation had not been previously conducted in an arid environment, where the typical stream has segmented perennial flow and intermittent ephemeral flow, there was added scientific merit to the project. The surface flow is dependent upon the water table gradient and by sediment aggradation and erosion. The study shows that large rain events, which follow long dry spells (typical of our region), have the greatest ability to create large sediment transit. In addition, this study shows that the timing of the transition of sediments is correlated to the gradient of the water table. During the dry pre-monsoon months, the extra wedge of de-watered alluvium in the streambed, created by the steeper water table slope, likely contributed to collapsed sediment structure and wetland vegetation die-off. Both of these changes appear to be loosening the sediments thereby directly contributing to the degree of erosion during subsequent monsoon floods.

FOOTNOTE:

1. *Pima Association of Governments, Evaluation of Riparian Habitat and Headcutting Along Lower Cienega Creek, Arizona Water Protection Fund Grant #07-144: March 2010*

PAG has established unique field methods for this system. This project has increased public awareness of management issues for this valued resource near the Tucson urban area. Due to the delicate nature of the creek preserve, PAG cannot make a recommendation to create in-creek sediment stabilization, although efforts in tributaries and uplands may be beneficial.

Figure 19. Photo of Depth of Erosion in Active Headcutting Study Area



This photo features the headcut at the "Railroad Horseshoe turn" where a second channel (behind the person on the upper level) branches of the main channel (person in the foreground).

Wildlife Observations

PAG regularly documents wildlife observations and habitat characteristics during field work in Cienega Creek. Observations of flora and fauna below were noted during quarterly walk-throughs and during the headcut habitat survey in March 2008 and March 2009. The native threatened and endangered fish and frog species observed by PAG in pools and other flowing reaches consisted of Gila Topminnow and Gila Chub. Lowland Leopard Frogs were present, whereas PAG did not see or hear Bullfrogs (an invasive species) within the creek. Longfin Dace is the most abundant native fish in lower Cienega Creek and though Topminnow is less dominant, it is commonly seen in most reaches. Pool habitats were present at various locations along Cienega Creek during each quarterly walk-through this year. PAG sees mud turtles less frequently, but it is not uncommon to come across one each year. PAG also commonly sees coatimundi, javelina, deer, hawks, barn owls, heron and reptiles and less commonly, Gila Monster. In the past few years, PAG has also seen mountain lion and tracks of bear and bobcat, but none were sighted this year.

As part of the habitat survey conducted for the headcut study, PAG found that the dominant native vegetation includes an overstory of Cottonwood, Goodding Willow, Mesquite and Ash, and an understory of Coyote Willow, Desert Broom, Deer Grass, Cattail, Bulrush, Horsetail and Canada Wildrye. There are only a few Sycamore trees along the creek. Invasive and exotic vegetation species commonly seen along lower Cienega Creek include Johnson Grass, Rabbitsfoot Grass, Tamarisk and Buffelgrass. PAG has not seen the Huachuca Water Umbel, the endangered plant species that is found in the upper watershed in Las Cienegas National Conservation Area. In order to present these findings to the public, PAG has created an informal guide for common species in the Preserve, which will be published on our Web site.

In order to communicate habitat and wildlife information, PAG reports incidental observations of species of concern on Pima County properties to the Office of Conservation Science with the goal to record observations of species that are part of the forthcoming U.S. Fish and Wildlife Service (USF&WS) Section 10 permit. Coordinates for location and species data from this effort is entered into an intranet database at Pima County and, over time, these data will become an invaluable resource for monitoring changes in the location of resources as well as providing a tool for current conservation planning efforts such as development of site-specific management plans. Threatened or candidate species that could potentially be present during our monitoring at Lower Cienega Creek include Gila Chub, Gila Topminnow, Northern Mexican Garter Snake, Southwestern Willow Flycatcher, Lesser Long-Nosed Bat, Sonoran Desert Tortoise, Chiricahua Leopard Frog and Huachuca Water Umbel. PAG has also been requested to record the presence of Longfin Dace, Sonora Mud Turtles and Lowland Leopard Frogs for this effort, as well as invasive species such as bullfrogs and buffelgrass for preserve management.

Drought Watch

In 2008, PAG began contributing Cienega monitoring data to the Local Drought Impact Group. On a quarterly basis, PAG uploads monthly reports on the impact and trends of drought on lower Cienega Creek to the statewide reporting Arizona Drought Watch Web site: <http://azdroughtwatch.org>. For groundwater and streamflow, PAG reports the presence of drought impacts and whether the trend is 'better' or 'worse' in severity. Flow extent data are reported within the quarter they are collected. Marsh Station serves as the streamflow site. Two wells (Cienega and Jungle) are used for groundwater analysis for this reporting system. These wells were selected because they have similar response times to precipitation, they are consistently accessible and they have a set of historic monthly data available. Data from the two well sites are averaged for the analysis.

To determine whether there are drought impacts, PAG compares the monthly data to the water levels seen in pre-drought years. PAG considers 2001 through the present to be the drought years and 1994 through 2002 the pre-drought years. To assess the trend of these impacts, PAG compares to data one year prior instead of one month prior, to account for seasonal changes. For example, during our monthly monitoring, if stream volume has decreased, flow extent has decreased or groundwater levels become lower when compared to the level that it was at one year prior, PAG submits a record of worsening trend.

PAG data clearly shows the presence of continued drought impacts. The gradual drying trend in Cienega flow lengths since 1984 (Table 5) is probably due in part to the current drought, but PAG cannot completely rule out all other contributing factors, such as water withdrawals from nearby wells or upstream land uses. The largest impacts of drought in our records were found during FY 04-05, although in September 2009, the flowing length was the lowest extent on record for September. During the last two monitoring years, PAG observed major declines. Starting with good winter rains that helped the first half of FY 08-09, the drought trend improved most fall and winter months. The trend worsened from March 2009 through January 2010, especially during the summer months due to

the lack of regular precipitation in the monsoon season. In FY 09-10, Cienega groundwater levels in our 2 drought monitoring wells averaged 4.67 feet lower than the pre-drought average, and averaged 4.15 feet lower than the previous fiscal year. Streamflow in FY 09-10 averaged 27.5% lower than pre-drought flow. Short term drought severity improved from February through June 2010, with flows increasing 43% to 86% compared to last year.

Outreach and Coordination

Public Outreach

PAG continues to raise public awareness about the unique habitat, wildlife, and water resources of Cienega Creek. PAG has incorporated Cienega information into outreach materials and Web site. During FY 09-10 PAG presented at the September 2010 annual Arizona Hydrological Society Symposium and ran a field trip to the headcut at Cienega Creek. Drought information is presented annually to the Cienega Corridor Conservation Council (4Cs). PAG also coordinated speakers from Pima County Local Drought Impact Group and the Climate Assessment for the Southwest with the Cienega Watershed Partnership for a special meeting on drought status and reporting systems in February 2010.

Coordination

PAG continues to connect with other agencies and professionals to facilitate, coordinate and support collaborative projects in the region. Information exchange and coordination take place in part through participation in the 4Cs and the Cienega Watershed Partnership (CWP). Toward that end, PAG coordinates with the Bureau of Land Management (BLM) and The Nature Conservancy (TNC) on methods of surface flow mapping to ensure that our hydrologic monitoring programs are consistent with those of the upper reaches of Cienega Creek within the Las Cienegas National Conservation Area. To organize a single week for Arizona rivers mapping, PAG also coordinates with Arizona Non-point Education for Municipal Officers (NEMO), who maps the Gila and Agua Fria Rivers; with TNC, Community Watershed Alliance, BLM, and CONANP (Comisión Nacional de Areas Naturales Protegidas), who map the San Pedro River; and with TNC, who maps Sonoita Creek.

Outside agency staff and other interested individuals are always invited to accompany PAG staff on quarterly walk-throughs to provide them an opportunity to learn about Cienega Creek and become more familiar with some of the management issues of the Preserve and the surrounding region. The invited agencies include PCRFC, PCNRP&R, Arizona Game and Fish Department, Arizona Department of Environmental Quality, USF&WS, TNC, Sonoran Institute, University of Arizona, CWP, Arizona Department of Water Resources, Sky Island Alliance, Empire-Fagan Coalition, the Sustainability of semi-Arid Hydrology and Riparian Areas center, Tucson Audubon Society, NEMO, USDA Agricultural Research Center, Rincon Institute, Watershed Management Group, Colossal Cave Park, Tucson Electric Power, Arizona State University, Congresswoman Gabrielle Gifford's Office and the Master Watershed Stewards program.

Conclusions and Recommendations

Cienega Creek is a unique Sonoran Desert low-elevation perennial stream with critical water, recreation and wildlife resources in southeastern Arizona. Since the mid 1980s, PAG has conducted research to firmly establish baseline hydrologic conditions for comparison purposes, in the event that future groundwater development or land use changes occur in the vicinity of the Creek. Originally focusing solely on groundwater and streamflow monitoring over the years, PAG's work has evolved into a multifaceted monitoring program that includes many more aspects of the Creek system, thus becoming an important part of regional and statewide drought assessment.

Fiscal Year 2009-2010 monitoring indicated progressively severe drought in the Cienega Creek watershed. Annual average streamflows decreased and groundwater levels dropped at all wells during this year as compared to the previous year. In addition, many normally flowing sites exhibited no ephemeral baseflow. Most notable during this year was the lack of significant precipitation during the summer monsoon season. As a result, groundwater levels did not rebound in typical fashion and the streamflows did not increase, giving us the lowest September flow length in our historical record. Groundwater levels appeared to be most stable in the Pantano Jungle and Cienega well areas, which are characterized by bedrock-bound shallow groundwater zones, associated with gaining stream reaches with relatively stable perennial flows.

A significant contribution to the FY 09-10 PAG program was investigation of a large erosional headcut in the horseshoe bend region of Cienega Creek¹. In-stream groundwater monitoring, structural habitat, geomorphology studies and streamflow documentation allowed understanding regarding sediment transport and habitat change associated with headcutting. In general, streambed incision, due to headcutting, resulted in increased flow extent where the ground surface intersected the groundwater table. These stream reaches provided good fish habitat partly because of their varied pool/riffle flow regimes. However, these areas also showed a dramatic loss of top-story established tree canopy, which will not be re-established for many years. This project also gave us unique information correlating shallow aquifer dewatering with unsettled sediments and vegetation die-off upstream of the headcut nick point. This helps to explain why extreme erosional incidents occur when floods follow extremely dry periods.

PAG's role connecting those that are passionately interested in, or working within, either the Cienega Creek or neighboring riparian systems has expanded in recent years. Because of its long-term and consistent monitoring program, PAG provides critical input to the Arizona Drought Watch Program regarding the status of drought in our region. PAG's connections with other agencies and professionals to facilitate, coordinate and support collaborative projects in the region have been very well received by others. Our photographic documentation helps communicate how the system is transforming over the years, and our wildlife sightings, habitat change observations and water quality analyses are all important tools in monitoring the health of the aquatic and riparian resource.

PAG recommends continued investigation into measures that will maintain or restore native riparian vegetation and habitat, stream geomorphology, channel characteristics and floodplain functions. New exciting work is being done in upland hydrology with the development of natural erosion control structures in Las Ciénegas through the BLM, Bill Zeedyk, the Sky Island Alliance and the Cienega Watershed Partnership. By continuing to participate with organizations that work in preserving the Cienega Watershed and by providing information and promoting awareness of the resource, PAG hopes to continue aiding PCRFC and PCNRP&R in their management of the Cienega Creek Natural Preserve. Continued groundwater and surface water monitoring, water quality analysis, and habitat and wildlife documentation are critical tools toward achieving integrated resource management for the system.

FOOTNOTE:

1. Pima Association of Governments, Evaluation of Riparian Habitat and Headcutting Along Lower Cienega Creek, Arizona Water Protection Fund Grant #07-144: March 2010