PIMA COUNTY

SUSTAINABILITY & CONSERVATION

Memorandum

Date: 5 October 2015

To: Dr. Robert A. Leidy, EPA ecologist, San Francisco

From: Ian Murray, Office of Sustainability and Conservation

RE: Cienega Creek base flow and its relationship to water temperature

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You requested any information that could show correlations between stream base flow and stream water temperature for the Cienega Creek basin or any other AZ streams. This may be important because it is reasonable to hypothesize that reductions in stream base flow could increase water temperatures due to the reduction in the water temperature buffering properties of ground water inputs in the face of high heat loads on the stream system. If reduced base flows are positively tied to higher water temperatures, then any stressors on the system which further reduce ground water input into the stream may lead to undesirable levels of thermal stress on the stream ecosystem.

We have available a dataset including concurrently recorded stream base flows (cubic feet per second; USGS Pygmy meter) and water temperatures (Ultrameter) taken at irregularly spaced monthly intervals between 2002 and 2014 at Marsh Station at Cienega Creek. These data are collected by the Pima Association of Governments.

The mean monthly base flows and mean monthly water temperatures at Marsh Station are plotted below (Figure 1). On average, the highest monthly base flows are seen in December-February, and reach a maximum of just under 1.0 cfs. The lowest base flows are seen during May, June, and November, with June values being the lowest at 0.24 cfs. Mean water temperatures are highest during the summer months of June-September, with mean August temperatures being highest at 24.1°C.

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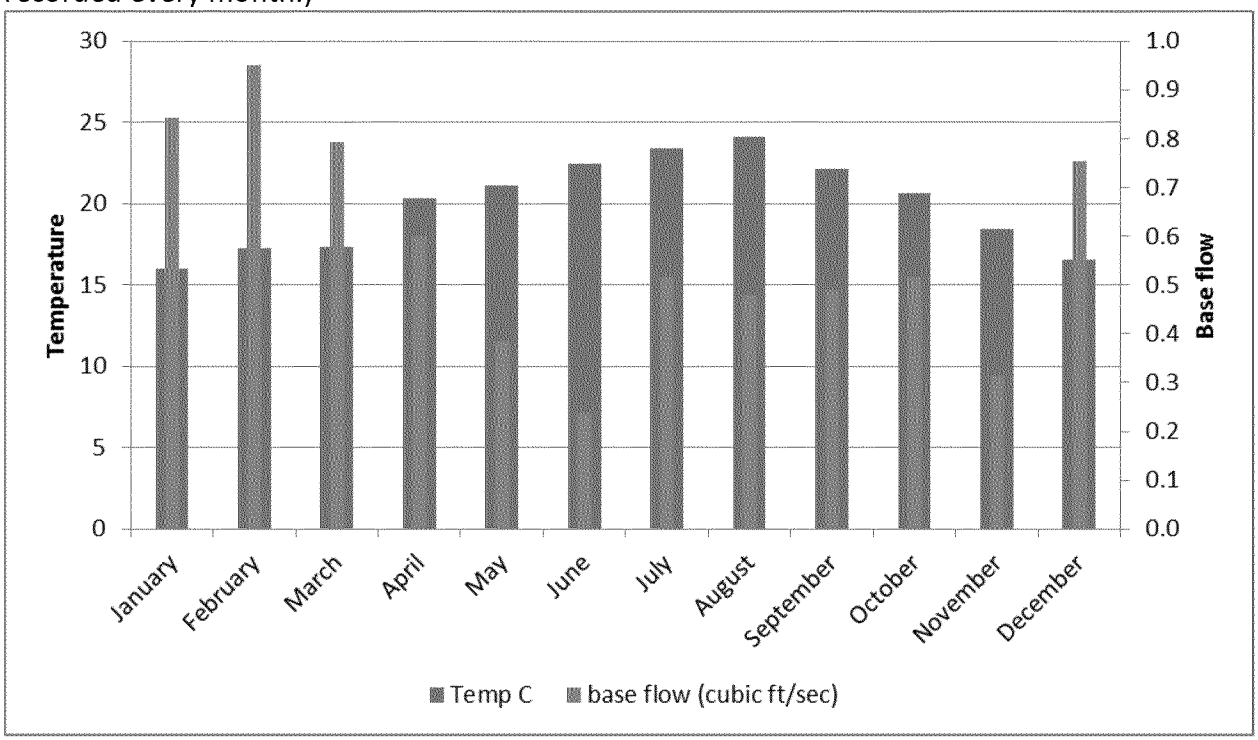
Figure 1. Mean monthly base flow ($ft^3 sec^{-1}$; cfs) and mean monthly stream water temperature (°C) recorded at Marsh Station, Cienega Creek 2002-2014. (Data were not recorded every month.)



Using multiple linear regression we modeled the effects of year, month, a year*month interaction variable, and base flow (volume) on stream water temperature ($F_{24,84}$ = 14.48; $P < 0.0001$; $R^2 = 0.79$). The largest effect on stream water temperature is due to month ($P < 0.001$) while the year and year*month interactions do not significantly predict water temperature. Stream base flow does have a significant impact on water temperature ($P = 0.0283$) but the effect size is smaller than that for month (e.g., Sum of Squares for month = 568.9 versus Sum of Squares for volume = 9.6).

Table 1. Summary statistics for multiple regression model

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Year	1	1	1.25521	0.6629	0.4188
Month	11	11	568.85727	27.3112	<.0001*
Year*Month	11	11	27.98496	1.3436	0.2238
Volume	1	1	9.56649	5.0522	0.0283*

These results suggest that additional consideration and analyses should be given to better understanding how stream base flow and stream water temperature are related. Stream temperatures factor importantly in the ecosystem functioning of aquatic systems, and can have major impacts on the physiology and ecology of aquatic

organisms (Allen 1995; Poole and Berman 2001; Zeigler et al. 2013). Additionally, ongoing climate change is likely to lead to temperature increases in the Southwest (2.5-4.5°F temperature increases by 2070 in the 'best case modeling scenario), as well as significant reductions in the winter and spring precipitation which is likely to negatively impact stream hydrology (Garfin et al. 2014). This coupled with the occurrence of a host of plant and animal species of conservation concern within the Cienega Creek watershed means that any additional stressors that could further impact the hydrological regime and thermal sensitivity of the aquatic system merits close scrutiny.

The fish species Gila chub (*Gila intermedia*), Gila topminnow (*Poeciliopsis occidentalis*), and Longfin dace (*Agosia chrysogaster*) occur in the Cienega Creek system and may be vulnerable to changes in stream hydrology and water temperature (Powell 2013; Powell et al. 2014). For example, there is a strong and statistically significant relationship between ground water levels in the aquifer and both stream base flow and fragmentation of stream flow (a measure of the linear extent of stream continuity; Powell et al. 2014). During the hot and dry month of June, a modeled decline of 0.1 feet in the aquifer would result in a 14.9% loss of base flow and a 3.4% reduction in the surface extent of stream water, while a 0.25 foot reduction in the aquifer would lead to a 37% loss of stream base flow and an 8.6% decline in surface water extent (Powell et al. 2014). These impacts are likely to negatively impact threatened and endangered species that call the Cienega Creek watershed home.

Historically fish in desert streams often occurred in a thermally heterogeneous arrangement of waters with fish able to access warmer surface waters as well as deeper and cooler waters in pools (John 1964; Deacon and Minckley 1974). However, between 1990-2011 surface water volumes as well as the length of continuous stream flow saw declines of over 80%, which are likely to negatively impact aquatic organisms such as these fish species (Powell 2013; Powell et al. 2014). These declines in surface water volumes and stream continuity may impact the ability of fishes and other organisms such as lowland leopard frog tadpoles, to access scattered pools with deeper waters, as well as behaviorally thermoregulate, which has fitness repercussions because even relatively small water temperature changes may lead to negative impacts on fish (Morgan et al. 2001).

For example, the survival of Gila chub larvae is highest at water temperatures of 24°C, above 28°C larval growth rates decline, and at 32°C the incidence of deformities begins to increase (Schultz and Bonar 2009). Not only do water temperatures impact the growth of aquatic organisms such as fish, but these same organisms are only able to persist within a specific range of water temperatures, the upper boundary which is often referred to as the critical thermal maximum. Carveth et al. (2006) examined the thermal tolerances of a variety of Arizona native and nonnative fish species, including Gila chub, Gila topminnow, and Longfin dace. They found that when acclimated at water temperatures of 25°C, on average Gila chub died at water temperatures of 38.3°C, Gila topminnow died at 39.4°C, and Longfin dace died at 38.9°C (fish acclimated at water temperatures of 30°C had slightly higher lethal maximum temperatures). The authors

noted an important disclaimer in that these lethal temperature estimates (derived in the laboratory) are likely to over-estimate actual thermal tolerance in the field by up to 3-4°C (Beitinger et al. 2000; Carveth et al. 2006). Furthermore, while an organism may be able to survive a given high temperature, life history parameters such as growth and reproduction, are unlikely to be optimized near these limits. Critically, some tested nonnative fish species such as Green sunfish (*Lepomis cyanellus*) seem to have a higher tolerance for enhanced thermal regimes compared to native fish species, which could further impact populations of these beleaguered native species (Carveth et al. 2006).

We recommend that further attention be given to the relationship between stream base flow and water temperature, and that these attentions could include a rigorous and standardized methodology for measuring water temperatures (e.g., see methods in Zeigler et al. 2013), and that these relationships be examined on a larger scale, for example within the Las Cienegas National Conservation Area.

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