AN ANALYSIS OF THE PROPOSED DECOMMISSIONING OF THE FOSSIL CREEK DAM, NEAR STRAWBERRY, ARIZONA

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In 1916, the Fossil Creek dam was built near Strawberry, Arizona to provide power for rural communities throughout the Verde Valley. Before 1916, Fossil Creek was fed by springs at a rate of 3.75 million liters per hour. One of Arizona's most productive and diverse ecosystems, this perennial stream served as a unique riparian habitat that supported native fish and a diverse assemblage of native Arizona flora and fauna. However, the hydropower operation diverted nearly 100 percent of the flows from Fossil Creek, leaving 22.4 km of the stream channel dry, ecologically degraded, and with little aesthetic value. In an effort to restore the creek, a coalition of environmental organizations has recently signed an agreement with Arizona Public Service to decommission the dam by 2005. The decommissioning will include partial removal of the dam and other related structures, leading to a complete restoration of the ecosystem by 2009. This analysis evaluates the alternatives for decommissioning the Fossil Creek dam to restore the stream to its proper functioning condition. Removing the dam and returning the full flows will speed the restoration process, but two areas that remain of concern are the proliferation of exotic fish and vegetation into the restored stream channel and post-restoration recreational impacts. A management plan should be developed prior to the initiation of restoration activities to protect against these impacts.

Introduction

Fossil Creek is located at the southern limit of the Colorado Plateau, in north-central Arizona, just below the edge of the Mogollon Rim. The creek and its associated canyon lie in an isolated region just northwest of the town of Strawberry (Figure 1). Historically one of Arizona's most lush and beautiful productive and diverse ecosystems, the watershed consists of a perennial stream flowing 22.4 km from a system of springs (Fossil Springs) to the confluence with the Verde River.

The series of seven springs produces a constant combined flow of 1218 L/s (Malusa 1997). This usually accounts for the full flow volume of the drainage, while seasonal run-off adds to the flow regime 20 percent of the time (Loomis 1994). The water released at Fossil Springs contains high concentrations of calcium carbonate ($CaCO_3$), resulting from groundwater flowing through a limestone geological formation. When groundwater saturated with $CaCO_3$ surfaces, $CaCO_3$ precipitates in the form of arc-shaped travertine dams. Over time, this process had created a stunning system of pools, riffles, and waterfalls in a unique riparian area nestled among the deserts of Arizona. Above each dam lay the clear blue pools that are characteristic of travertine-forming waters. Water cascaded from one pool into the next, oxygenating the waters for the fish that had been trapped within the pools. This unique environment was an ideal "natural fish hatchery" that supported a wide variety of native Arizona fish and fauna (Mockler 1999).

In the southwestern United States, water is a treasured commodity, especially for the flora and fauna that rely upon it. Riparian vegetation thrived at the fringes of the pools in the perennial waters of Fossil Creek. Riparian areas are very important habitat for birds, insects, reptiles, amphibians, and fish, and the restoration of these essential ecosystems has become a national priority (National Research Council 1992).

Historical Background

Historically, each travertine dam within the creek corridor grew approximately 1.0 m^3 every 43 days (Malusa 1997). Flash floods are a common occurrence of lower order streams in the southwestern United States; they accumulate intensity quickly and dissipate rapidly. Floods frequently destroyed or displaced the large travertine depos-

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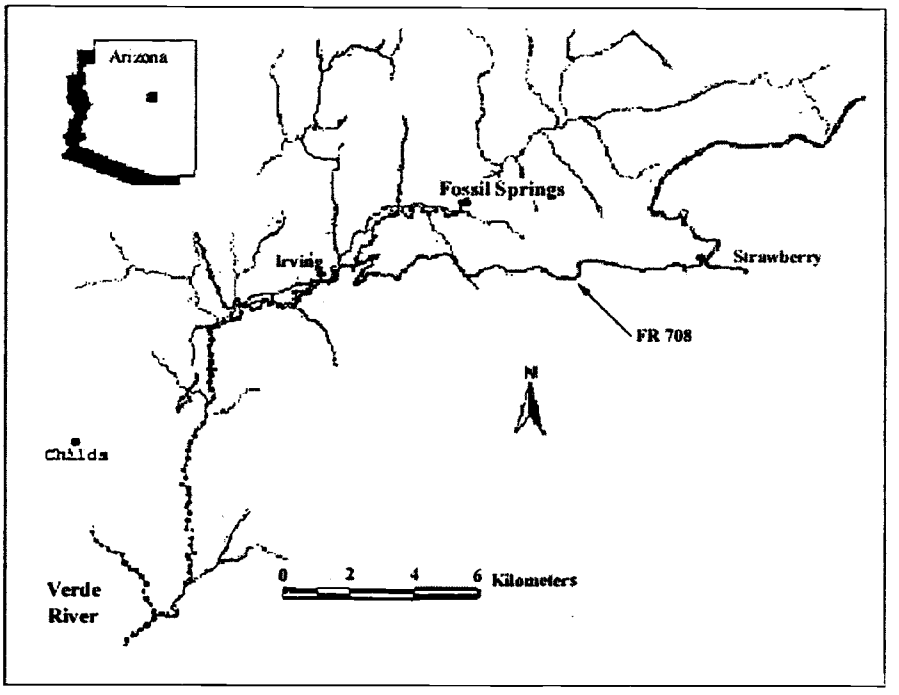

Figure 1. Fossil Creek and surrounding area. Map courtesy of USFS Rocky Mountain Research Station.

its, but new dams and pools were reestablished relatively quickly. After the initial 6.4 km below the springs, the CO_2 concentrations in the water equilibrated with the atmosphere and travertine deposition ceased.

Sycamore appeared to dominate the ecosystem overstory, and aquatic grasses were prevalent along the stream banks (Sayers 1998). The remaining 17 km of riparian corridor were lush and heavily utilized by the native species of the area. In the early 1900s, the perennial flow from Fossil Creek springs was tapped to produce hydropower for the growing communities in the Verde Valley. The Fossil Creek dam was constructed in 1916 (Figure 2), 250 m downstream from the springs; thus began the diversion of the 1218 L/s flow provided by Fossil Springs. The carbonate-rich water is now rerouted through a 6.7 km long flume to a hydroelectric power plant located at Irving, Arizona. At the Irving power plant, approximately 5.6 L/s of water escapes back to the streambed as normal seepage. The remaining flow continues another 7 km to the Childs power plant (Malusa 1997). The highly efficient operation (Figure 3) generates 5.6 megawatts per year (American Rivers 2001), which represents less than 0.1 percent of the total annual power production by Arizona Public Service (APS). It is worth less than $585,000 annually (Malusa 1997).

In 1994, APS applied to the Federal Energy Regulatory Commission (FERC) to renew their license for water diversion from Fossil Creek for power generation. As part of the re-licensing process APS was required to submit an environmental assessment to FERC. Upon review of this document many questions were raised regarding the unique qualities of the Fossil Creek watershed. A coalition of conservation and environmental organizations took an active interest in the re-licensing process and eventually negotiated a legal agreement with APS to decommission the Fossil Creek dam and restore full water flows to Fossil Creek by 2005 (American Rivers 2001). Furthermore, APS has agreed to remove the top 2 meters of the dam, including the intake structure and the entire aboveground flume system, and to restore the maintenance road to a hiking trail, by the year 2009.

Environmental Impacts of the Dam

No environmental assessments were completed prior to the construction of the Fossil Creek diversion structure. Therefore there are no data to compare pre- and post-dam conditions. To learn

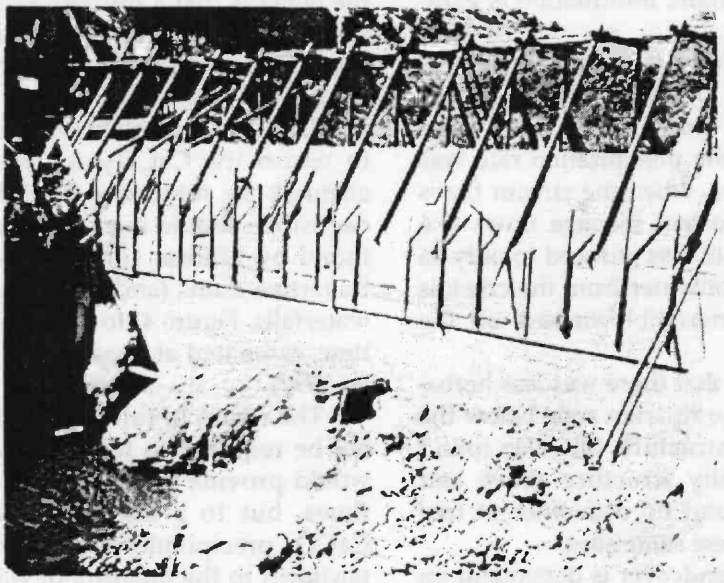

Figure 2. Construction of the Fossil Creek dam started in 1916. Photo courtesy of Arizona Public Service.

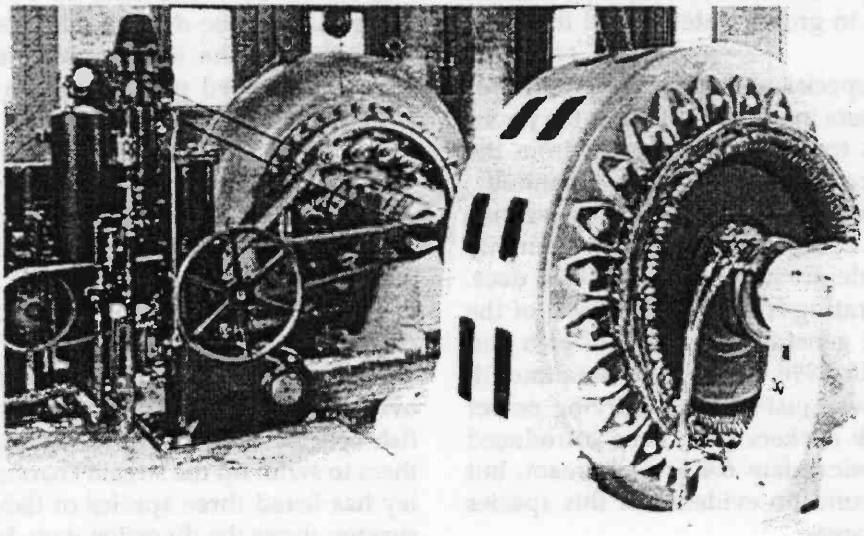

Figure 3. The simplicity of the Irving power plant (1916). Photo courtesy of Arizona Public Service.

about the effects of the dam, information is gathered above and below it.

Malusa (1997) studied the travertine deposition along the corridor of Fossil Creek. Malusa found that when full flows (1218 L/s) were restored to the stream the precipitation rate was 11,952 kg/day. However, when the stream flows were returned to the normal seepage flows (5.6 L/s) the precipitation rate was reduced to only 46 kg/day. The diversion of water from the creek is obviously having an incredible impact on the deposition of travertine.

Sayers (1998) found that there was less herbaceous groundcover in the riparian zone below the Fossil Creek diversion structure. She also found differences in community structure above and below the dam, but found no difference in tree growth rates between these same sites.

The herbaceous groundcover is dependent on the amounts of sediment present in each reach of the stream. The reduction in water flows also prohibits the transport and subsequent deposition of sediment in the system. The differing community structures are artifacts of differences in the amounts of surface water, stream morphology, canyon geomorphology, and travertine deposition, among other factors (Sayers 1998). Riparian trees often rely on groundwater rather than surface water; a change in growth rates would therefore not be expected.

Non-native species of fish are present in ever increasing numbers in Fossil Creek and the population continues to establish upstream from the Verde confluence to the Irving dam (Sponholtz, personal communication 2001). The native fish present in Fossil Creek below Irving are primarily roundtail chub, desert sucker, and speckled dace. The exotics migrating from the main stem of the Verde River are generally smallmouth bass and green sunfish. In 1996, 2–3 pound smallmouth bass were observed just below the Irving power plant. Razorback suckers have been introduced above the diversion dam 6.4 km upstream, but sampling has found no evidence of this species persisting in the area.

Restoration Alternatives

The effect that hydroelectric power generation is having on Fossil Creek seems apparent. An obvious next step in the research process would be to look at ways of restoring the stream. Ideally, a restoration analysis of Fossil Creek should examine several things: the costs of maintaining the status quo, the costs of decommissioning the dam, the benefits that a full restoration would have for the flora and fauna, the potential recreational impacts to result from the restoration, and how to minimize those impacts.

The most important aspect of the restoration is to return the $CaCO_3$-rich waters to the stream channel. By returning the full flows, travertine deposition should increase to rates similar to those found by Malusa (1997). These rates will allow travertine dams (and the characteristic pools and waterfalls, Figure 4) to rebuild in a relatively short time, estimated at a maximum of 10 years (Mockler 1999).

The return of full flows to Fossil Creek would not be required to fulfill this need. Partial flows would provide the ecosystem services of the full flows, but to a lesser degree. The amount of $CaCO_3$ precipitation to be achieved will be proportional to the quantity of water returned to the stream. A return of full flows would be ideal for ecosystem restoration, but there are some parties who argue against the restoration of any flows. The return of partial flows would represent a compromise option between the two viewpoints.

A return to the natural stream morphology will allow for increased sediment deposition, providing substrate for the establishment of riparian vegetation. An instantaneous return of the full flows may not be desirable for fish and riparian vegetation in the long term. These inhabitants have experienced periodic high flows and have sustained their populations, but a gradual return of full flows would be most desirable. Ramping the flows may allow the riparian vegetation to migrate up the stream bank without being instantaneously flooded and destroyed. If a mass killing of riparian vegetation does occur, the public may desire plantings of vegetation along the stream channel.

Among experts there is some disagreement over whether a return of flows may allow invasive fish species to infiltrate the system by allowing them to swim up the stream channel. W. L. Minckley has listed three species of fish that presently survive above the diversion dam, but believes that Fossil Creek offers a potential recovery area for the endangered razorback sucker and Gila topminnow (Mockler 1999). Minckley is convinced that the natural travertine dams will act as a barrier to invasive non-native fish (Mockler 1999).

Offering a different viewpoint, Sponholtz has suggested that "if management does not intercede and chemically renovate to remove the nonnative fishes and construct downstream barriers to fish

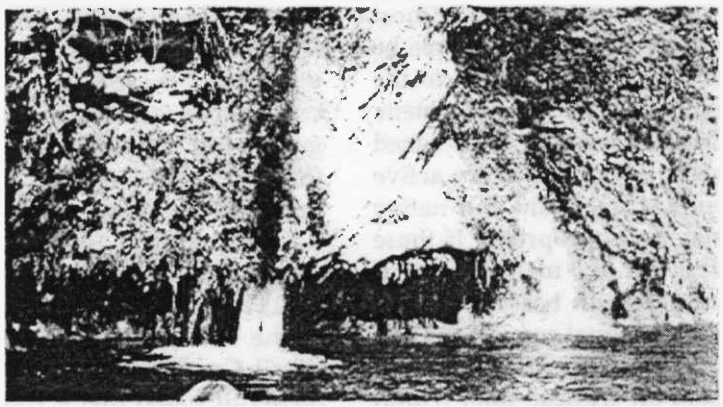

Figure 4. Travertine deposition at Fossil Springs (1916). Photo courtesy of Arizona Public Service.

movement, the outlook for the natives is grim" (Sponholtz, personal communication 2001). This course of action would likely include relocating native fish species below the Irving power plant to locations upstream of the renovation point.

Another management alternative suggested by Sponholtz (personal communication 2001) would entail promoting Fossil Creek as a roundtail and smallmouth fishery and removing all bag limits in the hopes that sport-fishing take would mitigate the impact of invasive smallmouth predation on endangered indigenous fish. Increased visitation as a consequence of re-watering would likely result in exotic fish introduction by fishermen, making this idea attractive. The management of flows to discourage non-native fecundity is an alternative that deserves consideration, but would require further study.

APS has agreed to remove the top 2 meters of the dam. In terms of restoration, a partial removal of the dam will not be necessary. The dam will be quickly covered with travertine and will soon resemble a large travertine waterfall. The United States Forest Service (USFS) is calling for APS to remove the entire structure. Their position is that the dam should be removed while it remains under APS liability; otherwise if the structure failed, expensive clean-up efforts would be required by the USFS.

The restoration of Fossil Creek will result in a unique and lush ecosystem. The recreational impacts to such a system could be tremendous without proper planning. Some ideas have been discussed, but there are no plans for such accommodations. There are many techniques to minimize recreation impacts, including developing park infrastructure through trails, picnic areas, restroom facilities, and camping sites. These areas would offer protection through sacrifice of "non-essential" areas along the stream corridor. Pam Sponholtz (personal communication 2001) stated that the USFS has asked APS to leave the structures near the Irving facility. These could be used as cabins for visitors or administrative buildings for the USFS. Cabins might provide some income for the USFS to maintain the area. Sponholtz also remarked that there was some discussion regarding the closing of FR 708, which leads from a trailhead at the top of the watershed to the Irving power plant and beyond. This could cut down the number of visitors because it would require a 3.2 km hike to the water. This seems like a good idea, with special permits being offered to handicapped persons, researchers, and others with special needs to allow easier access to the area.

Restoration Recommendations

A passive restoration approach seems appropriate for Fossil Creek. From an ecological perspective, the return of the full 1218 L/s to the stream channel will be ideal. This will allow for the characteristic travertine dams to develop and offer a structurally diverse channel. Increased sedimentation would enhance natural recolonization by riparian vegetation. To facilitate this recolonization, the flows should be ramped to full flows over a period of 6 months to a year. This ramping period should consider the natural reproduction cycle of the plants and try to facilitate the re-colonization process.

The alternatives for the fish are difficult to assess. It is therefore recommended that the most conservative and therefore cheapest measures be undertaken first. This would be to return to the full flows, allowing fish to migrate into the system. If the higher Fossil Creek ecosystem is colonized by invasive exotic fish species, then more active measures such as chemical treatment and native fish reintroduction may be appropriate. If these efforts are unsuccessful, then the management of the ecosystem as a smallmouth bass fishery as suggested by Sponholtz (personal communication 2001) may become a reasonable alternative.

The dam has created an artificial pool within higher Fossil Creek. These pooled waters have allowed for the invasion of exotic vegetation that prefers slow-flowing water, thus serving as a source population to possibly invade the lower stretches of Fossil Creek. The calm waters could support populations of fish and invertebrates that would not be able to exist in the natural flowing waters of Fossil Creek, but there is no evidence of non-native fish existing above the dam (Sponholtz 2001). For these reasons, reasonable measures should be taken to remove the exotic vegetation prior to the removal of the dam and more research should be done on the invertebrate and fish populations within Fossil Creek.

Because of the biological impacts of the dam, the upper part of the dam needs to be removed (as agreed upon in the signed agreement). Although the remaining dam structure would probably not be a threat to the restoration process, the USFS must consider the liability issue. Risks of structural failure increase with age; therefore APS should be required to completely remove the structure.

Finally, measures must be taken to anticipate the increase in recreational traffic. These measures should include designated parking areas, trails, picnic areas, restroom facilities, and camping sites. By offering facilities, the USFS will be able to direct the recreational impacts to specific areas. Closing FR 708 to the general public could prove highly desirable. This could be used as a USFS access road and permits could be offered to research groups and citizens with special needs. These measures would minimize recreational impacts and increase the chances of a successful stream restoration.

Alternatives to Restoration

There are alternatives to complete restoration. People pushing for a less than complete restoration include Sam Steiger (mayor of Prescott, Arizona), James Doolittle (Flagstaff consultant), and Dan Israel (Gila County Consultant). Steiger has written to the FERC stating that the Prescott community is interested in obtaining the power generating facility for their growing population (Steiger 2000). Doolittle has been searching for a group to purchase the water rights and FERC license from APS. If successful, he stands to gain a substantial profit from the transaction (Sponholtz 2001). Israel recently approached Jerome Stefferud of the USFS about using the diverted waters of Fossil Creek in Gila County for residential use. Stefferud stated that it was not feasible, but Israel was not curtailed (Stefferud 2001).

Acknowledgments

We'd like to offer special thanks to Pam Sponholtz (AZ Department of Game and Fish), Mindy Schlimgen-Wilson (Nature Conservancy), Phil Smithers (APS), Rod Parnell (NAU Geology), Matthew Loeser, and Bradner McRae. Each was a great help in various aspects of the analysis and in discussing the Fossil Creek dam and its decommissioning.

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