



US Army Corps
of Engineers ®

Tulsa District

Kiamichi River - Environmental Flows Workshop Summary Report



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June 2022

Authored by the U.S. Army Corps of Engineers with input from The Nature Conservancy, Oklahoma Center for Nonprofits, and workshop participants.

Suggested Citation: U.S. Army Corps of Engineers. 2022. Kiamichi River - Environmental Flows Workshop Summary Report. Tulsa District. Sustainable Rivers Program. 28 pps.



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Acknowledgments

This project was made possible with funding from the Sustainable Rivers Program (via the U.S. Army Corps of Engineers), The Nature Conservancy, and with time and effort contributed by numerous agencies and individuals throughout the project. The development of the information was based on collaborative efforts and inputs from regional and state scientists and stakeholders that were critical to this effort.

The shared purpose of the project was to convene key personnel and partners to provide scientific and stakeholder input to improve the ecological flows and related health of the Kiamichi River system. Stakeholders and partners provided the input, expertise, and hypotheses on current and historical conditions as well as issues and needs.

A core team, represented by the project partners led the science and technical integration effort. This group spent extensive time developing a plan for coordination and communication of science-based planning across stakeholder groups and identifying and targeting technical assistance as needed. The Nature Conservancy, Oklahoma Chapter, and the U.S. Army Corps of Engineers, Tulsa District, initiated the project as well as provided input, guidance, and feedback throughout this initial phase (literature review and summary).

We are grateful to everyone who participated for their interest and contributions to improving the health of the Kiamichi River. The extensive contributions and collaboration efforts from the various agencies and individuals are integral to the effort now and for future coordination and implementation efforts.

Disclaimer: The development of environmental flow plans was based on best available science and will be carefully balanced with the needs and requirements of stakeholders, to benefit the Kiamichi River ecosystem while improving or not adversely affecting the system. Environmental flow plans are developed within the constraints of authorized purposes of the reservoirs, water rights, and other human use requirements, and in collaboration with stakeholders

1.0 Sustainable Rivers Program

The Nature Conservancy (TNC) and U.S. Army Corps of Engineers (USACE) have partnered to form the Sustainable Rivers Program (SRP) to examine opportunities to optimize reservoir releases and river flows to benefit river ecology while maintaining the federal mandates of the reservoir system in the United States. The mission of the SRP is to improve the health and life of rivers by changing water infrastructure operations to restore and protect ecosystems, while maintaining or enhancing other project benefits. The founding objective of SRP is implementation of environmental flows (e-flows), which are defined as the quantity, timing, and quality of water flows required to sustain ecosystems. Here, e-flows are considered management decisions that manipulate water and land-water interactions to achieve ecological environmental goals. SRP efforts complement other reservoir-centric water resource projects by demonstrating that a strategic and science-based approach can be used at USACE projects to maintain or enhance benefits provided to the nation. As of 2019, SRP involved work on 66 USACE reservoirs in 16 river systems and 5,083 river miles. SRP is now the largest scale and most comprehensive program for implementing e-flows at USACE reservoirs.

The Kiamichi River was added to the SRP in 2020. This river was chosen because of the high biological diversity, expert stakeholders in the watershed, cultural interests, and demand for water in the watershed. E-flows are important to consider in this watershed because of endangered mussel species and their fish hosts. Specific flow regimes are needed to maintain this biological diversity as well as meet the current and future water demands in the watershed. E-flows incorporate the biology and ecology of a system as well as the hydrologic components that keep this system functioning at high biological diversity. The timing and magnitude of flows are important hydrologic components to consider for e-flows. Fish and mussels need flows at certain times of the year to aid in completing their life history cycles. Dams have impacted the life histories of many aquatic species.

Dams and reservoirs have fragmented our river systems to the point where 70% of aquatic species have declined. It is important to consider the impacts our management of dams have on aquatic ecosystems. This not only impacts aquatic species, but the humans that depend on these ecosystems for their livelihood. Oklahoma started working on e-flows in the Barren Fork in Northeastern Oklahoma in the early 2000's and then on the Illinois River in Northeastern Oklahoma in the mid-2000's. To date, no e-flows have been implemented on any Oklahoma river or stream.

Oklahoma is one of only two states without a formal e-flows program. This has been a contentious issue with attempts to pass legislation in previous years. Now, we are trying to work with stakeholders in the basin to show them the state of the science and what is possible in terms of water management changes from reservoirs in the Kiamichi River watershed.

Using input from stakeholders and data obtained related to hydrology and information from the ecological assessment, an e-flows workshop was held in June 2022. The goal of the workshop was to develop Kiamichi River e-flow recommendations that could result in benefits to fish, wildlife, and the ecosystem while avoiding conflicts with current human uses. Participants included multi-disciplinary experts and representatives from federal government, state government, academics, non-governmental organizations (NGOs), private industry, and utilities. During this meeting experts crafted e-flow prescriptions for one reach of the mainstem Kiamichi River below USACE dams. This document summarizes the results of that meeting.

2.0 Summary Ecology/Flow Recommendations

During the Kiamichi River Basin SRP e-flows workshop, experts worked through a series of tasks and questions to draft e-flow prescriptions for specific reaches of the Kiamichi River mainstem downstream of one or more dams. A list of the focus reaches considered is included below and shown in Figure 1.

Focus Reaches

- Reach 0 – Sardis to Kiamichi
- Reach 1 – Kiamichi to Hugo Reservoir
- Reach 2 – Kiamichi (Hugo Reservoir) to Below Hugo Reservoir

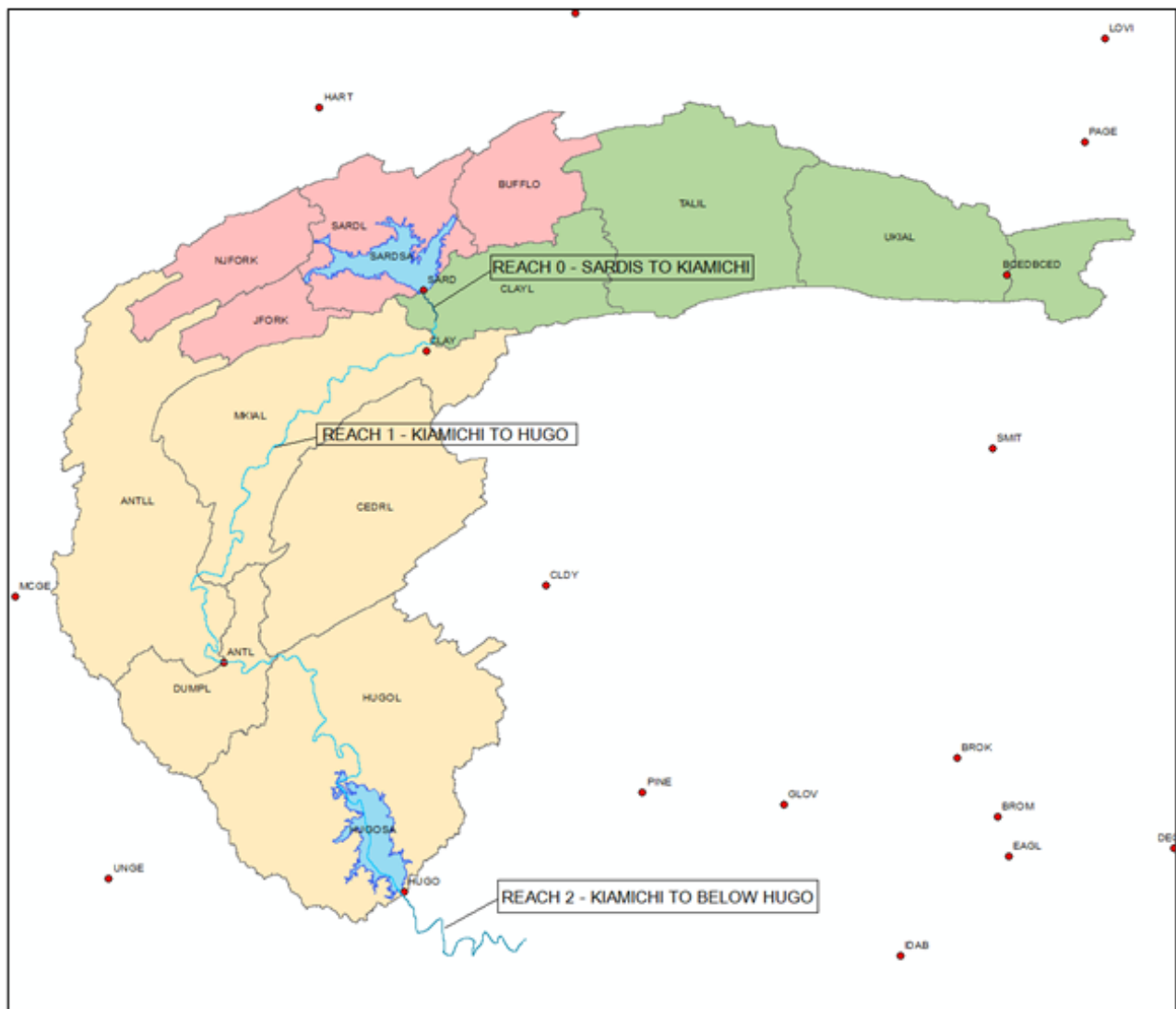


Figure 1. Kiamichi River SRP focus reaches.

3.0 Workshop Goals and Agenda

The Oklahoma Center for Nonprofits was engaged to facilitate the SRP workshop for the Kiamichi River in southeastern Oklahoma. The workshop was held 28 June 2022 in Oklahoma City. The initial agenda was set for 9 a.m. - 3 p.m. with working group discussions continuing until 4:30 p.m.

Janetta Cravens led the group through a Wave Analysis (Crest, Trough, Emergence and Undertow). A Wave Analysis is a facilitation technique designed to reveal everyone's interpretation of current reality with objective clues and thereby form a collective perspective about current reality. Participants were broken up into four small groups to work on the Wave Analysis. Below are the discussion points for each area as well as key priorities agreed upon by the group.

Crest: Peaking now; producing results but maybe little energy left. Growth limited.

- Sardis conservation fully contracted/allocated to water supply.
 - Conservation pool has been fully contracted out for Sardis Lake. The water supply owner pays a portion of interest back to the federal treasury justification for taxpayers. Congressionally allocated. 100% allocated water supply.
- Aquatic biota limited by fragmentation.
- Future stresses would diminish aquatic biota.
- Currently wet cycle, what will dry cycle look ecologically?
 - Wet years in a row is where the data is currently. Some of the issues brought up were related to dry cycle. There is data available on a dry cycle.
- Collected/actionable knowledge at a high.
 - The scientific data is there it just needs to be implemented. There is enough science available to make some decisions, but additional data is wanted.
- Public Interest.
 - Peaking now because people are really interested right now.

Trough: It's not working well, confusing signals, unclear where to go; may produce anxiety.

- New development/Crowding and the water effects.
 - Congressional uses for the water and limitations from when the original dams were built. Now there are more people than there were 57 years ago, but Congress would need to change the parameters.
- Pipeline Moyers to McGee connection for OKC.
 - AMEPA processing has started. The first pipeline is in place, but the second is in process. Atoka and McGee. The environmental work for the second pipeline hasn't started yet. Still working on the water permit.
- Workshop toward common understanding today. Working together.
- Pending decisions on water management.
 - Variety of things-water use agreement hasn't been finalized, U.S. Fish and Wildlife Service, how we use the water and management of the system. Is there legislative action that needs to be taken?
- Increasing demand for water from this system.
- Pending federal listing Pyramid Pigtoe and Peppered Shiner-Fish and Mussels endangered species.
- Climate variability and drought.
- Low-flow targets may be overestimated.
 - The analysis periods of time where under extreme conditions the system currently can't meet them. Not generally overestimated. From the Indicators of Hydrologic Alteration

(IHA) analysis.

- Delayed signing at the Water Unity Agreement.
 - Went to the federal level to be signed, but it is held up in court and not finalized. Need to keep an eye on this.
- Tribe Sovereignty-McGirt v. Oklahoma could change everything.

Emergence: Actions beginning to build; realities gaining energy fast.

- Uncertainty regarding hydrology and connection between channel and shallow aquifer.
- Uncertain modeling hydrological modeling.
 - Which hydrological model is being used?
- Uncertainty regarding water rights and allocations.
- Appears to be a losing stream. May be difficult to maintain environmental flows through water releases from Sardis.
- Census for sensitive species (locations, elevations, data levels, etc.).
 - Species kills downstream don't hear about them until they are already dead. Needing a more accurate census as to where they are beforehand to make sure releases are worked around.
 - There was a question as to how frequent mussel location census is taken, and it was noted that it is dependent upon funding.
 - Location of the mussels could change after a significant flood, but it isn't known collectively. There is data that can be shared on flood levels and where the mussels are located. It was noted that the group can work to improve this together.
- Unauthorized (voluntary reporting) water users. Accounting/Meters
 - It was discussed that there are some areas where the water goes down during duck season or for a new sod farm. It was noted that perhaps people are taking more than they are reporting. Hard to know because there may not be a monitoring station in that location.
 - Sometimes not enough water is released to cover the mussels. There are minimum releases. There isn't a low-flow continual release from Sardis. People put pumps in the river unpermitted during a drought. The group would like to see some kind of accounting. Likely people don't know they aren't supposed to do this. There are permits along the river. There are a number of diversions along the river. Water board is responsible for reporting and it's currently on the honor system.
- Water temperature management
- OKC Water conservation pool release sharing
 - Thinking about environmental flows. If OKC owns conservation pool, then do we have to enter into a contract with OKC? How can we implement an environmental flow if OKC owns the pool? Example-Consider looking at Big Cypress in east Texas on how they handle environmental flows.
 - 2011-2012 last extreme drought-Contacted the USACE and negotiated emergency releases that were small for a period of weeks, because they were seeing a lot of mussels dying. It was noted that this was not an ideal arrangement, and it requires a lot of monitoring and extreme circumstances. Prefer having something more robust and planned ahead instead of in a crisis situation.
- Communication with ALL stakeholders
 - Lots of players (OKC, Residents, Tribes, Business Owners, Tourists)
 - People that live in the watershed have not been involved in any of the decision making. All closed-door conversations. There have been an influx of people coming into southeastern Oklahoma. Economic value towards water from tourism

that is sustaining the state and is now 50% of tourism for Oklahoma, but the water is going away. Authorized purposes.

- Understand triggers for regulations.
 - There is a process to change flows, but it takes a good bit of process through congressional approval. It would take changes in the laws for fish and wildlife in storing water. It's an open question. There are triggers in what OKC pulls. Certain conservation efforts have to be made before OKC pulls water from the lake. Need to know steps that need to be taken first.
- Authorized purposes.
 - There was discussion regarding the authorized purpose for the water. Regional, state, national economic development for water consumption vs non-consumption. This area of the state has historically been the poorest and hasn't really had an avenue of building an economy. Ecotourism is a great way to get the county out of this place. Focused on the flow of the river versus the lake.

Undertow: Deep patterns that cause trouble, even in the midst of success; caution to not get sucked down with it.

- Who owns what water, where does it go, how do we get access to it? Who owns the groundwater and surface water?
 - Connectivity isn't really considered under the law. Groundwater is privately held if you are the surface owner. Who owns when they are interconnected? SRP and the USACE are not asking the law to be changed. We understand that there is science and data regarding the ecological aspect. Can back into it working with it within SRP without the legal framework. How can we affect change if things are determined at the federal level? What flow targets are we talking about to see what is feasible.
- Limitations of knowledge and monitoring.
- Competing or conflicting priorities.
- Travel time (flow response).
- Climate change with nature.
- Variability for managed systems. How much variability is acceptable?
 - When a lake is put into a river system. When is the system managed and how much variability should we expect? How much do we need to compensate for a managed system?
- Social justice in water uses and allocation. Involving all stakeholders in water flow.
- Trust between key stakeholders. The importance of building trust between all stakeholders.

High Level Issues/Priorities Identified

Following the Wave Analysis there were two key areas identified as areas of priority for the group to work towards.

1. Keep a sustainable flow (related to protect the species that live there).
 - Protect Species-pulled under the sustainable flow and not separate. Include people in nature as part of the species.
 - Agreement/Commitment-Implementation from stakeholders like an MOU. Need action here.
2. Communication-Improved with stakeholders. How will we agree to communicate? Master list of those who have attended today.

Hydrologic Engineering Center Regime Prescription Tool Presentation

Presenters of the HEC-RPT discussed the tool using an example of a wet vs. dry year to see what potential

hydrographs might look like at Antlers, assuming that the waters are being released and flowing all the way to Antlers. RPT is a visualization tool of what has been observed.

The presenters reviewed the tool and explained the program and what the data means on the graphs so everyone could understand.

Additional goals identified during the afternoon discussion in relation to the RPT

- Utilize RiverWare to identify flow prescriptions that meet the needs.
- Focus on ecological purpose. Low flows when the temperature gets too hot as the water is shallow for mussels to live long before the riverbed dries up. High flows also need to be managed.
- Set the flows that everyone agrees upon.
- Start to identify the critical points-Dry season prescription.
- Ecotourism goals.
- Minimize fish and mussel mortality.
- Quality of the water as the quantity of water reduces. What does the flow need to be?

Potential partners: National Weather Service for assisting in predicting drought as they do floods.

Afternoon discussions continued following the morning session and were led by USACE team members with HEC-RPT used for visualization purposes. Due to the technical nature of the discussions, the HEC-RPT modeler took notes the remainder of the day.

4.0 Basin Characteristics and USACE Operations

4.1 Basin Characteristics

Hugo Lake is located on the Kiamichi River at river mile 17.6, about 7 miles east of Hugo in Choctaw County, Oklahoma, and 30 miles north of Paris, Texas. Hugo Lake was authorized by a Flood Control Act (24 July 1946), Project Document HD 602, 79th Congress, 2d Session. Construction began on 6 September 1968, and embankment closure was completed on 29 October 1971. Impoundment of the lake began on 18 January 1974 and the conservation pool filled to elevation 404.5 feet on 12 March 1974. Authorized purposes include flood control, water supply, water quality, recreation, and fish and wildlife.

Sardis Lake is located at river mile 2.8 on Jackfork Creek, a tributary of the Kiamichi, about 2.5 miles north of Clayton in Pushmataha County, Oklahoma. Sardis was authorized by a Flood Control Act (23 October 1962), Project Document SD 45, 87th Congress, 2d Session. Public Law 97-88 (4 December 1981) changed the name from Clayton Lake to Sardis Lake. Public Law 99-88 (15 August 1985) authorized access road improvements. Public Law 98-63 (30 July 1983) authorized an intake structure. Construction of the reservoir began in August 1975 and the project became operational in December 1982. Impoundment started in January 1983, and the conservation pool filled to elevation 596.00 feet in March 1984. Authorized purposes include flood control, water supply, recreation, and fish and wildlife.

Four major tributaries of the Kiamichi River are located between the confluence of Jackfork Creek (Sardis Lake) and the Highway 3 bridge (Hugo Lake) southeast of Antlers. These tributaries (Pine Creek - John's Valley, Buck Creek, Tenmile Creek, and Cedar Creek) account for approximately 30% of inflows to Hugo. Approximately 25% of inflows to Hugo are contributed by Jackfork Creek. Each tributary provides habitat for a warm water aquatic community. The Oklahoma Water Resources Board (OWRB) considers the Kiamichi River a source of high-quality water. Water quality along this segment of the river is generally good, with agricultural runoff being the primary source of nutrient load to the river.

Hydrologic data within the basin are available from the U.S. Geological Survey (USGS) and USACE. USGS data sources include observed (measured) discharge at the Big Cedar (USGS 07335700), Clayton (USGS 07335790), and Antlers (USGS 07336200) gages. USACE data sources include observed (measured) discharge from Sardis and Hugo lakes. The daily discharge period of record (POR) for the Big Cedar gage is 3 March 1992 to present, for the Clayton gage is 11 November 1980 to present, and for the Antlers gage is 1 October 1972 to present. Discharge between the Big Cedar and Jackfork Creek confluence consists of unregulated flows. Flows entering the Kiamichi River from Jackfork Creek are regulated by Sardis Lake and those regulated flows affect discharge observed at the Clayton and Antlers gages. Flows in the lower portions of the basin are regulated by Hugo Lake. USGS gage locations are shown in Figure 4. Additional data are available from USACE via the RiverWare Kiamichi Basin model used to produce pre-impoundment discharges at all gaged locations, USGS and USACE, over a POR from 1 January 1938 to 31 December 2019.

Table 1. Kiamichi River water management projects.

Water Management Project	Basin or Stream	Date of Closure	Operating Agency
Kiamichi River Basin			
Sardis Reservoir	Jackfork Creek	1980	U.S. Army COE
Hugo Reservoir	Kiamichi River	1974	U.S. Army COE

There are approximately 860 freshwater stream miles, and approximately 109,000 acres in the Kiamichi River Basin, of which 26,400 acres are federally owned freshwater impoundments.

There are many tributaries contributing to the Kiamichi River. Table 2 summarizes the origin, length, and basin area of the various tributaries.

Table 2. Kiamichi River tributaries.

Tributary	Origin	Length	Basin Area
Kiamichi River	OK	172 mi	1709 mi ²
Buck Creek	OK	32 mi	--
Ten Mile Creek	OK	31 mi	--
Cedar Creek	OK	30 mi	--
Pine Creek	OK	22 mi	--
Big One Creek	OK	18 mi	--
Frazier Creek	OK	15 mi	--
Rock Creek	OK	14 mi	--
Cane Creek	OK	13 mi	--
Turkey Creek	OK	13 mi	--
Dumpling Creek	OK	12 mi	--
Spencer Creek	OK	11 mi	--

The Kiamichi River watershed is located in southeastern Oklahoma in portions of Choctaw, Pushmataha, Latimer, Pittsburg, and LeFlore Counties. The basin is crescent-shaped, 169 miles long, and varies in width from 5 to 30 miles. The total drainage area in the basin is 1,830 square miles, with 1,709 square miles above Hugo Lake. The upper two-thirds of the basin is heavily timbered, with the remaining portion well covered with grasses. There is little cultivation in the basin. There are numerous tributaries, with some of the larger ones being Jackfork, Buck, Tenmile, and Cedar Creeks. Elevations in the basin range from about 1,600 feet NGVD (National Geodetic Vertical Datum) at the source to about 370 feet NGVD at the confluence with the Red River. The slope of the stream varies from 0.8 foot per mile at the mouth to 1.5 feet per mile near Hugo Lake and to more than 100 feet per mile at the headwaters.

The upper two-thirds of the Kiamichi Basin is in rugged Kiamichi Mountains of the Ouachita Mountain system with the lower one-third consisting of gently rolling hills of the Gulf Coastal Plains region. The channel of the Kiamichi River in the upper one-third is shallow and poorly defined, with the middle third varying from 10 to 30 feet in depth, and the lower third V-shaped, averaging about 30 feet in depth and 300 feet wide. The stream flows through a succession of widely contrasting reaches, alternating from comparatively wide valleys to steep gorges having banks 80 to 90 feet high. The stream consists of a series of pools and shoals during low flows. The southern part of the Kiamichi River meanders along a wide alluvial valley.

Channel capacities vary from 4,000 cubic feet per second (cfs) immediately below Sardis Lake to 22,000 cfs at Antlers, Oklahoma on the Kiamichi River (USACE, Hugo WCM 1982).

4.1.1 Floodplain and Channel Modifications: Geomorphology

The Kiamichi River floodplain and the floodplains of its tributaries are important resources that convey large stormwater events and provide an abundance of wildlife habitat. The floodplain of the Kiamichi River is considered a riverine floodplain, which is comprised of the floodway and the flood fringe. The floodway encompasses the channel and a portion of the adjacent floodplain area necessary to convey floodwaters. The flood fringe is land located outside the floodway that is at or below the base flood elevation and stores but does not effectively convey floodwaters.

Floodplain and channel modifications were not identified by the e-flows workshop group as a concern and therefore were not evaluated.

4.1.2 Streambank Erosion and Sedimentation

The Quachita Mountains through which the Kiamichi River flows are characterized by high, rugged mountains with very shallow soil cover. The rock is mostly shale and sandstone with some limestone. The soil is generally lean clay and clayey, silty sand and gravel. Overburden depth varies from practically none in the upper parts of the mountains to 60 feet in the lower part of the basin.

The Kiamichi River is considered a light sediment-bearing stream. Little sheet erosion has occurred as most of the basin is in forests or grasslands. The banks and beds of the stream and its tributaries are stable and contribute little sediment. Two hundred and forty-eight suspended sediment samples have been collected from the Kiamichi River at the Belzoni stream gaging station during the period June 1938 to July 1963. These samples were analyzed for concentration and the results used to develop a sediment rating curve. This curve applied to a flow duration curve for the Belzoni gage, adjusted by drainage area ratio to Hugo damsite, gives an annual suspended sediment load rate of 0.18 acre-foot per square mile. Considering the bedload movement to be 10 percent of the suspended sediment load, the total sedimentation rate is 0.20 acre-foot per square mile per year. A minimum sedimentation rate of 0.25 acre-foot per square mile per year is considered applicable for use in areas where the sediment load is a minor problem. The authorized Sardis and Tuskahoma Reservoirs would intercept part of the sediment load above Hugo Lake. A 100-year sediment deposition of 30,000 acre-feet in Hugo Lake was adopted for design purposes.

Sedimentation and streambank erosion were not identified by the e flows workshop group as a concern and therefore were not evaluated.

4.2 Operations and Authorized Purposes for the Kiamichi River

4.2.1 Operations Overview

The USACE Tulsa District includes the Kiamichi River which is operated as one of five subsystems to the Red River Basin. There are two projects in Kiamichi River basin, both owned by USACE. Sardis Lake and Hugo Lake are both multipurpose projects that account for 8.5% of the total conservation storage and 8.6% of total flood control storage in the Red River Basin. The area of focus for the Kiamichi River SRP is shown in Figure 1.

Kiamichi River flows serve as a critical drinking water supply for more than 600,000 people along with being used for irrigation, municipal wastewater and industrial discharges, power generation, and as a source of commercial sand and gravel. Additionally, recreation use in the Kiamichi River Basin (boating, kayaking, camping, picnicking, fishing, swimming, hunting, wildlife viewing, etc.) provides substantial

benefits to the local, regional, and national economy.

Each USACE reservoir operates for specific congressionally authorized purposes and has a Water Control Manual which details the rules and regulations specific to each reservoir. The following sections summarize the main rules used to regulate releases in both flood control and multipurpose pools. Within the Kiamichi River Basin, the congressionally authorized purposes include flood control, water supply, water quality, fish and wildlife, recreation, navigation support, and irrigation. Table 3 summarizes the authorized purposes for each.

Table 3. Kiamichi River Basin reservoirs authorized purposes.

Reservoir	Flood Control	Water Supply	Water Quality	Fish and Wildlife	Recreation	Navigation	Hydropower	Irrigation
Sardis	X	X	X	X	X	–	–	–
Hugo	X	X	–	X	X	–	–	–

* Authorized purpose, not operating purpose

Based on PR-19 Authorized and Operating Purposes of Corps of Engineers Reservoirs July 1992, revised 1994

Operations can be broken into three major categories, flood control, multipurpose, and surcharge, each being governed by separate rules. Releases made from USACE reservoirs serve to fulfill one or more of the authorized purposes. Flood control and the various multipurpose operations are explained in the following sections.

4.2.2 Kiamichi River Basin Reservoir Operations

Typically, the flood control pools are designed to store runoff from major floods based on a standard project storm. When floodwaters are accumulating in the system, each lake is regulated as much as possible to balance the flood control capabilities.

When flooding is not occurring, USACE works to seasonally fluctuate reservoir elevations near the multipurpose pool level in order to principally benefit on-reservoir fish and wildlife purposes. Minor releases at some projects are managed to benefit downstream fish and wildlife and special requests from river users. Minimum releases are maintained at some projects for the purpose of sustaining water quality control in the first reach downstream. If flow from the Kiamichi River above Clayton is insufficient to meet the downstream water rights, then releases from inflow to satisfy water rights will be made at the request of the OWRB.

Minimum releases from each of the USACE reservoirs in the Kiamichi River Basin were established during the original design and authorization process using U.S. Public Health Service guidelines for downstream water quality needs along the tributary before it reaches the Kiamichi River.

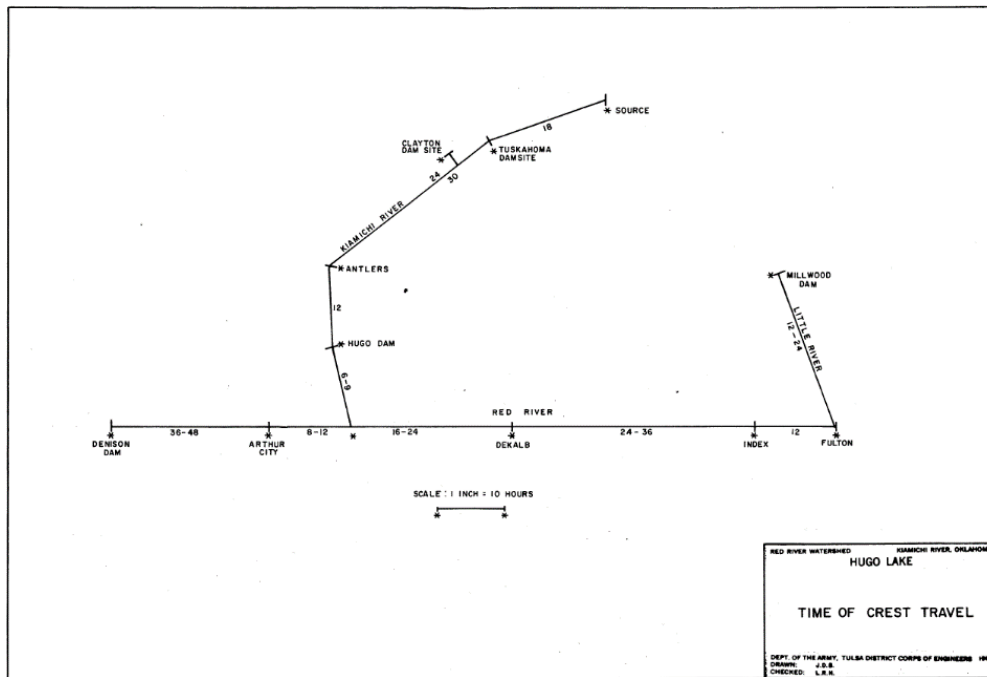


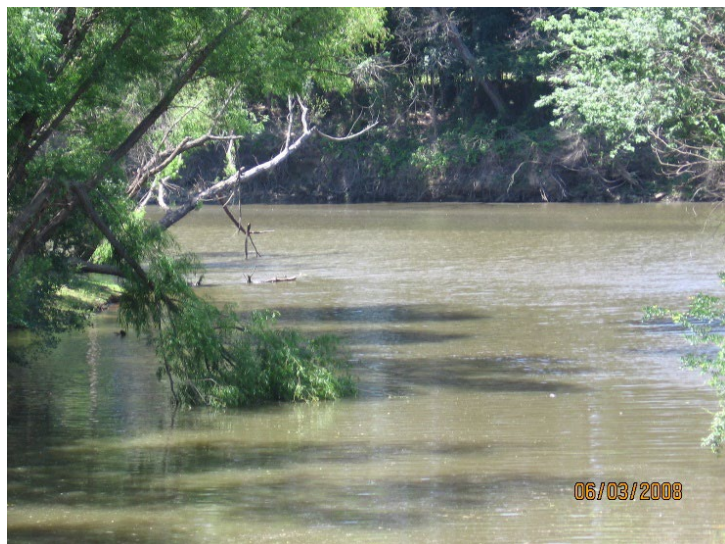
Figure 3. Kiamichi River Basin time of travel.

Cooperation between the USACE Tulsa, project operating personnel, and OWRB has resulted in operation plans recognizing reservoir fish and wildlife management objectives. One significant feature of this cooperation is the annual development of water level management plans for each reservoir. These plans modify the effective multipurpose pool elevation for water release guidance to principally benefit fish and wildlife on the reservoir.

Figure 4. Low flows in the Kiamichi River during a wet cycle (USACE photo).

The typical water level management plan for Kiamichi River reservoirs calls for low winter levels for additional storage for large winter and spring flows. In spring, a slow pool rise is preferred to enhance fish spawning.

For the same reason, large releases are minimized to prevent fish entrainment through dams and improve nesting/rearing conditions for bank spawning species. Later in spring and in summer, the pool is usually maintained close to the multipurpose level to enhance recreation and maximize flood control benefits during the wet season



(Figure 4). In late summer or early fall, the pool may be lowered to enhance shoreline vegetation growth. Then later in the fall the pool is allowed to rise when water is available to inundate the vegetation growth and maximize waterfowl habitat and hunting access. In late December, the pool is lowered to its winter level.

5.0 Key Findings from the Literature Review

5.1 Fish

The Kiamichi River watershed is home to a diverse fish fauna. There are 100 species that have been reported in the watershed (W.J. Matthews, personal communication). Many of the species are quite rare, though no extirpations of species from the watershed have been documented and there are no federally listed species.

Fish assemblages in the river have changed very little over the last few decades, and fish species that were present before the dams were built are largely still there (Matthews and Marsh-Matthews 2015). Matthews et al. (1988) found that the rank order of fish abundance was stable across 5 years in the 1980s in the river. Fisher et al. (2005) compared species richness between collections made in 1969-73 and 1996 for 8 sites in the river before and after the construction of impoundments and found no difference in the number of fluvial specialist species. In contrast, Pyron et al. (1998) collected fish from 12 sites in the river in 1992 and compared this date with previous surveys in 1972. They found that species richness was higher prior to reservoir construction and that sites further from the Sardis reservoir outflow were more similar in composition over time than sites closer to the outflow.

Most stream fishes are adapted to the natural flow regimes in the systems where they evolved (Lytle and Poff 2004). Fish have biological traits, including habitat preferences, dietary preferences, life history characteristics, and physiological traits such as thermal optima, that underly their survival, growth, and reproduction (Tonkin et al. 2019). When stream conditions, such as flow and temperature, deviate in magnitude, duration or frequency from what is typical under the natural flow regime, fish may not be able to adapt to these new conditions.

Fish species in the Kiamichi River vary widely in their habitat needs and habits, ranging from species that rely on riffles, to pool dwellers, to those that live over mud and detritus at the stream margins. However, most species can be generally classified as either fluvial specialists that need flowing water at some life stage or generalists that can inhabit flowing or standing water (Fisher et al. 2005). Many of the fish species that inhabit the reach of the Kiamichi River that could be impacted by water withdrawals are fluvial specialists (Fisher et al. 2005). These species would be particularly vulnerable to disturbance caused by the construction of low head dams for water withdrawals and susceptible to subsequent alterations in flow (Fisher et al. 2005). Low water levels in summer can compress fish habitat and make species such as minnows more vulnerable to predation. Fish species in the Kiamichi River also vary in their feeding behavior and diets and life history traits, including when and where fish spawn. Spawning is often cued by particular water temperatures, light levels, flow events or a combination. When these factors are altered, fish may not reproduce successfully. Low water levels in the Kiamichi River in the summer can lead to high water temperatures. These temperatures can affect fish performance and lead to mortality.

Environmental flow recommendations for fish should consider that climate change will alter stream flows and temperatures in the future. Bertrand and McPherson (2019) used statistical down-scaling of global climate model outputs to create estimates of air temperature and precipitation in the Red River basin for 2010 - 2099 for nine climate scenarios based on three general circulation models and 3 representative concentration pathways. Gill et al. (2020) used these estimates and species distribution models to predict the future distribution of fishes in the Red River basin, including the Kiamichi River. They concluded that the range extent of most species will contract over the new few decades with increasing mean summer air temperature as an important driver of this phenomenon.

5.2 Freshwater Mussels

The Kiamichi River is home to a diverse fauna of 31 mussel species (Galbraith et al. 2008a; Vaughn et al. 1996) which represents ~56% of the Oklahoma mussel fauna. Unlike many North American rivers, there are no known species extirpations of mussels from the river, although abundance has declined substantially. Common species include the three ridge, mucket, pimpleback, and Wabash Pigtoe. The Kiamichi also harbors at least two federally listed endangered species.

The Kiamichi River has been a focal river globally for the study of ecosystem processes and services provided by freshwater mussels. Over the past 30 years, overall abundance of mussels in the Kiamichi River has declined ~60% and species composition has changed. These changes seem to be linked to very low summer flows and accompanying high water temperatures during periods of severe drought, which have been exacerbated by human water management (Atkinson et al. 2014a; Galbraith et al. 2010; Spooner and Vaughn 2000; Vaughn et al. 2015). Mussels are very sensitive to changes in flow regimes and water temperature because of their unusual life history and habitat needs. Increases in the magnitude of high flows can prevent juveniles from settling in new habitats, and low flows in summer can lead to high water temperatures that are detrimental to mussels.

Jackfork Creek, the main tributary of the Kiamichi that would normally drain into the Kiamichi, is now impounded by Sardis Reservoir. After construction of the dam, water that would normally drain into the Kiamichi has been held in Sardis Reservoir, exacerbating drought conditions and causing sections of the Kiamichi to stop flowing and in some cases go completely dry (Galbraith et al. 2010; Vaughn and Julian 2013), leading to high water temperatures. In summer 2000, Spooner and Vaughn (2000) monitored the effect of extremely low water levels on a mussel assemblage in the lower Kiamichi near Moyers for which they had two previous years of population data; at this particular site, there was no flow and water temperature during the sampling exceeded 40°C. Mussel mortality was significantly correlated with water depth, with the highest survival in the deepest, coolest water. In an effort to minimize mortality, the Army Corps of Engineers released a series of 12 cfs (cubic feet per second) surges of water from Sardis Reservoir resulting in a 4.4 cfs spike in discharge at Clayton and a 1.2 cfs spike at Antlers. Unfortunately, because the riverbed was already very dry, most of the flow was lost to the water table, and the release was insufficient to reduce water temperature for mussels.

These mussel declines have consequences for river health and ecosystem services. Vaughn et al. (2015) asked how observed changes in mussel biomass and community composition resulting from drought-induced changes in flow regimes might lead to changes in river ecosystem services between 1991 – 2012. They used data on mussel declines discussed above. They combined these data with laboratory-derived physiological rates and river-wide estimates of species-specific mussel biomass to estimate three aggregate ecosystem services provided by mussels over this time period: biofiltration, nutrient recycling (nitrogen and phosphorus), and nutrient storage (nitrogen, phosphorus, and carbon). Mussel populations declined over 60%, and declines were directly linked to drought-induced changes in flow regimes. All ecosystem services declined over time and mirrored biomass losses.

Establishing environmental flows that safeguard mussel populations will protect the endangered mussel species and hopefully prevent future litigation related to these species.

6.0 Flow-Ecology Relationships for the Workshop

A natural flow regime or hydrologic regime refers to the characteristic pattern of a river's flows in terms of quantity, timing, and natural variability. The natural flow regime influences many of the key characteristics of, and processes in, river systems such as physical habitat (channel structure and

characteristics such as substrate), water quality (issues such as chemical and temperature regimes), energy supply in terms of nutrient input and availability, and species interactions. Flow regime ecosystem influences vary greatly depending on if the flow is low, high, or flooding, but all can benefit the ecological integrity of a river system.

A dam-altered flow pattern can result in significant changes to a river's hydrologic regime with impacts to timing, duration, magnitude, frequency, and rate of change. The aim of the Kiamichi River SRP is to identify preferred flow regimes for fish and other aquatic species (e.g., mussels) populations, ecosystem function, and river and riparian floodplain habitat health that could later be explored to determine whether it is possible to modify Corps' dam operations to accommodate these flow regimes. The task was to consider e-flows in the Kiamichi River. The goal was to identify opportunities for congruency between hydrology and species/habitat flow needs. The desired outcome was e-flow prescriptions that create adequate conditions for all native species/habitats enough of the time.

6.1 Mussels and Other Aquatic Species

Experts were tasked with considering the life history needs of mussels and other aquatic species.

Mussels

Mussel needs considered:

- Habitat permanence for existing mussel beds
- Optimal shear stress
- Water quality including temperature, dissolved oxygen, and ammonia
- Promotion of overlap with fish hosts during appropriate season

Environmental flow recommendations should consider future conditions in terms of altered stream flows and water temperatures. Appendix C details the e-flow prescriptions formulated during the workshop.

6.2 Assessment Tools

Assessment tools used in support of this e-flows workshop included CADSWES RiverWare (Center for Advanced Decision Support for Water and Environmental Systems – RiverWare) to estimate flows available for downstream use, HEC-RPT (Hydrologic Engineering Center – Regime Prescription Tool) to visualize how the water management recommendations would impact the stream, HEC-EFM (Hydrologic Engineering Center – Ecosystem Functions Model) to analyze ecosystem responses in the stream with the water management recommendations, and TNC-IHA (The Nature Conservancy – Indicators of Hydrologic Alteration) to help analyze and assess changes in daily hydrologic data in meaningful terms ecologically.

7.0 Summary of Regime Prescription Tool (RPT)

The USACE and TNC used RPT to help technical experts craft their e-flow prescriptions. RPT was developed by the USACE Hydrologic Engineering Center and TNC to facilitate entry, viewing, and documentation of flow recommendations in real-time, public settings. The RPT seeks to improve 1) communications in group settings by allowing real-time recording and plotting of the recommendations as they are developed, and 2) the recommendations produced by making hydrologic information more immediately accessible to scientists, engineers, and water managers during the formulation process. RPT is a visualization tool and not intended to perform the quantitative analyses already performed by

other software packages. Instead, RPT seeks to complement those packages by making it easier to create flow time series that other software can import and use in analyses.

The USACE and TNC displayed hydrographs of wet, dry, and average years in the RPT. A description of how water years were categorized is in Appendix C. The software was then used to draw hydrographs on top of the data. RPT is primarily a visualization tool and is not intended to perform the detailed quantitative analyses (e.g., statistical analyses or reservoir and river routing) already performed by other software packages. Instead RPT seeks to complement other software by making it easier to create flow time series that other software packages can import and use in their analyses (USACE 2012).

8.0 Next Steps in the SRP Process

The Kiamichi River SRP team successfully hosted a technical stakeholder e-flows workshop in June of 2022 and produced flow prescriptions for the river. No further work is required to implement an e-flow recommendation within the basin at this time.

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Appendix A: Agenda

AGENDA

Environmental Flows Workshop Kiamichi River Watershed

June 28, 2022

4224 N. Lincoln Blvd., Oklahoma City, 73105

9AM-3PM

1. **Introductions:** 9AM-9:15AM
2. **SRP overview:** Kimberly Elkin, TNC; 9:15AM-9:30AM
3. **Ecology/biology of the Kiamichi River watershed:** Caryn Vaughn, OU; 9:30AM-10:00AM
4. **Hydrology and operation of Sardis Reservoir/Kiamichi River:** Jordan McQueen, Army Corps of Engineers; 10:00AM-10:30AM
5. **Questions on presentations:** Everyone; 10:30AM-10:45AM
6. **Breakout groups for HEC-RPT:** Everyone; 11AM-12PM
7. **Lunch** (box lunches @ meeting) 12PM-12:30PM
8. **Breakout groups continued:** Everyone; 12:30 PM-2PM
9. **Questions/comments/concerns:** Everyone; 2PM-3PM

Appendix B: Participant List

Barney Austin	AquaStrategies
Bruce Moring	East Central University
Caryn Vaughn	University of Oklahoma
Daniel Fenner	United States Fish and Wildlife Service
David Martinez	United States Fish and Wildlife Service
Duane Smith	Oka'Institute
Ethan Schuth	Choctaw Nation
Evin Fetkovich	United States Geological Survey
Grace Johnson	Oklahoma Water Resources Board
Jim Burroughs	Oklahoma Department of Wildlife Conservation
John Hickey	Army Corps of Engineers
Jordan McQueen	Army Corps of Engineers
Joseph Vicarca	United States Forest Service
Kenneth Roberts	Kiamichi River Legacy Alliance
Kevin Stubbs	United States Fish and Wildlife Service
Kimberly Elkin	The Nature Conservancy
Kristopher Patton	Chickasaw Nation
Larry Hare	Oklahoma City
Lindsey Bruckerhoff	Oklahoma State University
Malarie Gotcher	Oklahoma City
Michelle Mattson	Army Corps of Engineers
Owen Mills	Oklahoma Water Resources Board
Paul Leonard	Brown and Caldwell
Richard Cole	Oklahoma Water Resources Board
Robert Bastarache	United States Forest Service
Samantha Mackey	Army Corps of Engineers
Sarah Harris	Army Corps of Engineers
Scott Henderson	Army Corps of Engineers
Shana Mashburn	United States Geological Survey
Shanon Phillips	Oklahoma Conservation Commission
Sherri Tilley	Oklahoma Department of Environmental Quality
Tony Clyde	Army Corps of Engineers
Trey Lam	Oklahoma Conservation Commission
Mark Howery or Curtis Tackett	Oklahoma Department of Wildlife Conservation
Grace Johnson	Oklahoma Water Resources Board
Shawnda Cox	Oklahomans for Responsible Water Policy
Bill Redman	Kiamichi River Legacy Alliance
D.J. Thompson	Oklahoma Center for Nonprofits
Janetta Cravens	Oklahoma Center for Nonprofits
Laurie Monetti	Oklahoma Center for Nonprofits

**Appendix C: Fish, Mussels,
and Other Aquatic Species:
Break-out Group Findings**

Fish, Mussels, and Other Aquatic Species Break-out Group Findings

- Participants worked together to considered e-flow needs. No breakout groups were required.

Process

The group was tasked with evaluating low flows that met stakeholders required prescription goals.

Mussels and Other Aquatic Species, Reach 1

The team focused on Reach 1 during the workshop. Mussels were a key ecological community considered.

A flow prescription was developed in wet, average, and dry years to maintain habitat needs for mussels.

E-flow recommendations for mussels were designed primarily to reduce thermal stress, which is most pronounced during hot periods in the summer months of dry years. Thermal stress has been observed and documented as a population-limiting variable for mussels of the Kiamichi. In the e-flows workshop, low flows were prescribed for reach 1 of the Kiamichi River (from confluence of Jackfork Creek to Hugo Lake; Figure 1). E-flow recommendations are shown in Table C1 and Figure C1.

Table C1. Environmental flow recommendations for reach 1 of the Kiamichi River.

Water Year Type	Low Flow (cfs)	Notes (and related pulse flow dynamics)
Wet	15	Multiple pulses up to and routinely exceeding 1,000 cfs as typical in wet years
Average	25	Multiple pulses occasionally exceeding 1,000 cfs as typical in average years
Dry	35	No pulses anticipated or required though any pulses would likely provide ecological benefits

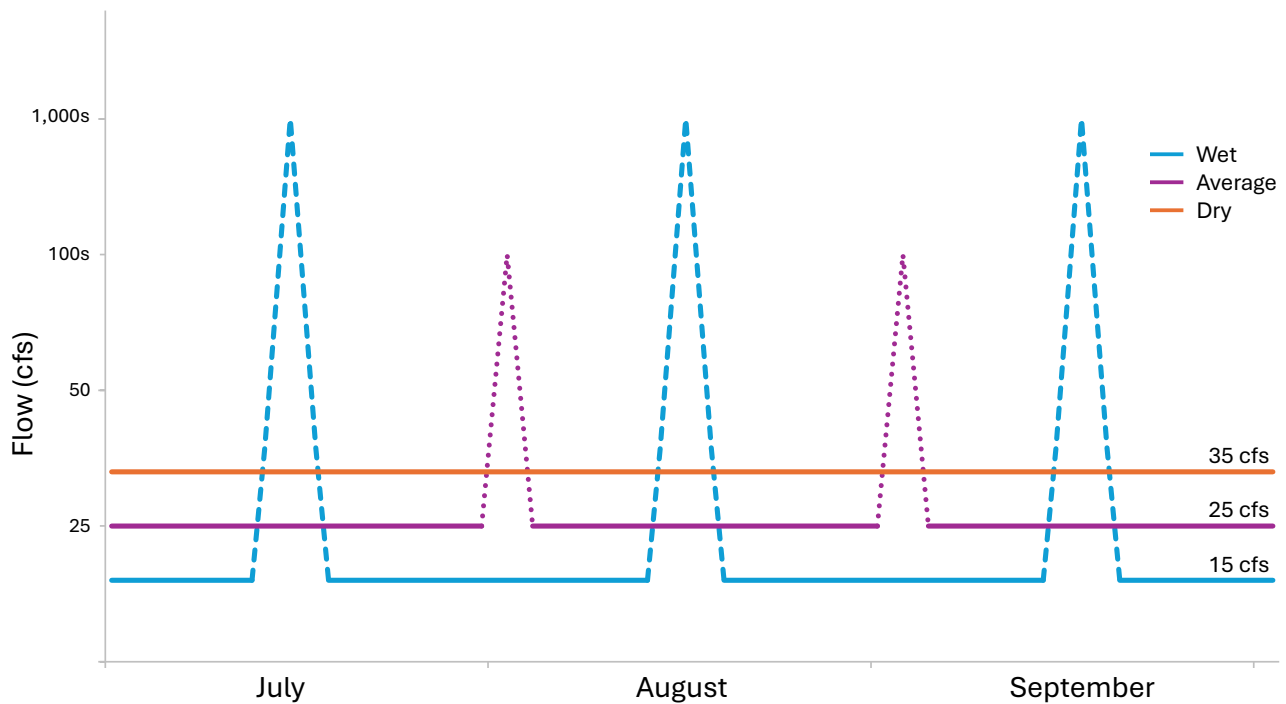


Figure C1. Visualization of environmental flow recommendations for reach 1 of the Kiamichi River.

Wet years had the lowest low flow recommendations of the three water year types. Low flows recommendations were set at a daily minimum of 15 cfs with multiple and variable pulses occurring to maintain suitable water quality for mussels. Wet year pulses are typical of flow conditions in wet years, important to mussel viability during summer months, range from hundreds to thousands of cfs, and not expected to require any water management to occur though any prolonged hot and dry period, even if nested within a generally wet year, should be monitoring with associated thermal stress being mitigated when possible.

Average years were similar in strategy to wet years. Low flows were set at a daily minimum of 25 cfs with multiple and variable pulses occurring to maintain suitable water quality for mussels. These pulses are general smaller, fewer, and of shorter duration than pulses in wet years. Average year pulses are typical of flow conditions in average years, important to mussel viability during summer months, range from hundreds to occasionally thousands of cfs, and not expected to require any water management to occur though any prolonged hot and dry period, even if nested within a generally average year, should be monitoring with associated thermal stress being mitigated when possible.

Dry years had the highest low flow recommendations of the three water year types because thermal stress is most pronounced during hot periods in dry years. Low flows recommendations were set at a daily minimum of 35 cfs. Due to the generally dry conditions during dry years, no pulses are anticipated or required though any pulses would likely provide ecological benefits via alleviation of thermal stress.

Meeting e-flow targets in wet, average, and dry years would likely require flow releases from Sardis Lake and are therefore highly likely to produce ecological benefits in reach 0 (Figure 1) in addition to reach 1. Season for the low flow recommendations was set as 01 Jul to 30 Sep to include the warmest summer months, but seasonality considerations are really about thermal stress and therefore best viewed as guidelines that can be adjusted however needed to encompass the critical periods of thermal stress observed as a population-limiting variable for mussels of the Kiamichi.