Attachment A

Scope of Work
Development of Draft Environmental Flow Recommendations for Caddo Lake

Preparation of Literature Reviews and Summary Report

Dr. Kirk Winemiller will serve as the principal investigator for this project. In this role, Dr. Winemiller will foster regular communication among contributing scientists to ensure coordination of the tasks described below.

Four additional academic researchers will work with Dr. Winemiller as a team to compile the following information. The focus of the investigation will be on Caddo Lake and the lower reaches of the tributary rivers feeding into the lake. Researchers will focus on riverine and lake fishes and other significant faunal elements that may include sensitive or threatened taxa; floodplain ecosystems associated with tributary rivers and forested wetlands in the lake; hydrology and geomorphology; and physical and chemical characteristics of the tributary rivers and Caddo Lake.

1. Conduct a literature review of sources that appear useful in informing environmental flow recommendations for inflows to Caddo Lake. This review will include, but is not limited to, informational sources that will be identified during a November 2004 orientation meeting.
2. During the orientation meeting in November, a list of potential science reviewers will be compiled. Contact each of these scientists and ask them to review the list of potential information sources compiled at the orientation meeting. Ask the scientists to prioritize the available information sources according to their relevance for informing ecological flow needs in Caddo Lake and its tributary rivers. Also, ask scientists to identify representative indicator species for fishes and other aquatic organisms, the riparian systems, and the lake. These indicator species will be organisms that are known, or thought, to be dependent upon specific water conditions for one or more aspects of their life cycle needs.
3. Obtain and review all prioritized information sources. Summarize information provided in each priority information source. When summarizing pertinent information about species requirements and flow-dependent ecological processes, organize this information using the following components of flow: subsistence flows, base flows, high pulse flows, and overbank flows.[1] (see Figure 1)
4. As a team, develop an integrated summary report of information available to inform ecological flow recommendations. This summary report will, at a minimum, address

[1] As used here, a high pulse flow or overbank flow would be generated by a rainfall event (see Figure 1). A high flow pulse remains within the banks of the channel, whereas an overbank flow spills into floodplain areas. All remaining (non-runoff) river flow periods would be characterized as being either a base flow or a subsistence (extremely low) flow; the threshold for the latter should be defined for each river, but might be defined as being the lowest 10^{th} percentile of low flows.

each of the questions posed in Appendix A. In addition, the summary report will include: (a) key findings about linkages between specific ecological flow components and biotic tolerances or dependencies; (b) pictorial models or box-and-arrow diagrams illustrating connections between flow components, life cycles of representative indicator species, and key ecological processes. Contractor and The Nature Conservancy will work together to determine the format requirements of this document.

5. Solicit peer review of summary report by all scientists listed in (2) above, and incorporate summary comments in an interim report.

Workshop to Develop Draft Flow Recommendations

1. Distribute the final drafts of the literature review and summary report to all workshop participants at least three weeks prior to workshop and ask them to review these materials prior to the workshop.
2. During the workshop, help facilitate interactions among scientists in small group discussions to define environmental flow recommendations. These environmental flow recommendations will include quantified values for subsistence, base, high pulse, and overbank flows; and include (as necessary) different values for dry, average, and wet years.
3. Prepare report of ecosystem flow recommendations and obtain review and approval from all workshop participants.

Appendix B
Questions to be Addressed in Summary Report

Hydrology

1. Do stream gauges exist along the river, and if so, where are they located, who maintains them, and how long have they been in operation?
2. Have lake level elevations been monitored, and if so, for how long and by whom?
3. What are/were the typical seasonal patterns of natural river flow and lake level fluctuation, e.g., when do higher flows tend to occur, when do the lowest flows occur?
4. To what extent have lake levels and the base, high pulse, and overbank flows in the river changed over time in response to human influences? Have extreme low flows (i.e., subsistence flows) become more frequent or extreme?
5. What are the primary human influences on the flow regime, and where do these impacts occur? Do certain human impacts (e.g., dam construction) appear to dominate over other human influences?
6. What types of water development activities are planned for the future, and how might those developments influence river flows and lake levels?
7. How important are ground water contributions to base flows? What is the nature of hydraulic connections between river or lake stage and alluvial water table levels?

Suggested approaches:

- Prepare a schematic drawing of the drainage network, noting the mean annual flow and drainage basin area at all available stream gauge stations.
- Provide a tabular summary of water uses and water structures, at the finest level of detail available.
- Prepare "typical" hydrographs (both annual and decadal hydrographs) for undeveloped and developed conditions at all river and lake monitoring stations.
- Categorize the natural hydrologic regime into ecological flow components: subsistence flows, base flows, high pulse flows, overbank flows. Using the Indicators of Hydrologic Alteration (IHA) software, estimate quantitative values for each of these components under natural, historic, present, and future conditions (if hydrologic simulation data are available). Assess changes in the magnitude, duration, timing, and frequency of each flow component.
- Prepare flow duration curves for undeveloped and developed conditions at all stream gauges.
- Characterize typical groundwater-surface water interactions using monitoring well data or other sources of information.

Hydraulics

1. Has any hydraulic modeling been performed for the river? Has any flood hazard mapping been undertaken?
2. How well are relationships between river and lake stages (water elevations) and river flow understood?
3. How well are relationships between river flow and the distribution of velocities and depths in the river channel understood?
4. Is there longitudinal (upstream to downstream) connectivity in flow or are there major discontinuities (i.e., diversion dams), and if so where?
5. Has the lateral connectivity between the river and its floodplain been altered in any way?

Suggested approaches:

- Develop river stage-discharge relationships (e.g., at flow monitoring stations or from hydraulics models).
- Develop relationships between river inflows and lake level fluctuations.
- Plot the relationship between flow and estimated percent floodplain inundated at representative river transects (e.g., at stream gauges or from aerial photos).
- Develop flow depth and velocity estimates across river transects (e.g., at stream gauges or using hydraulics models)

Geomorphology

1. Have any topographical surveys been conducted of the river channel, floodplain, or lake? (including any surveying for bridges, roads, floodplain mapping, etc)
2. Is the channel and floodplain system in dynamic equilibrium or disequilibrium? Is the sediment input to each segment in equilibrium with the capacity of the channel to transport it through the segment? Are there detectable trends in the elevation of the river bed or lake bottom, indicating degradation or aggradation? Has the river's longitudinal profile changed over time?
3. Is the lake filling with sediment and organic matter, and if so, how rapidly?
4. Has the channel or floodplain width changed over time?
5. Has the channel's planform changed over time, such as between meandering and braided forms?
6. Has the size distribution of streambed sediments changed over time?
7. Has the availability of instream physical habitats changed over time? (e.g., changes in availability of pools or riffles)
8. Are lateral channel migration or bar formation important ecologically? (e.g., to support riparian plant communities). Is sediment deposition in the lake important to recruitment or survival of plants?
9. Has human activity and land use significantly altered the stream channel and floodplain morphology and processes?

Suggested approaches:

- Plot the river's present-day longitudinal profile from topographic maps or field survey information
- Characterize historical changes in longitudinal river slope, if adequate data are available (e.g., at multiple river flow monitoring station locations).
- Characterize changes in lake bathymetry, if adequate data are available.
- Review historical aerial photographs to assess changes in river plan form and floodplain over time
- Assess changes in channel cross-sectional shape, if data are available (e.g., at stream gauges)
- Develop sediment budget estimates for appropriate representative time periods, such as historic, pre-dam agricultural, and post-dam periods.
- Estimate flows necessary to entrain river sediments (to maintain desired streambed composition or move sediment downstream to lake).
- Estimate channel forming flows necessary to maintain desired channel geometry.
- Estimate channel migration flows needed to sustain floodplain development and riparian ecosystem.

Water Quality

1. Has water quality data been collected for the tributary rivers or lake, and if so, by whom, where, for how long, and of what type?
2. How do water quality conditions vary spatially in the rivers or in the lake?
3. What is known about water quality problems in the rivers or lake? Are any of the water quality problems in the lake related to river inflows? Are any of the designated uses for the rivers or lake impaired? If so, has a TMDL study been done, and what are its results?
4. Where are the wastewater discharge permit locations on the segment? What are their permitted flows? What proportion of the summer low flows in the river arises from upstream wastewater discharges?
5. What is known about daily, seasonal, annual fluctuations in key parameters such as dissolved oxygen or temperature in the rivers or lake?
6. How do human activities, including the operation of any upstream reservoirs, affect water chemistry, temperature, or dissolved oxygen?
7. What water quality components are of greatest concern to the target organisms, life stages, or riverine processes (e.g., dissolved oxygen, suspended sediment, temperature, chemical elements, nutrients)? Are species distributions or abundances thought to be affected by water pollution?
8. Is large woody debris an important component of the aquatic ecosystem?
9. Are any invasive plant species an issue of concern?

Suggested approaches:

- Characterize natural and post-development patterns of water temperature, including seasonal and diurnal fluctuations.
- Characterize natural and post-development patterns of dissolved oxygen in the water, including seasonal and diurnal fluctuations.
- Identify known relationships between reservoir releases and discharge of contaminants present in the reservoir.

Freshwater Ecology

1. What type of biological data has been collected for the tributary rivers or lake? Who collected these data, over what time frame, and how often?
2. Has the abundance or distribution of certain species changed over time? Are these changes thought to be linked to changes in river flow or lake levels? Are data available to document these trends?
3. What species (fish, birds, mammals, invertebrates, aquatic plants or riparian vegetation) are of greatest concern from either ecological or socioeconomic, or recreational standpoints?
4. What is known about the linkages between flow or lake level variations and life histories of aquatic species? What times of year are most critical for indicator species, life stages, or species assemblages?
5. Can the flow needs of certain indicator species be used to represent the flow needs of assemblages of organisms (e.g., fish communities, riparian vegetation)?
6. If the river flow regime has been altered by human influences, are necessary flow conditions still properly sequenced to enable successful life cycle completion for indicator species?
7. Which habitats are most limiting, and what is the importance of drought, flooding and intermediate flow conditions for developing and maintaining these habitats?
8. Are riverine habitats critical for maintaining fish populations in the lake?
9. Are aquatic floodplain habitats critical for maintaining fish populations in rivers?
10. Is the aquatic ecosystem dependent upon energy subsidies (e.g., detrital matter) that are brought into the river from the floodplain during floods?
11. Do certain species require particular flow levels to facilitate movements in the river?
12. If reservoir releases are proposed in order to provide recommended flows, could there be the effects on the ecology and fisheries of the reservoir?

Suggested approaches:

- Define life history stages for a diverse cross-section of species, such as aquatic plants, invertebrates, and resident and anadromous fishes, along with any known relationships to flow components and their seasonality. Specific life history aspects to consider include adult foraging, survival, and gonadal development; spawning migration and activity; egg, larva, and juvenile development; juvenile growth and survival.

- Define relationships between flow components and maintenance or access to critical habitats for completion of life history stages for key species.
- Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics.

Riparian Ecology

1. Have the riparian plant communities or distributions of riparian plant or animal species been surveyed or characterized? Have they changed over time?
2. What is known about relationships between river flows, alluvial water table levels, floodplain inundation patterns, and the influence of these hydrologic conditions on riparian plants or animals?
3. What is known about relationships between lake level fluctuations and the influence of these hydrologic conditions on lake-dwelling plants, including submerged and floating aquatic plants as well as trees?
4. Do certain riparian plants or animals depend upon physical habitat conditions that are shaped by river flows? Is lateral channel migration or bar formation important in forming these physical habitats?

Suggested approaches:

- Define life history stages for a diverse cross-section of riparian obligate flora and fauna species, along with known relationships to flow components and the seasons in which they occur.
- Define relationships between flow components and maintenance or access to riparian habitat conditions.
- Describe relationships between flow components and vulnerability to disturbances such as fire or introduced species invasions.
- Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics.

Appendix C

Project Schedule

Compilation of information sources	30 November 2004
Complete review of priority information sources	31 January 2005
Complete summary report	15 March 2005
Obtain reviews from selected reviewers	7 April 2003
Revise and re-distribute literature review and summary report	15 April 2005
Participate in workshop	To be scheduled in April 2005
Final workshop report	15 May 2005