CADDO LAKE ANNOTATED BIBLIOGRAPHY MARCH 2005

Texas A&M University Team
Kirk Winemiller, Daniel Roelke, Anne Chin, Stephen Davis,
Bradford Wilcox, Luz Romero

This document contains a bibliographic review of Caddo Lake, located in the Cypress Creek Basin. This annotated bibliography has been divided into eight sections as follows:

CADDO LAKE HISTORICAL BACKGROUND:

The documents below provide information of different aspects of the Caddo Lake history such as hydrologic changes, formation of Caddo Lake, vegetation, and navigation.

Dahmer, F. 1995. Caddo Was… A Short History of Caddo Lake. University of texas Press.

This book narrates the natural history of Caddo Lake. The initial name recorded in 1840, was Sodo Lake. This name came from the Indian name Tso'to, which was a body of water twenty miles long and eight miles wide. Sodo or Soda Lake was roughly between present day Mooringsport and Shreveport, Louisiana.

This Lake was a result of the Red River overflow into what it is now called Caddo Lake. The same overflow of the Red River caused the Big, Little, and Black Cypress Rivers to back up, and the lake formed what was called Fairy Lake (Caddo Lake). It was about 1845 when the steamboat industry was brought to Caddo Lake into the little settlement of Jefferson. The Caddo was somewhat a seasonal route, depending on the water levels in the Cypress River and the Red River, but there was usually enough water required for the operation of fairly large steamboats. Steamboat traffic in Caddo Lake continued to increase until the remaining part of the Great Raft of the Red River was removed in 1873. After this, the water levels slowly decreased each year. The Big Lake diminished in size and depth until it became almost as much swamp as lake. It was possible to wade on the hard sandy bottom of the lake in many places along the shoreline. Therefore, Fisherman soon discovered that the bottom of the lake was covered with large freshwater mussels, which produced pearls of great beauty. The pearling industry had a short life and ended when the first dam on Caddo Lake was built and water levels increased, thus, flooding the mussel beds. Oil then replaced the pearl industry. At the end of the book, the author describes the presence of some aquatic plants.

Janes, L. (1914). Examination of Ferry (Caddo) Lake, Volume II, U.S. Department of Interior.

This is a set of early documents related to vegetation studies in the Caddo Lake area. These documents have been summarized by Jacques Burger, and his summary appears below.

This is the second volume of a three-volume set of materials on the U.S. Department of the Interior's 1914 investigation of Caddo Lake. The present volume contains the reports of the ecologist, Lionel Janes, including his summary report, main report, and description of wood specimens. All of these reports were obtained from the National Archives.Volume III of this set contains Janes' folio of photographs. Janes also prepared six maps of his ecologic survey plots, which are housed separately. With the exception of the wood specimens themselves (which are not included for obvious reasons and may not be available), these are all of the materials produced by Janes for his ecologic survey of Caddo Lake. Throughout these reports, Janes refers to tree numbers and sample plots. Some of the trees are described and pictured in the photographic folio, and the location of all numbered trees is shown on the sample plot maps. The location of the sample plots is shown on the "Hydrographic and Topographic Map," which is in two parts. Janes' reports are distinguished for their impeccable research and stylistic elegance. On the basis of his age analysis of trees on the Big Terrace and Lower Terrace, Janes reached the conclusion that Caddo Lake came into existence in 1777. Caution should be exercised in reviewing Janes' dating of cypress trees, since he was working at a time before the problem of false rings became known. His dating of some overcup oaks is incompatible with historic evidence for the origins of Caddo Lake in 1800, particularly in light of his observations on number of years required for germination and number of years required to reach stump height.

Kidder, A. (1913). Examination of Ferry (Caddo) Lake. Volume I, Miscellaneous

Documents.

This is the first of three reports compiling early work examining hydrology and ecology of the Caddo Lake region. Volume I has been summarized by Jacques Bagur. In 1913-14, the U.S. Department of the Interior conducted a major study of the Louisiana side of Caddo Lake, which was then known as Ferry Lake. Oil had been discovered in the area, and there were disputes over public versus private ownership and among private interests. The disputes resulted in a number of court cases called collectively the "Ferry Lake Cases," some of which went to the U.S. Supreme Court. A lot of money was at stake, and the various parties to the disputes had their own teams of lawyers and technical experts. The Department of the Interior was brought into these disputes because it was necessary to answer certain technical questions that could only be answered through a large, detailed, and objective study that could stand up in the face of minute analysis and intense questioning. There were three principal investigators in the study. Arthur Kidder, the Supervisor of Surveys for the General Land Office of the Department of the Interior, was in charge of the study. Major contributions were made by Frank Leverett, a geologist with the U.S. Geological Survey, and Lionel Janes, an ecologist with the General Land Office. They were assisted by a large team of technicians. The study had three major purposes:

1) To determine whether Caddo Lake existed and was a navigable body of water in 1812 when Louisiana entered the Union. This needed to be done because public claim to waterbodies is based on navigability.
2) To determine the mean (or ordinary) high water level on the lake in 1812 and in 1839 when the original state survey of the Caddo Lake area was conducted by A.W. Warren of the Louisiana General Land Office. This was done because mean high water is the dividing line between public and private property.
3) To determine whether Warren had correctly meandered Caddo Lake (that is, whether Warren's survey maps correctly showed the mean high water line).

The question of when Caddo Lake came into existence had been addressed by Arthur Veatch in 1899 in a report on the geology of Louisiana published by the Louisiana Geological Survey. Veatch had provided an estimate of 1777 on the basis of the upward rate of movement of the Red River Raft. Janes provided a similar estimate on the basis of an analysis of the age of tress that could have only come into existence after the lake was formed. Navigability of the lake for later periods was easily determined through historic texts and personal testimony, although there was considerable controversy as to whether the lake was navigable outside of the old channel of Cypress Bayou. The only thing the study team needed to determine was whether these conditions prevailed in 1812.The bulk of the study effort was, therefore, directed toward establishing the historic mean high water level on Caddo Lake and rerunning Warren's survey to determine corrections and establish greater precision in the survey line. Since there were no records of the historic mean high water level on the lake, it was necessary to establish one through geologic and ecologic evidence. The primary piece of

geologic evidence was the escarpment formed on the lake edge by the lapping of water at the mean high water level line. The primary piece of ecologic evidence was the types of trees along the shoreline (cypress grows in a water fluctuation zone up to the mean high water line). The studies went beyond the question of mean high water levels. The stumps in the bed of Caddo Lake were analyzed to determine the composition of the forest in the valley of Cypress Bayou before the lake came into existence. The channel of Cypress Bayou below lake waters was located and mapped. Numerous historic texts relating to the issues at hand were collected and analyzed. The investigations by the Department of the Interior and the responses to those investigations by a multitude of interested parties resulted in many thousands of pages of documents, legal briefs, and court testimony. Most of the materials produced by the Department of the Interior were collected by the National Archives. These files were obtained from the National Archives on microfilm, and the key documents have been reproduced in a three-volume set, of which this is the first volume.

Volume I contains the following documents:

1) List of papers and exhibits through June 1915
2) Decision of Commissioner of General Land Office
3) Letter directing that the investigation be conducted
4) Special instructions to Arthur Kidder
5) Kidder's transmittal letter for the reports
6) Kidder's report
7) Frank Leverett's summary report
8) Leverett's main report.

Volume II contains the reports by the ecologist Lionel Janes, including his summary report, main report, and description of wood specimens. Volume III is Janes' photographic folio.

The maps produced in conjunction with these reports can be found elsewhere in this depository and include:

1) Janes' six ecological survey plats
2) A hydrographic and topographic map of the study area (two parts)
3) A general drainage map of the Caddo Lake and Red River areas
4) A traced enlargement of a portion of the general drainage map (two parts)
5) A resurvey plat of the study area
6) A supplemental topographic map of Mooringsport.

These three volumes, with the accompanying maps, contain all of the primary documents produced in conjunction with the Department of the Interior investigation, with the exception of Kidder's field notes.

U.S. Army Corps of Engineers, 1994b. Historic Watercraft Survey. Red River Waterway Project: Shreveport, LA, to Daingerfield, TX Reach, Reevaluation Study In-Progress Review.

This report presents the results of a cultural resource investigation, along the historic navigation route from Shreveport, Louisiana, to Jefferson, Texas. The study involved historical research, remote-sensing survey, and diving, all undertaken to try to locate, identify, and evaluate any boat wrecks which may exist within the old navigation channel.

HYDROLOGY AND GEOMORPHOLOGY

There has been relatively little hydrologic and geomorphologic research conducted for the Caddo Lake Area in terms of published reports and journal articles. The main source of hydrologic information are the data archives collected and managed by government agencies such as the United States Geological Survey, the Corp of Engineers, Texas Commission on Environmental Quality, Texas Water Development Board, and the National Weather Service. The USGS manages stream flow monitoring stations at several locations on the Big Cypress Creek, Black Cypress Bayou and Little Cypress Creek. The Corp of Engineers has information on Caddo Lake as well as Lake of the Pines. The most comprehensive evaluation of ground water resources in the region is the Ground Water Availability Model and Report prepared in 2003 for the Texas Water Development Board. The primary study focusing on geomorphology is the Geomorphic Investigations conducted by the Corps of Engineers (1994) for the Red River Waterway Project. A comprehensive list of data sources pertaining to hydrology and geomorphology appears below."

Ground Water Hydrology

Baker, E. T., A. T. Long, et al. (1963). Reconnaissance investigation of the ground-water resources of the Red River, Sulphur River, and Cypress Creek basins, Texas, U.S. Geological Survey and the Texas Water Commission.

This report describes the ground water resources for northern Texas, including that of the Cypress River which drains into Caddo Lake. It provides additional information related to geology, physiographic setting and irrigation practices. The primary aquifers in the west Gulf Coastal Plan region are the Trinity Group, Woodbine Formation and the Wilcox Formation and Carrizo Sands. Secondary aquifers are the Blossom Sand, Nacatoch Sand, Mount Selman Formation and Sparta Sand. Most of the groundwater is provided from the Carrizo Sand and Wilcox Formation, the Woodbine Formation, and the Trinity Group. Fresh to saline water is available in all the aquifers. In the primary aquifers, water is mostly fresh. In 1959 about 93% of the water was used for irrigation. At the time the report was written, water tables were already beginning to decline in areas of heavy development. At that time water levels were declining as much as 6 feet per year in the Trinity Group, 12 feet per year in the Woodbine Formation, and 3 feet per year in the Wilcox Formation and Carrizo Sand. Some wells in the region had stopped flowing naturally (due to artisian conditions) and required larger and larger pumps for extracting water. At the time of the report, there was considerable uncertainty as to the total amount of ground water available in the West Gulf Coastal Plain, largely because of the limited

data. The authors estimated that about 6800 acre-feet per year. There was an additional 28,000 acre-feet in storage. From the Woodbine, about 11,700 acre-feet per year of water was available and for the Wilcox and Carrizo sand about 18,000 acre-feet year are available. Together these two aquifers have about an additional 36,000 acre feet of water in storage. The authors conclude that because of the limited data these numbers have a high level of uncertainty.

Fryar, D., R. Senger, et al. 2003. Groundwater Availability Model for the Northern Carrizo-Wilcox Aquifer-Final Report, Texas Water Development Board. http://www.twdb.state.tx.us/gam/czwx_n/czwx_n.htm

This report provides probably the most comprehensive description of the Carrizo-Wilcox Aquifer. Below is a summary statement in the report. This report documents a three-dimensional groundwater model developed for the northern Carrizo-Wilcox aquifer in northeastern Texas. The model was developed using MODFLOW and consists of six layers which include four layers for the Carrizo-Wilcox aquifer, and additional layers for the overlying Reklaw and Queen City formations. The model incorporates the available information on structure, hydrostratigraphy, hydraulic properties, stream flow, and recharge estimates. The purpose of this model is to provide a tool for making predictions of groundwater availability through 2050 based on current projections of groundwater demands during drought-of-record conditions. The model has been calibrated to predevelopment conditions (prior to significant groundwater withdrawal), which are considered to be at steady state. The steady-state model reproduces the predevelopment aquifer heads well within the estimated head uncertainty. The model was also calibrated to transient aquifer conditions from January 1980 through December 1989, incorporating monthly variations in recharge, streamflow, and pumping. The transient model reproduces aquifer heads within the calibration measures and available estimates of aquifer-stream interaction. The transient-calibrated model was verified by simulating aquifer conditions for the verification period between January 1990 and December 1999, reproducing observed aquifer heads within the calibration measures and available estimates of aquifer-stream interaction. The initial estimates of hydraulic conductivity in the model required some adjustment to better reproduce the observed water-level declines in the confined section of the Carrizo-Wilcox aquifer during the transient period. The verified model was used to make predictions of aquifer conditions for the next 50 years based upon projected pumping demands as developed by the Regional Water Planning Groups. The predictive modeling indicated noticeable rebound of hydraulic heads in some areas of the confined section even though total pumping showed a gradual increase. This was due to changes in pumping for individual layers in certain areas during the transition from the historical period to the predictive period. This model provides an integrated tool for the assessment of water management strategies to directly benefit state planners, Regional Water Planning Groups (RWPGs), and Groundwater Conservation Districts (GCDs). The applicability of the model is limited to regional-scale assessments of groundwater availability (e.g., tens of miles) due to the relatively large grid blocks (1 mile2) over which pumping and hydraulic property data are averaged in the model. In addition to uncertainty in pumping and hydraulic property data, the

model is limited to a first-order approach of coupling surface water and groundwater, and does not provide a rigorous solution to surface water flow in the region.

Sedimentation and Contaminants

Barrett, M.L., 1995. Sedimentary record of a 19th century Red River raft lake: Caddo Lake Louisiana. Compass of Sigma Gamma Epsilon, 72(1): 3-11.

This study reconstructs the physical aquatic ecosystem of Caddo Lake, Louisiana using historical documents to supplement geological observation. The purpose of the investigation is to understand sedimentation rates and patterns from the 1800's to the present. Lake sediment-thickness measurements and timeline construction allowed comparison of sedimentation rates through time. Caddo Lake received its greatest sediment input on the Louisiana side during the 1800's, when red mud was actively transported from the Red River into the lake. Comparison of sedimentation rates indicates sediment accumulation was approximately 10 times greater during the lake's 19th century history as compared to the 20th century.

Barrett, M.L., 1996. Reconstruction of the modern sedimentary history of Caddo Lake, Texas and Louisiana. Abstracts with Programs - Geological Society of America, 28(1): 3.

This study attempts to understand sedimentation patterns and rates from the 1800's to the present day. Multiple timeline establishments allow calculation of sedimentation rates plus identification of individual time units where various natural and man-made events may be recorded.

Lisantti, J., 2001. Measuring modern sedimentation rates in Caddo Lake (LA, TX) using 137Cs depth profile. Gulf Coast Association of Geological Societies Transactions, L1: 459-461.

Modern sedimentation rates were measured using gamma ray spectroscopy to measure the depth profile of 137Cs activity in sample cores from Caddo Lake. Seven cores were taken from various environments including a freshwater delta, back bays, and midlake channels, and also near inlet bayous and near the dam.

Wilson, J.T., 2003. Occurrence of and Trends in Selected Sediment-Associated Contaminants in Caddo Lake, East Texas, 1940-2002. Water-Resources Investigations Report 03-4253, U.S. Geological Survey, Austin, Texas.

This report describes the occurrence of and trends in selected sediment-associated contaminants in age-dated sediment cores from four sites in the Texas part of Caddo Lake. Radionuclides were used to age date the sediment layers in the cores, which makes possible evaluation of changes in contaminant concentrations over time. The report explains the age-dating process and associates dates of deposition with successive intervals in each core. Trends based on contaminant concentrations in intervals of core sediment were tested for statistical significance. Potential sources of contaminants, particularly mercury, are discussed.

Geotechnical and Geomorphic Investigations

U.S. Army Corps of Engineers, 1992. Geotechnical Investigations. Red River Waterway Project Shreveport, LA, to Daingerfield, TX, Reach Reevaluation Study In-Progress Review.

This report describes the geology and soils of the Red River Waterway. The geology description is based primarily on a series of geologic maps published in 1992. Soil investigation utilized field exploration, laboratory testing, and analytical study.

U.S. Army Corps of Engineers, 1994a. Geomorphic Investigations. Red River Waterway Project Shreveport, LA, to Daingerfield, TX, Reach Reevaluation Study In-Progress Review.

This investigation provides a geomorphic analysis of the Red River Waterway Project. It identifies and maps the geomorphic features or landforms in the study area, defines the geomorphic processes active in the study area, reconstructs to the extent possible the geomorphic development of the study area, and determines the significance of the geomorphic features in terms of locating previously unknown archaeological sites and the potential for discovering buried sites.

Surface Hydrology

Brandes, R. J., B. L. Harris, et al. (2004). Final Report-Science Advisory Committee Report on Water for Environmental Flows.

This report reviews the environmental flow issue as related to the State of Texas. The committee was charged with (1) providing a description of the current hydrologic conditions, streamflow patterns across the state in the major river basins, and freshwater inflow patterns for major bay and estuary systems along the coast, relative to historical and existing environmental flows (2) evaluating the analytical tool that are used or available to assess the requirements for preservation, maintenance, or enhancement of aquatic resources and riparian habitat (3) identifying ecological parameters or ecosystem characteristics to be considered in determining environmental flow needs for the state's surface water resources and (4) providing other technical information that may be of use. Specifically the report provides a review of environmental flow activities in the State, the hydrological setting, regulations related to water, Texas aquatic biological resources, environmental flows, and environmental flow assessment tools. Finally it makes some recommendations for implementation strategies for environmental flows. The report makes eight specific recommendations related to the environmental flow issue and calls for stronger science to backup environmental flow decisions.

The USGS Water Resources gages at the following sites measure streamflow, gage height, and water quality data.

- Big Cypress Ck nr Jefferson, TX: http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=07346000&agency_cd=USGS

This site contains the following data: Annual, monthly and daily streamflow means (from 08/01/1924 to 09/30/2003); peak streamflow from 03/23/1913 to 03/05/2003. It also includes daily discharge and gage height data up to 730 days. This is also a Real-time site, which typically records streamflow and gage data at 15-60 minute intervals.

- Black Cypress Bayou at Jefferson, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346045&agency_cd=USGS
  This site contains the following data: Annual, monthly and daily streamflow means (from 10/01/1968 to 09/30/2003); peak streamflow from 04/17/1969 to 02/27/2003. It also includes daily discharge and gage height data up to 730 days. This is also a Real-time site, which typically records streamflow and gage data at 15-60 minute intervals.
- Little Cypress Ck nr Ore City, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346050&agency_cd=USGS
  This site contains the following data: annual, monthly and daily streamflow means (from 01/01/1963 to 03/17/2001); peak streamflow from 04/29/1963 to 02/26//2003. It also includes daily discharge and gage height data up to 730 days. This is also a Real-time site, which typically records streamflow and gage data at 15-60 minute intervals. Little Cypress Ck nr Jefferson, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346070&agency_cd=USGS
  This site contains the following data: Annual, monthly and daily streamflow means (from 06/01/1946 to 09/30/2003); peak streamflow from 06/04/1946 to 02/23/2003. It also includes daily discharge and gage height data up to 730 days. This is also a Real-time site, which typically records streamflow and gage data at 15-60 minute intervals.
- Lake O' the Pines nr Jefferson, TX:
  http://nwis.waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07345900&agency_cd=USGS
  This site contains elevation above NGVD data and water quality data from 08/18/1965 to 09/21/1977.
- Caddo Lake at Mooringsport:
  http://waterdata.usgs.gov/la/nwis/nwisman/?site_no=07346310&agency_cd=USCE
  This site contains elevation above NGVD.

NOAA Precipitation information: The sites listed below have precipitation data for the last five days and a forecast precipitation for the next five days. These sites also include flood stage and flood of record.

- Little Cypress Ck nr Jefferson, TX:
  http://www.srh.weather.gov/lmrfc/forecast/tributaries/UPPER_RED_BASIN/JFFT2.shtml
- Big Cypress Ck nr Jefferson, TX:

http://www.srh.weather.gov/lmrfc/forecast/tributaries/UPPER_RED_BASIN/JFET2.shtml

- Black Cypress Bayou at Jefferson, TX: http://www.srh.noaa.gov/orn/forecast/tributaries/UPPER_RED_BASIN/JEFT2.shtml
- Caddo Lake at Mooringsport: http://www.srh.weather.gov/lmrfc/forecast/tributaries/UPPER_RED_BASIN/LCOL1.shtml

Texas Water Development Board:

http://www.twdb.state.tx.us/publications/reports/waterconditions/conservationstorage/plothtm/LakeOthePines.htm

This site contains a plot of conservation storage since 1990 for Lake O' the Pines

Texas Water Development Board:

http://www.twdb.state.tx.us/hydro_survey/lk_o'_the_pines/

This site contains a hydrologic survey of Lake O' the Pines. Below is the description of information found in each of the files listed in the website.

- cont2dd.e00.gz: is an ARC/INFO decimal degree coverage of the 2-ft. contours in ESRI's interchange format that is compressed with "gnu zip"
- lotp_area_cap.zip: is Microsoft Excel file with Area-Capacity Curves and data compressed using Winzip.
- lotp_gen.zip: is x,y,z file in NAD83 State plane projection, formatted for input into ARC\INFO TIN module.
- lotp_is.e00.gz: is an ARC/INFO decimal degree coverage of the islands digitized from digital orthophotos taken around 03/08/1995. These photos were created for the Texas Orthoimagery Program.
- lotp_lk.e00.gz: is an ARC/INFO decimal degree coverage of the lake boundary digitized from digital orthophotos taken around 03/08/1995.
- lotp83_tin.e00.gz: is an ARC/INFO TIN model in NAD83 State plane projection.
- x-sections58-98.zip: is a zipped Microsoft Excel spreadsheet with
  - cross-section profiles from previous surveys overlaided with cross-section
  - profiles from the 1998 TWDB survey.

Evaporation and Precipitation data for Texas:

http://Hyper20.twdb.state.tx.us/Evaporation/evap.html:

Lake evaporation and precipitation rates are provided at this site for each one-degree quadrangle in Texas. The quadrangle data were determined from all available data collection sites operated by the National Weather Service and the Texas Water Development Board. Monthly and annual gross lake surface evaporation data are available from 1954 through 2002, and precipitation data are available from 1940 through 2002.

US Army Corps of Engineers- Fort Worth District:

http://www.swf-wc.usace.army.mil/reports2.htm

This site provides historical reports about precipitation, storage and gated flow for Caddo Lake and Lake O' the Pines:

Texas Commission on Environmental Quality (TCEQ) Continuous Water Quality

Monitoring Project:
http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/swq_realtime_alt.html
This site provides real-time data at four watersheds in Texas. "Real-time" means that the data collected in the field is reported almost simultaneously to the TCEQ, so the agency knows almost immediately about changes in surface water quality in critical watersheds.

There are two monitoring sites operating at Caddo Lake since 2003. These sites measure dissolved oxygen, specific conductance, pH, temperature, precipitation, wind speed/direction, and air temperature**.** The information for each monitoring stations is found at the following websites:

- Caddo mid-lake: http://www.tnrcc.state.tx.us/cgi-bin/monops/site_photo?707
- Caddo upper mid-lake: http://www.tnrcc.state.tx.us/cgibin/monops/site_photo?708

WATER QUALITY

Many water quality parameters have been measured in the Cypress Creek Basin in the past three decades. More thorough, and spatially and temporally relevant sampling, however, has occurred only over the past decade. As a whole, the Cypress Creek Basin appears to be positioned at the transition zone between a mesotrophic and eutrophic system. However, the process of eutrophication seems to be accelerated due to anthropogenic activities within the watershed. Many water quality parameters, such as dissolved oxygen, become problematic during periods of low flow. Regarding nutrients, controls of phosphorous-loading have been suggested. In-water increases in nutrients are detectable in regards to nitrogen, but not phosphorus. This is likely because of phosphorus sequestration in the biota and sediments, i.e., most likely nitrogen accumulates in the water column because it is no longer a limiting nutrient as it was 30 years ago. Rampant growth of macrophytes in the upper reaches of Caddo Lake are problematic in that decay of this accumulated biomass also leads to conditions of low dissolved oxygen and may fuel summer phytoplankton blooms. Caddo Lake suffers from pollution of heavy metals from multiple sources. In the past, this has even led to warnings to lake recreational users to not eat larger fish. Not well documented in the papers listed below is the role of organic carbon loading, especially from poultry farming activities that might be stimulating heterotrophic bacteria and leading to conditions of low dissolved oxygen. Finally, taxonomic richness of phytoplankton has not been determined on Caddo Lake. While phytoplankton blooms have been observed, taxa have not been identified in detail since 1977, at which time nuisance taxa were not prevalent. Therefore, the current threat of phytotoxins to human health and foodweb stability remains an unknown

The USGS Water Resources gages at the following sites have water quality data

- Big Cypress Ck nr Jefferson, TX:
  http://nwis.waterdata.usgs.gov/nwis/nwisman/?site_no=07346000&agency_cd=USGS
  This site has water quality data available from 08/26/1981 to 10/18/2000.
- Black Cypress Bayou at Jefferson, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346045&agency_cd=USGS
  This site has water quality data available from 03/22/1965 to 08/20/2003.
- Little Cypress Ck nr Ore City, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346050&agency_cd=USGS
  This site has water quality data available from 10/22/1964 to 05/05/2000.
- Little Cypress Ck nr Jefferson, TX:
  http://waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07346070&agency_cd=USGS
  This site has water quality data available from 10/22/1964 to 10/02/1996.
- Lake O' the Pines nr Jefferson, TX:
  http://nwis.waterdata.usgs.gov/tx/nwis/nwisman/?site_no=07345900&agency_cd=USGS
  This site has water quality data from 08/18/1965 to 09/21/1977.

Brock, G. 1994. A study of the coliform bacterial contamination in Caddo Lake, Texas, fall term, 1994. East Texas Baptist University: Marshall, Texas. Report was incomplete!

From the pages recieved, studies from 1981 and 1993 indicated that eutrophication of Caddo Lake was being accelerated primarily from anthropogenic inputs. Fecal bacteria (coliform and streptococci) contamination appeared to accompany this eutrophication. Maximum counts exceeded 1000 colonies per 100 ml at stations throughout Caddo Lake, sometimes maximum

Crowe, A. and F. Hambleton. 1998. Cypress Creek Basin aquatic life use and dissolved oxygen concentrations during low-flow, high stress summer conditions 1995-1996. Report AS-157-SR. Texas Natural Resources Conservation Commission: Austin, Texas.

This study focused on the ecology of the Cypress Creek basin (just river sites, Caddo Lake excluded) during low-flow, high-stress conditions. At the majority of sites, DO means and minima did not meet even limited criteria for water quality. When flow was zero, most sites experienced DO <2mg/l, however, the relationship between flow and DO was not significant. DO was correlated (R2=0.53) with drainage area. DO was also strongly effected by rainfall, but only during the first two days following a rainfall event. Of the biota, benthic communities were more sensative to low DO than fish communities. Despite low DO conditions, aquatic life use scores were typically intermediate to high. (To me, this report underscores the importance of looking at seasonal and interannual data. Time lags must be accounted for).

Crowe, A.L., 1996. A survey of mercury concentration in the Cypress Creek and Upper Fabine River Basins of northeast Texas, Texas Natural Resource Conservation Commission, Austin, Texas.

This study assesses the geographical occurrence of mercury in northeast Texas. Sediment, soil, water, and fish samples were collected during 1993-95 from two river basins in northeast Texas that had factors favorable for mercury uptake (e.g. low pH, low alkalinity, low calcium, high total organic carbon, and seasonally flooded wetlands).There was a significant difference ($P<0.05$) between mercury concentrations in largemouth bass muscle tissue from fish of different size groups from Caddo Lake. Mercury concentrations in largemouth bass from Caddo Lake were positively correlated to size.

Cusack, T.M. 1984. A study of the benthic microinvertebrate community structure of Caddo Lake, Texas and Louisiana and possible effects of offshore oil production. M.S. Thesis. Stephen F. Austin State, University: Nacogdoches, Texas

This study looked at benthic communities, i.e., taxa, biomass, and productivity, as it related to ecosystem condition. Based on benthic organism density and productivity, Caddo Lake was classified as eutrophic. These measurements probably reflected the high benthic primary and water column plant/algae biomass and productivity due to the shallow nature of Caddo Lake and the sub-tropical climate (although no statistically significant trends between these parameters were found). Benthic communities throughout most of the lake were more so dominated by species representative of "poor water quality". The exception was in the very most upper reaches of the lake. Also in the upper reaches of the lake, it is thought that dense macrophyte stands cause low DO, high NH4, and low PH near the sedimaent-water interface. Off-shore oil wells might be responsible for the lower species diversity found at stations lower in the lake.

Darville, Roy, Dwight K. Shellman, Jr. and Ray Darville. 1998. Intensive Water Quality Monitoring at Caddo Lake, a Ramsar Wetland in Texas and Louisiana, USA. Caddo Lake Institute, Aspen, Colorado and Austin, Texas. Conference Paper Team Wetlands.

This report presents the methodology to determine the overall condition of Caddo Lake. The lake was divided into riverine, wetland, and open water habitats. There were 79 monitoring sites, which were sampled during a 25- day period. Results from the Mitchell and Stapp's water quality index indicated good water quality for the lake sites, while the wetland and riverine sites showed medium water quality due to low dissolved oxygen levels, high fecal coliform, turbidity and suspended solids. The Lake sites were characterized by low alkalinity, whereas wetland sites by high alkalinity. The concentration of phosphorus in the lake indicated that Caddo Lake is eutrophic. This report also points out that the Caddo Lake (segment 0404) is on the state's 303 (d) list under the federal clean water act due to elevated levels of barium, manganese, mercury, nickel, and zinc in the sediments and dissolved zinc in the water.

Darville, R.G. 2002. A five-year water quality monitoring report on Caddo Lake. Caddo Lake Institute.

This Power Point presentation includes water quality data from the three Caddo Lake systems from 1997 to 2001. Sampling was conducted seasonally and during spill and no spill conditions (flow or no flow over the dam). Results show a decreasing trend in dissolved oxygen and pH. There was a dramatic increase in

nitrogen concentrations. Water Quality Index, however, indicated that Caddo Lake is in the lower good category.

Darville, Roy and Dwight K. Shellman, Jr. 1997. The Development of a Water Quality Monitoring Protocol at Caddo Lake, a Ramsar Wetland. Caddo Lake Institute, Aspen, Colorado and Uncertain, Texas. Conference Paper at Communities Working for Wetlands, Alexandria, Virginia. May 7-9, 1997. http://clidata.org/reports.htm).

The Caddo Lake Institute began the Lake Monitoring Program in 1994. Currently up to 29 sites are sampled (locations vary) at monthly intervals. Sampled parameters (long-term) include temperature, DO, conductivity, pH, and secchi depth. More recently, sampling has been expanded to include alkalinity, carbon dioxide, nitrate, ammonia, phosphate, sulfide, zinc, copper, and turbidity. These data are within natural ranges for water parameters in east Texas and reveal no specific water quality problems.

To complement the chemical monitoring program, the Institute has adopted two biomonitoring protocols: benthic biodiversity and fecal coliform bacteria. Fecal coliform monitoring indicates that a significant coliform problem exists in certain areas of the lake.

In addition, analyses of chemical pollutants of concern included heavy metals like mercury, arsenic, barium, cadmium, nickel, and zinc; organic compounds such as trichloroethene, dichloroethene, vinyl chloride, and acetone; and several pesticides. The Texas Department of Health issued a fish consumption advisory for Caddo Lake during January, 1995. The advisory recommended that people do not consume largemouth bass greater than 18 inches in length, or freshwater drum of any size from Caddo Lake due to elevated mercury concentrations.

The utility of the data for determining water quality at Caddo Lake is limited. For instance, all of the sites that have been monitored so far are located along the shoreline, and station locations are not constant. In addition, many of the kits used in the chemical testing are not sensitive enough to detect small changes in surface water quality.

To monitor the lake more thoroughly, a comprehensive sampling was initiated in 1997 that included seasonal sampling and open water stations. For both the monthly monitoring program and the intensive summer monitoring program, the following water quality parameters were tested at the surface and bottom of each site: temperature, DO, carbon dioxide, pH, alkalinity, conductivity, chloride, total solids, suspended solids, dissolved solids, hardness, nitrate, ammonia, total phosphorus, reactive phosphorus, secchi depth, true color, apparent color, turbidity, chlorophyll a, and biological oxygen demand (BOD). All sampling and testing follows USEPA. So far, most of the statistically significant parameters are indicators of poor water quality:low DO, high ammonia, high nitrates, high color, and high fecal califorms.

Must look for follow on studies!

Ensminger, Paul A. Water-Resources Investigations Report 99-4217. Bathymetry Survey and Physical and Chemical- Related Properties of Caddo Lake, Louisiana and Texas, August and September 1998. US Department of Interior-US Geological Survey.

This poster presents detailed bathymetry of Caddo Lake with hypsographic curves reported. The lake surface area was 18,700 acres and the volume was 85,100 acre-feet. Low DO was found in deeper waters towards the lower end of the lake.

Giggleman, C.M. and Lewis, J.M., 2002. Contaminants investigation of western portion of Caddo Lake National Wildlife Refuge, Texas 2002. Project ID No. 94420-02-Y037, U.S. Fish and Wildlife Service Region 2.

This investigation determines contaminant levels in soils and/or sediments in the western portion of the Caddo Lake National Wildlife Refuge. Samples were collected from 43 sites. The contaminants sampled for included metals, semi-volatile organic compounds, organochlorine pesticides, total polychlorinated biphenyls (PCBs), dioxin/furans, and perchlorate. Overall results indicate that further investigation and possibly remedial efforts are required for the majority of the sites.

Hartung, August A. 1983. Physicochemical limnology of Caddo Lake, Texas and Louisiana. MS thesis. Stephen F Austin State University.

This study divides Caddo Lake into three regions: swamp region, open-water region, and the oil-producing region. Caddo Lake does not stratify, presumably due to its shallow nature. Winds and inflows keep the lake vertically well-mixed. High-turbidity events can happen at any time of the year, but perhaps not lasting very long because of the low water retention time (huh?). CO2, color, NH4 all positively correlated well with turbidity, while TP, apparent color, and COD inversely correlated with turbidity (Actually, I disagree. The correlations were very weak. Furthermore, they don't make sense.). Lower turbidity was found in the fall compared to other seasons. Seasonal trends in temperature were not consistent, probably due to the shallow nature of the lake and its ability to heat up quickly on sunny days. In the swamp region, the dense macrophytes altered the physicochemistry of the water, with the most notable change being low DO during times of warmer temperatures. The highest sulfate concentrations were found in the swamp region, probably coming from sediment-water interface. Phosphorus was higher in the swamp region, which probably reflects a source coming from Cypress Bayou. Also, the detritus produced from the macrophyte die-off in the winter might be responsible for the high BOD found throughout the lake in the winter. Chlorophyll values were lowest in the swamp region. In the open-water and oil-producing regions DO remained fairly high. A spring phytoplankton bloom seems to be absent from this lake, and maximum chlorophyll values were found in the summer and fall (If less-edible species proliferate, this makes sense. But this would be bad news for foodweb dynamics and presence of phycotoxins. There needs to be a survey of phytoplankton species). CO2 and COD were highest in the oil-producing region due to the large amounts of organic matter in this region, perhaps coming from oil spills and oil-contaminated sediments found in this region. This survey indicates that Caddo Lake is eutrophic.

Kirkpatrick, J. S. (1977). Intensive Surface Water Monitoring Survey for Segment No 0401 (Caddo Lake), Texas Water Quality Board: 39.

This is a small report but very useful in terms of providing background information related to water quality of the Caddo Lake area. Below is a summary provided in the report.

Caddo Dam and Caddo Lake are located in the Cypress Creek Basin in Caddo Parish, Louisiana and Harrison and Marion Counties, Texas. The lake is 29 miles northeast of Marshall, Texas. A natural dam was formed many years ago by log jams, resulting in the formation of the lake. Construction of the dam and the navigation channel from Mooringsport, Louisiana to Jefferson, Texas was completed in 1914. The project is owned by the U. S. Government and operated by the U. S. Army Corps of Engineers. The lake has a capacity of 175,000 acre-feet, a surface area of 32,700 acres, and a drainage area (in Texas) of 2,639 square miles.

There are no Texas Water Quality Board permitted wastewater discharges into Caddo Lake (Segment 0401). Several facilities located in Segment 0402 (Cypress Creek above Caddo Lake to Lake O' the Pines Dam) discharge wastewaters which ultimately reach Caddo Lake. Most of these are sewage treatment plants. The City of Jefferson's treated wastewater discharge is probably the most significant due to its proximity to the lake and its relatively high loading of BOD5 and nutrients. The most probable origin of non-point source loads to the lake are septic tank effluent, forest and agricultural runoff, and runoff from oil and gas producing areas.

Most of the inflow to the lake (76%) was from Little Cypress Creek (720 cfs), Big Cypress Creek (363 cfs), and Black Cypress Bayou (600 cfs). Tributary inflow was higher than normal during the survey due to appreciable rainfall during the previous week. Water was released from Caddo Dam at a rate of 11,900 cfs.

All dissolved oxygen levels were above the minimum segment standard of 5.0 mg/l and none exceeded 100% saturation. Diurnal fluctuations were minimal, indicating little photosynthetically induced water quality changes. Depth-integrated pH levels ranged from 5.5 (Station 4) to 7.2 (Station 6), averaging 6.1. Observed individual values at Stations 2, 3, and 4 (located in Louisiana) were below the minimum segment standard of 6.0. Whether or not these levels are natural is not known. Conductivity and alkalinity levels were typically low and water temperatures were normal for the season. Tributary field data did not indicate any problem areas.

Chemical analyses of all lake water samples and most tributary samples indicated good water quality, as indicated by low concentrations of conservative substances, organic material, nutrients and suspended solids. The organic and inorganic constituents of Tiger Branch in Louisiana (Station 17) were relatively high. The cause for these values is not known, but the impact upon water quality of Caddo Lake is probably minimal.

Sediment samples of the lake, except those at Stations 7 and 9, had high contents of organic material (as indicated by COD and volatile solids), total phosphates, and Kjeldahl nitrogen. Decomposing plant material is probably the major contributor of these elevated concentrations. Sediment pesticides (except PCB's) were not detected at any lake station. The average level for PCB's (48.3

ug/kg) is the second highest found in the 31 reservoirs studies to date in the intensive monitoring program. The cause and significance of these levels has not been determined. Lead and zinc concentrations in the sediments exceeded the levels reported for natural soils and were apparently high in Caddo Lake. Station 4 had the highest level of lead (47 mg/kg), and Stations 4 and 8 both had the highest zinc levels (170 mg/kg). The causes and effects of these apparently elevated levels are unknown.

Chlorophyll a levels in the lake and its tributaries were low and are considered indicative of mesotrophic waters. Phytoplankton assemblages were very diverse and were composed of green algae and diatoms in roughly equal proportions. Several genera recognized as clean water types were present, while none associated with polluted water were found. Phytoplankton densities were relatively low and the diversity indices were high, which indicates the community in Caddo Lake was well-balanced and stable during the study period. Fecal coliform densities were relatively low, which suggests that contamination from warm-blooded animals is minimal. Algal assay results revealed that the filtered lake water is incapable of stimulating significant algal growth. The lake is apparently both nitrogen and phosphorus limited for phytoplankton production, since these additions together resulted in significant algal biomass increases directly proportional to the amount added.

Paul Price Associates Inc. 2000. Cypress Creek Basin Summary Report. Prepared by Paul Price Associates, Inc. for submission to TNRCC, Austin, Texas. http://www.netmwd.com/reports/reports.html

The 2,812 square mile Cypress Creek Basin includes 5 subwatersheds: James and Black Bayou, Black Cypress Bayou, Big Cypress Creek, Little Cypress Creek, and Caddo Lake. The Caddo Lake watershed consists of Caddo Lake (segment 401) and segment 402. Streamflows originating in the black Cypress Bayou, Big Cypress Creek, and Little Cypress Creek watersheds dominate the Lake Hydrologically and probably has an effect on its water quality. Included in this report is a detailed description of the Cypress Creek Watershed and subwatersheds. The monitoring program for this basin has been divided into fixed stations, systematic stations, and special studies monitoring stations, with the fixed and systematic monitoring stations providing the primary data source for this report. The actual sampling events at all stations sampled during 1994-1999 are presented in table 3-2; figures 3-2 and 3-3 show the locations of fixed and systematic stations. The technical process, which includes data preparation and data screening are also well described in this report. Results were pooled to characterize water quality conditions at each of the five major subwatersheds. From this results it was concluded that the most prevalent concern is metal toxicity in the sediments of Caddo Lake and Lake O' the Pines reservoirs. There is also a concern with low dissolved oxygen and excessive nutrient levels in some areas of all the major subwatersheds. Eutrophication at Caddo Lake is more advanced than other reservoirs in the basin.

Paul Price Associates Inc., and Roy Darville, Caddo Lake Institute. Prepared for Northeast Texas Municipal Water District for submission to Texas Natural Resource Conservation Commission. 2000. Targeted monitoring in the Cypress

Basin: Nutrient study in Lake O' the Pines. Paul Price Associates and Roy Darville Caddo Lake Institute. http://www.netmwd.com/reports/reports.html.

Water quality sampling for this study was done during the year 1998 and 1999 at eight stations within the Lake and large coves. Furthermore, fourteen transects were selected for a bathymetry and aquatic vegetation (submerged and emergent) distribution mapping. Temperature, conductivity, dissolved oxygen, and pH data were also taken at different depths along these transects.

Paul Price Associates Inc., and Roy Darville, Caddo Lake Institute. Prepared for Northeast Texas Municipal Water District for submission to Texas Natural Resource Conservation Commission. 2002. Targeted monitoring in the Cypress Basin: Study of contaminants at Caddo Lake Associated with the Longhorn Army Ammunition Plant. http://www.netmwd.com/reports/reports.html

The purpose of this study was to provide a preliminary assessment of the presence of chemical compounds of Caddo Lake waters.(i.e. ammonium perchlorate or any volatile organic chemicals) There is a concern with chemical contamination in Caddo Lake because soils of the Longhorn Army Ammunition Plant (LHAAP), which is located on the southwestern shore of Caddo Lake were found to be contaminated by a number of organic compounds. Also two of the four natural drainages that run through the plant and empty into Caddo Lake have been identified by USACE (United States Army Corp of Engineers) as being significantly contaminated. For this study, water and sediment samples were taken from four stations in Caddo Lake during fall and summer of 1998. Results showed that all water and sediment contaminants for both monitoring events were below detection limits. However, some of the pH values were lower than the normal pH values found for Caddo Lake (5.8-7.0).

Paul Price Associates, Inc. Prepared for Northeast Texas Municipal Water District in cooperation with the Texas Commission on Environmental Quality. 2004. Cypress Creek Basin Clean Rivers Program 2004 Summary Report. http://www.netmwd.com/reports/reports.html

This report contains a summary of the special studies that deal with specific water quality issues and a summary table of water quality impairments in the Cypress Creek Basin identified on the draft 2004 Texas 303(d) list. It also highlights the significant findings from the 1998-2002 sampling period. In conclusion, there is concern with low dissolved oxygen for most of the Cypress Creek Basin with the exception of Lake Cypress Springs and Lake Bob Sandlin. However, in most locations, low dissolved oxygen concentrations are associated with low flow conditions and high levels of photosynthesis and respiration. Nitrogen and phosphorus are a concern only in areas with low flow or impoundments. The heaviest loads of these nutrients originate from Tankersley Creek watershed, but most of it is assimilated during transport in Big Cypress Creek before entering the headwaters of Lake O' the Pines. Also, included in this report are wastewater discharges for Lake O' the Pines, Little Cypress Creek, and Caddo Lake watersheds.

Paul Price Associates Inc. prepared for Northeast Texas Municipal Water District 2003. Lake O' the Pines Watershed TMDL Project documentation report. Paul Price Associates Inc. http://www.netmwd.com/reports/reports.html.

This is an internet presentation optimized for MS-Explorer. It focuses on water quality issues for Lake O' the Pines. Many of the questions below are my thought as I looked through the presentation.

Selenium contamination is problem that has resulted in banning of certain fish species. The source of the selenium was identified (not mentioned) and actions taken (?).

DO can be low during the summer months and times of water stagnation in the upper segments of the reservoir. Nutrients are a concern, but reported in-lake values are not excessive, although they are high. The presentation seemed to suggest that loading of total P from nearby chicken farms was the problem. It might be that the TP accumulates as biomass instead of dissolved in the lake. The recommendation was that in-lake TP be reduced by 44%, which would require a 56% reduction in the TP-load.

There are lots of point and non-point loading data shown that would serve to parameterize an ecology-based numerical model. The non-point estimated were based on SWAT.

Low DO events are associated with large diel changes (no anoxia in their data). Chlorophyll levels are not excessive, but they are moderate to high, and occasionally get up 30 ug/l. Inflows are high during the non-summer months, and DO is not a problem.

The DOC seems to be high. Is this a bacteria story? Production of chickens has increased in the watershed. Does "more labile" carbon generated on chicken farms make it into the reservoir, thereby stimulating bacteria, i.e., increased respiration?

Texas Natural Resources Conservation Commission and the Texas State Soil and Water Conservation Board. 1999. Annual Report Texas Nonpoint Source Pollution Management Program. Pg 36-37.

There are concerns with parameters such us dissolved oxygen concentrations, high pH values, water temperature, mercury, cadmium. Lead, zinc and metals in fish tissue in some water bodies of the Cypress Creek Basin. Poultry operations and its management practice are a concern with regard to nutrient loads into the Cypress Creek Watershed.

Twidwell, S. R. 1977. Intensive surface water monitoring survey for segment no. 0404 Big Cypress Creek above Lake O' the Pines to Fort Sherman Dam. Field Operations Division Texas Water Quality Board.

Data for this report was collected at the time of the Fort Sherman Dam construction and there were four sewage treatment plants discharging during the time of the survey. There was little water flowing in Big Cypress Creek and its tributaries; discharge varied from 5cfs to 10cfs and one site was dry. Most of the pHs were neutral to slightly acidic and dissolved oxygen levels were generally low. Phosphorus and nitrogen levels of water and sediments were high at stations located downstream from wastewater discharge. Chlorophyll a levels were relatively low at the lower portion of Big Cypress Creek (below 0.02mg/l). The Phytoplankton community on the upper Big Cypress Creek was mainly composed of the blue green algae Anacystis sp. whereas the phytoplankton community in the lower portion of Big Cypress Creek was the most diverse. There was low

diversity in benthic macroinvertebrates assemblages. Pollution tolerant oligochaete worms dominated the benthos at most of the stations. Benthos of the lower Big Cypress creek was the most diverse with low numbers of five different taxa.

Twidwell, S., 2000. Bioaccumulation of Mercury in Selected East Texas Water Bodies. AS-180, Texas Natural Resources Conservation Commission, Austin, Texas.

Largemouth bass were collected from 11 reservoirs and two natural lakes in East Texas to determine relationships between mercury concentration in fish and physicochemical variables in water and sediment. Total mercury concentrations in edible largemouth bass muscle tissue were found to positively correlate with fish size. Mercury concentrations in largemouth bass, standardized to length for comparison, were positively correlated with total organic carbon in water and negatively correlated with pH, hardness, calcium, total dissolved solids, sulfate, magnesium in water, and manganese in sediment. No significant correlations were observed between standardized mercury concentrations in fish and mercury concentrations in water or sediment. These relationships suggest that mercury concentrations in water and sediment are not nearly as important as are in-reservoir and lake processes which control the production of methylmercury and its subsequent bioconcentration and bioaccumulation in largemouth bass in East Texas reservoirs and lakes.

Twidwell, S.R. and David, J.R., 1989. An Assessment of Six Least Disturbed Unclassified Texas Streams (Black Cypress Bayou section), Texas Water Commission.

This section of the report presents the data from Black Cypress Bayou. After a brief description of the physical environment, field measurements are presented. Field measurements of physical stream characteristics including dissolved oxygen, temperature, pH, and conductivity, taken at four sites indicated poor water quality. Laboratory analysis of total dissolved solids and nutrients (ammonia, nitrates, and orthophosphorus) indicated little variability among the stations and generally good water quality. Analysis of the benthic macroinvertebrates and fish found low diversity as well. However, presence of juvenile fish indicates self-propagating communities and existence of permanent water. Overall, based on Texas Water Commission criteria, the appropriate aquatic life subcategory classification would be intermediate (based on physical, chemical, and biological criteria).

AQUATIC ECOLOGY

The reports summarized in the fish community section include broad surveys of aquatic habitats of the Big Cypress Bayou Basin, surveys of fishes (and waterfowl in one instance), and analyses of fish habitat and flow requirements for maintenance of current fish stocks in lotic habitats of the basin. Approximately 71 fish species have been documented from the basin. The only significant threatened species is the paddlefish (*Polyodon spathula*), an unusual plankton feeding fish that does not appear to have been collected from the basin after construction of the Caddo Lake weir many decades ago,

and certainly not present in any surveys conducted since 1950. The principal fishery concern are stocks of game fishes, and most of the species evaluated for instream flow requirements were gamefishes (white bass, channel catfish, spotted bass), although the river darter, longear sunfish and some other species were evaluated in at least one of the studies. The methods and estimates of instream flows needed for fish stock maintenance (status quo) were relatively crude and based on limited data (mostly obtained from other regions of the country), and these initial estimates were viewed with a high degree of skepticism by the Espey, Huston and Associates (1987) report. This set also includes two reports on Caddo Basin fish mercury levels and a review paper on fish-plant interactions.

Fish Community

Cloud, T. 1984. Planning aid report on the aquatic resources of the Cypress Bayou Basin, Texas. USFWS, Ecological Services, Arlington, Texas.

Aquatic resources information was collected to assist planning for a broader Cypress Bayou Basin study. Aquatic baseline information, characterizations of aquatic habitats (streams and reservoirs larger than 250 acres), and preliminary assessments of instream flow and fishery-recreation needs are presented. Citing earlier TPWD surveys, the report lists a total of 71 fish species in the watershed. Three species (bowfin, creek chubsucker, and striped shiner are only reported from small tributary streams). Major stream sportfishes are largemouth and spotted bass, channel catfish, white bass, white and black crappie, and the sunfishes. Principal forage fishes included gizzard and threadfin shad, forage size sunfishes, and various minnows, shiners, and suckers. Aquatic habitats and aquatic vegetation of the region are described. An analysis of fish habitat under variable flow conditions was conducted according to the instream flow incremental methodology (IFIM). This involves a hydraulic simulation model and habitat model. The hydraulic model is calibrated with field measurements of known flows. The one-flow, water surface profile (WSP) model was used for hydraulic simulation. The physical habitat simulation modeling approach (PHABSIM) was used to create habitat preference curves for fishes. The preference factors are multiplied by the surface area of the stream having the specified velocity, depth and substrate combination to obtain the species' weighted usable area (WUA). For Little Cypress and Black Cypress Bayous, flows from 25-150 cfs were evaluated. The report states that future research may allow expansion of this range of flows for estimates. Instream flow recommendations for the Cypress Basin are based on habitat needs of channel catfish, spotted bass, white bass, longear sunfish, and river darter. WUAs for spawning, fry, juveniles and adults were estimated for these species (Tables 2-4, Figs 1-4). Maintenance flows are defined as the instantaneous discharge required to maintain the fishery at a biologically acceptable level of productivity, or the flows necessary to maintain the status quo of the stream fishery. Fry and juveniles appear to require flows of 50-75 cfs in Little Cypress Bayou, and adults and spawning required 75-100 cfs. Overall estimates for Black Cypress Bayou were the same. Preference was given to the spawning requirements of white bass during the months of March and April, since these fish are early spawners and

require relatively high flows for their upstream spawning run. Recommendations for May-June were based on spawning requirements of spotted bass and channel catfish. Recommendations for July-November were based on the habitat requirements of fry and juveniles of white bass, spotted bass, and channel catfish. Adult requirements were emphasized for the remaining months. The report also provides estimates of the recreation resource requirements (in man-days) needed to maintain the quality of sportfishing in this basin. Cass, Gregg, Harrison, Marion, and Upshur counties were used for this analysis. Aquatic habitat, fishery production estimates, and harvest statistics were used for these estimates. It was estimated that a surplus of reservoir fishing opportunity existed in all counties of the study area (Table 8). The future potential opportunities for reservoirs that potentially could be constructed on Little Cypress and Black Cypress Bayous are presented (Table 9). The report recommends maintenance of flows of 100 cfs from December-June and 75 cfs from July-November in both Little Cypress and Black Cypress Bayous. The report recommends exploration of the feasibility of in-channel, downstream water transfers as an alternative for maintaining instream flows, in lieu of specific mitigation storage.

Cloud, T.J., Jr. 1995. A characterization of habitats and fish and wildlife management opportunities at Cypress Bayou Basin, Texas and Louisiana. USFWS, Ecological Services, Arlington, Texas.

This report summarizes information on fish and wildlife resources collected over the preceding decade from the Cypress watershed. Emphasis was on identifying structural components of habitats and evaluating the value of these habitats to wildlife. Twwelve general wildlife habitat cover-types were identified, but bottomland hardwood forests and wetlands received most attention due to their high value to wildlife and threats from development. Recommendations for management range from preservation of the highest quality habitats and resources to restoration of degraded habitats. Opportunities of private landowners, agencies and conservation organizations to enhance existing habitats within the watershed are discussed.

Cormier, K.A. 1995. Mercury levels in largemouth bass, *Micropterus salmoides*, in Twelve North Louisiana Lakes. Louisiana Dept. of Environmental Quality, Water Quality Management Division, Monroe, LA.

Overall, 177 of 180 bass sampled had some detectable level of mercury. The highest value was 1.5 ppm from Cheniere Lake. Five of the sampled lakes produced samples above the 1.0 ppm FDA alert level. The mean for Caddo Lake was 0.3 ppm (based on 15 fish taken in 1993). Values for Caddo ranged from 0.244 to 0.417 ppm.

Dibble, E.D., K.J. Killgore, and S.L. Harrell. 1996. Assessment of fish-plant interactions. American Fisheries Society Symposium 16:357-372.

This paper reviews 1) the functional importance of plants to fish, 2) methods for measuring aquatic plant and fish populations, 3) the spatial scales that studies have adopted for investigation fish-plant interactions, and 4) how fish behavior influences population structure at a macroscale. A general conclusion has been that intermediate densities of aquatic plants promote high species richness and are optimal for fish growth and survival. Aquatic plants reduce

predation mortality, and some species are specialists for vegetated habitats. Pelagic and benthic species sometimes decline in abundance when aquatic plants increase in abundance. When aquatic plants become too abundant (dense), fishes may become stunted (small size and age) due to food limitation.

Espey, Huston & Associates. 1987. Report on minimum flow considerations, terrestrial mitigation and ecological effects on Caddo Lake asscociated with Little Cypress Reservoir Development. Document No. 870464, EH&A Job No. 8848.

This document reviews instream flow related studies associated with impact assessment for a proposed Little Cypress Reservoir on Little Cypress Creek. The report summarizes and evaluates results from two instream flow studies involving fishes: a habitat evaluation procedure (HEP) study conducted by the Army Corps of Engineers, and an instream flow incremental methodology (IFIM) study conducted by the Fish and Wildlife Service. These are two very different methodologies, with HEP estimating flow required to maintain habitat units for fishes, and IFIM estimating flow required to maintain weighted usable areas for fishes. Table 2-1 summarizes the flow estimates derived from both methods over 12 months. As might be expected, estimates from the two methods do not match well. The HEP estimates were based on 9 fish species (the means of integrating to achieve an overall fish estimate is not explained). The IFIM estimates were based on 5 species (only spotted bass and longear sunfish appear in both analyses). It was felt that use of white bass and river darter was not warranted in the IFIM study, because these species are very rare in surveys Little Cypress Creek, and thus unlikely to respond demographically to flow variation. A problem identified in both studies is the lack of clear definition of the term "maintenance flows". The HEP study also estimated compensation flows (flows to enhance fish stocks in the channel to compensate for lost lotic habitat in the region of the reservoir). Routine summer flows are much lower than the estimates for maintenance flows based on IFIM, but closer to the HEP maintenance flows. It was concluded that maintenance flows estimated by both methods would render the reservoir economically infeasible. There was no estimate of the economic value of the fishery resources within the 7.3 miles of Little Cypress Creek, and it was hypothesized that this would be very minimal and comprised mostly of forage species at low densities. The value of the new reservoir fishery had not been considered. The report summarizes historic flow data, and notes that the system is not particularly flashy but has high between-year variation. The average monthly flow (based on a 38-year record) varies from 52 cfs (Aug.) to 1,066 cfs (May). Flows much higher than 200 cfs appear to be needed for overbanking and creation of shallow water habitat. Table 2-8 presents two alternative flow scenarios proposed for the new reservoir. The third chapter of the report is an analysis of terrestrial and wetland habitat mitigation for construction of the new reservoir. Thirteen habitat categories are evaluated. The appendix contains usable area data under different flow regimes for fishes.

Giggleman, C.M., D.L. Baker, and J.D. Lusk. 1998. A contaminant survey of three lentic systems within the Cypress Creek Watershed, Texas 1993-1995. USFWS, Region 2, Arlington, Texas.

USFWS examined organic and metal contaminant levels in Cypress Springs Reservoir, Lake O' the Pines, and Caddo Lake from 1993 through 1994. Cypress Springs Reservoir was the least contaminated lake. Cadmium levels in surface waters of all three lakes exceeded the state's chronic aquatic life protection criteria, and sediments from Caddo Lake exceeded the states mercury criteria for aquatic life. Alipyhatic hydrocarbons were detected in sediments from all three lakes in low concentrations. Sediments from Lake O the Pines contained some elevated polycyclic aromatic hydrocarbons. Mercury in whole body fish samples had elevated mercury levels according to predatory protection limits set by USFWS. Fillet samples contained mercury levels below the USDA's action level for human consumption. Macroinvertebrates (grass shrimp) and great blue herons had elevated levels of mercury, and herons had high zinc levels. Fish from all three lakes had low levels of DDE according to National Academy of Science standards. One fish from Lake O the Pines had PCB in excess of the predatory protection level recommended by the Great Lakes International Joint Commission.

Hubbs, C. 2002. A Preliminary Checklist of the Fishes of Caddo Lake in Northeast Texas. Texas Journal of Science 54: 111-124.

Based upon both historical records and recent collections, a total of 86 species of fish in 19 families are reported from Caddo Lake in northeast Texas. A large fraction of these are both native and essentially freshwater species; only four are introduced (*Cyprinus carpio, Morone chrysops, M. saxatilis* and *Stizostedion vitreum*) and only two migrate from estuaries (*Alosa crysochloris* and *Angulila rostrata*). This diversity represents more than half of the native nonestuarine species known from Texas. Seventeen additional species which are expected to occur in Caddo Lake are also reported. The fish diversity of Caddo Lake is compared with other regions of North America.

Texas Game and Fish Commission. 1955. Inventory of the species present in Caddo Lake, Job Completion Report, Texas Project No. F-3-R-2, Job B-1.

This report summarizes findings from fish surveys in CL from December 1, 1953 to May 31, 1955. Fishes were collected using gillnets (4 locations), hoop and fyke nets (4 locations), and a seine net (5 locations). Due to the presence of heavy vegetation cover, only five sites were surveyed with the seine net. The gillnets, hoop nets, and fyke nets yielded 5,241individuals, and 1,057 of these were dissected for stomach contents analysis (findings appear in Table 15). The seine surveys yielded 8,953 individuals from 50 species and 12 families. Overall, the survey yielded 69 species from 16 families (checklist in Table 16). Water quality and temperature data are presented for each survey site and date.

Texas Game Fish and Oyster Commission. Quarterly Report for the Period Ending July 31, 1950. (Robert J. Kemp, Jr.)

This document reports results from a survey conducted at 4 locations along the shoreline of Caddo Lake (seine samples). Thirty-one fish species were collected, and it was noted that fingerling largemouth bass were taken in each collection. Almost every seine haul also produced abundance freshwater shrimp.

Texas Game and Fish Commission. 1954. Check on Commercial Catch of Rough Fish

from Caddo Lake, Job Completion Report, Texas Project No. F-3-R-2, Job B-3. (Charles E. Gray)

This document reports findings from a survey of commercial fishermen and the principal buyer on Caddo Lake during the period Nov. 1, 1953- Oct. 31, 1954. The objective of the study was to determine the effectiveness of commercial fishing to control rough and predaceous species, and to assess the value of the fishery and the relative abundances of species caught in this fishery. Buffalo were the most abundant species in the fisher (41.7 % of catch by weight). It was noted that most commercial fishermen throw the undervalued rough fish species (gar, shad) into the lake immediately after removing them from their nets, so true catch figures are underreported. Perhaps of greatest interest to us is the fact that paddlefish were collected during half of the months of the survey. The average retail market price of paddlefish ($0.15 per pound undressed) was the lowest among the 7 commercial species reported (others ranged from $0.25 to $0.40).

Texas Game and Fish Commission. 1954. Inventory of species present and their distribution in those portions of Little Cypress, Cypress, and Black Cypress bayous which lie with Marion County, Texas. Texas Project No. F-3-R-1, Job B-5. (Robert J. Kemp, Jr.)

This study was performed to determine the distribution of species, their relative abundances, and the ecological factors influencing their distributions. A total of 96 collections were made at size locations: 35 collections were made with a bag seine, and the others were made with hoop nets with 1, 2, and 3-inch mesh. Problems with equipment prevented some seine collections and environmental data from being obtained. 64 fish species were collected, with 20 of these found in all three bayous. Black Cypress Bayou had the most species (46) and Little Cypress had the least (38). Seining yielded 55 species, with *Notropis amabilis* being most abundant (yet completely absent from Black Cypress). Cyprinids made up 55% of the seine collections. Hoop nets yielded 18 species. Table 1 is a checklist of species collected from the 3 bayous.

Texas Game and Fish Commission. 1956. Basic survey and inventory of species present and their distribution in the Cypress Creek drainage in Region 2-B. Texas Project No. F-8-R-3, Job B-11. (E.W. Bonn and C.R. Inman)

At total of 254 collections was made at 67 locations in the lakes, sloughs, bayous, and creeks of Cypress Creek drainage in Region 2-B. This region includes Lone Star Lake in southern Morris County, all of Camp County, and the southern half of Franklin, Titus, and Cass counties. The area covers ca. 1,450 square miles. The general direction of flow of the upper Cypress is southeast into Caddo Lake. Fishes were collected using a seine, gillnets, and a rotenone cove sample. Table 3 lists the species and their general abundances in Lone Star Lake (42 species) and in the Cypress drainage (57 species). It was noted that five species known to be common in the region were not collected during the survey (buffalo, carpsucker, Mississippi silversides, white bass, and alligator gar). Stomach contents from 170 individual gamefish were analyzed (results in Figure 2). Weight, length, and condition (K) of 557 specimens from Lone Star Lake

were measured. Black crappie were more abundant and in better condition than white crappie in this lake.

Texas Parks and Wildlife Department (TPWD). 1960. Report of fisheries investigations: Resurvey of the major streams in Region 5-B. Federal Aid Project F-3-R-7, Job B-15. (John N. Dorchester)

Seining and hoop net collections were made on the Cypress bayous (Little Cypress, Cypress, Black Cypress) and seining collections were made on the Sabine River between June 1, 1959 and May 31, 1960. Two collection sites were visited on each of the Cypress bayous. It was determined that there were no major changes of either river. Cyprinids were the most commonly collected fishes. The most significant environmental change was creation of Lake O' the Pines during the period preceding this survey, but water chemistry remained similar to earlier assessments. A total of 31 fish species were collected from the 3 Cypress bayous, compared with 35 species that were collected in a prior seine survey of the area. Two species not collected before were taken during this survey (*Notropis volucellus, Percina caprodes*).

TPWD. 1963. Fisheries investigations and surveys of the waters of Region 3-B. Federal Aid Project F-3-R-10, Job B-18. (John N. Dorchester)

This document reports findings from netting trips made to 7 reservoirs, with Lake O' the Pines and Caddo Lake included among them. Fishes were collected with gillnets and bag seines (the latter used only in certain reservoirs). Water analysis included pH, alkalinity, chlorides, turbidity, and temperature. Lake O' the Pines was originally surveyed in 1958-59 after which the lake level was lowered to facilitate further construction. The lake was resurveyed in 1960, 1961, and 1962 (basis for this report). Table 8 (not included in my copy of the document) is a checklist of fish species collected during the four periods. Table 9 (included) shows the percentages (relative abundances) of species captured during the four survey periods. Black crappie showed an increase between 1961 and 1962. Largemouth bass and most rough-fish species showed decreases over the same period. The exception was the spotted gar, which increased. Water quality in the lake had not changed much. Excessive growth of submerged vegetation, especially in the upper reaches of the reservoir, was perceived as a major problem. The text summarizing Caddo Lake findings was missing from my copy, but Tables 20, 21, and 22 (the first two are incomplete in my copy) provide a species checklist, species numerical relative abundances and species biomass relative abundances, respectively. Rough fish outnumbered game fish in terms of numerical abundance and biomass during three periods (1953-55, 1961-62, 1962-63). No paddlefish or American eels were reported as captured.

TPWD. 1964. Fisheries investigations and surveys of the waters of Region 3-B. Federal Aid Project F-3-R-11, Job B-18 (Seg. 4). (John N. Dorchester)

This document reports findings from netting trips made during 1963 to 7 reservoirs, with Lake O' the Pines and Caddo Lake included among them. Fishes were collected with gillnets and bag seines (the latter used only in certain reservoirs). Water analysis included pH, alkalinity, chlorides, turbidity, and

temperature. Caddo Lake showed a decline in gamefish numbers relative to the previous annual survey. It was cautioned that survey numbers for Caddo Lake in 1963 might not be reliable (25 species captured) due to low water levels, lake of vegetation-free areas for sampling, and low efficiency of sampling. Abundance of gizzard shad was higher and black crappie abundance was lower in Lake O' the Pines in 1963. One new species record (*Etheostoma chlorosomum*) was added to the Lake O' the Pines checklist. All lakes had below normal water levels. Excessive submerged aquatic vegetation was perceived as a serious management problem in all 7 lakes.

TPWD. 1965. Fisheries investigations and surveys of the waters of Region 3-B. Federal Aid Project F-3-R-12, Job B-18. (John N. Dorchester)

This document reports findings from netting trips made during 1964 to portions of three rivers and six reservoirs, with Lake O' the Pines and Caddo Lake included among them. Fishes were collected with gillnets and bag seines. Water analysis included pH, alkalinity, chlorides, turbidity, and temperature. Sunfish and black bullhead abundance had increased in 1964 in Lake O' the Pines, and gizzard shad, black crappie and largemouth bass showed declines. The author expressed doubts that such limited sampling of a large reservoir could produce reliable abundance data, and noted that the lake supported an outstanding sport fishery for largemouth bass and black crappie. He recommended that annual fishery surveys comprised of limited effort be discontinued. It was noted that low flows in Big Cypress Bayou had resulted in excessive growth of aquatic vegetation in Caddo Lake. During the fall of 1964, heavy rains increased flow and turbidity substantially, and this was expected to control aquatic macrophytes and perhaps lead to improved fishing in the following year. Only 11 fish species were captured in the 1964 survey of Caddo Lake, which undoubtedly reflects poor sampling efficiency. The chestnut lamprey was collected for the first time during the 1964 survey.

TPWD. 1993. Survey Report for Caddo Lake, 1992. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R-20. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report summarizes current sportfish harvest regulations, stocking history, and findings from an electrofishing, gillnetting and frame netting survey of CL. Data were used to compute catch per unit effort (CPUE), proportional stock density (PSD), relative stock density (RSD), and relative weight (Wr). In addition, ages were determined (using otoliths) for largemouth bass, spotted bass, chain pickerel, white bass, yellow bass, white crappie, black crappie, redear sunfish, warmouth, bluefill sunfish, and channel catfish (spines used in place of otoliths for the latter). An aquatic vegetation survey also was conducted (a checklist of aquatic vegetation appears in Table 6). Various CPUE and size data are presented in tables and graphs. No interpretations are provided in the report, other than those that appear in Appendix A which states the management goals for largemouth bass (desire is to increase abundance of LMB 14 inches or longer by 1995) and crappie (to increase production and angler catch of quality-size crappie). Other goals are to control noxious aquatic vegetation (hyacinth) to

maintain fishing access, to increase fishing access (more parking at existing boat ramps), and to make management more efficient by coordinating efforts between TX and LA.

TPWD. 1994. Survey Report for Caddo Lake, 1993. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R-20. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report is the annual update that outlines TPWD efforts in Caddo Lake sport fish monitoring and management activities. This report adds creel survey findings. Two management objectives were retained from the previous annual report: to increase abundance of largemouth bass 14 inches or longer by 1995) and to control noxious aquatic vegetation (hyacinth) to maintain fishing access.

TPWD. 1996. Survey Report for Caddo Lake, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report is the annual update that outlines TPWD efforts in Caddo Lake sport fish monitoring and management activities. No creel survey was conducted in 1995. Four management objectives are stated: to increase abundance of quality-size largemouth bass, to control noxious aquatic vegetation (hyacinth) to maintain fishing access, to increase parking for fishing access at ramps, to develop an inter-jurisdictional cooperative management plan (TX-LA).

TPWD. 1999. Survey Report for Caddo Lake, 1998. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R-20. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report is the annual update that outlines TPWD efforts in Caddo Lake sport fish monitoring and management activities. Several trends were summarized. Forage species are shads, bluegill sunfish, and a variety of minnow species. Bluegill CPUE was lower in 1998, but there was still adequate prey to support predators. CPUE of chain pickerel declined “precipitously” in 1998, despite the fact that fishermen rarely target this species. Channel catfish CPUE was higher in 1998 than in 1992 and 1995 gillnet surveys. Flathead catfish CPUE was low just as in previous annual surveys. White bass CPUE was lower in 1998 than 1995. Like bluegill, redear sunfish showed reduced CPUE in 1998, but plenty of larger fish were available to support a fishery. The CPUE of largemouth bass declined in 1998 compared to earlier surveys (by approximately 50%). Most of this decline was for the largest size classes (> 8 inches). Angler catch and harvest rates in 1998 were similar to those in 1995. Florida largemouth bass have been stocked in recent years (since 1994), and a recent genetics survey indicated an average of 35.8% Florida strain alleles in the population. CPUE for black and white crappie were greater in 1998 than previous years. Declining CPUE of largemouth bass, sunfishes, and chain pickerel are the main concerns at CL. Unseasonably warm water temperatures, low water conditions, and/or changes in the sampling regime could have contributed to lower catches in 1998. Aquatic plants (especially *Hydrilla* and hyacinth) continue to be a major problem, with 95% of the lake’s surface covered annually. It was estimated that 50% of preferred fish habitat on the Texas side of the lake is lost annually to aquatic plants.

TPWD. 2002. Survey Report for Caddo Lake, 2001. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R-20. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report is the annual update that outlines TPWD efforts in Caddo Lake sport fish monitoring and management activities. Several trends were summarized. High densities of native and non-native plants continue to reduce preferred habitats for fishes during summer and fall. Shad and bluegill CPUE were lower compared to previous years, but the availability of these forage species was deemed adequate to support predatory fishes. The CPUE for chain pickerel was higher in 2001 compared to 1998, but this is lower than the 1995 CPUE. Aquatic plant and associated water quality problems may be responsible for the apparent decline in this species. Channel catfish CPUE was higher in 2001 than in previous gillnet surveys. Flathead catfish CPUE was low and similar to previous annual surveys. White bass CPUE has been consistent since 1989. The species is not particularly abundant in CL. Yellow bass are more abundant. Sunfish CPUE was lower in 2001 than in 1995 and 1998, but similar to level obtained in 1989. Electrofishing CPUE for largemouth bass has declined since 1997. It was felt that apparent reduced abundance of LMB was due to harvest by anglers (77% of anglers practice catch and release) and reduced water quality associated with aquatic plant encroachment. The aquatic plant problem has now become the major fishery management problem in Caddo Lake. In addition, there are concerns regarding reports of Mercury (Hg) in tissues of largemouth bass and freshwater drum from CL.

TPWD. 1996. Survey Report for Big Cypress River, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R-20. TPWD, Inland Fisheries Branch, District 3-A, Marshall.

This report summarizes current sportfish harvest regulations, stocking history, and findings from an electrofishing, gillnetting and hoopnetting survey of Big Cypress River conducted in 1995. Data were used to compute catch per unit effort (CPUE), population size structure, proportional stock density (PSD), relative stock density (RSD), and relative weight (Wr). The Cypress River is navigable approximately 5 river miles upstream of Lake O' the Pines and within the section below Lake O' the Pines to its confluence with Caddo Lake. Land uses in the watershed include agriculture, timber harvest, oil/gas production, and mining (clay, lignite, iron ore). Paddlefish have been stocked in Big Cypress River since 1993. The survey involved seining (14 sites), hoop nets (15 sites), and electrofishing (7 sites). A checklist of species captured (Table 4) shows 34 fish species and one hybrid sunfish. Apparently, no paddlefish were captured during the survey. Basic water quality data (Tables 9 and 10) and flow data (Table 11 and Figure 2) are presented. Base discharge was considered to be 2,500 cfs. Between October 1994 to September 1995, peak discharges that exceeded this base flow occurred on 8 occasions and varied from 3,310 to 25,300 cfs (USGS station 07344500). Two management objectives were stated: monitor pollution/habitat degradation in the watershed, and continue the paddlefish restoration program.

USFWS. 1993. Caddo Lake: A unique wetland ecosystem. USFWS, Arlington, TX, April 1993.

This report summarizes features of CL fish and wildlife resources and habitat that support them. It is motivated by federal Mitigation Policy that prevents or mitigates losses of 'habitat value' that can result from development activities. The report covers Caddo Lake from the dam/spillway upstream to the vicinity of Stumpy Lake west of Highway 43, and associated backwaters, sloughs and bottomland hardwood forests to an elevation of approximately 175 ft. msl. Habitat value is ranked according to 4 levels (highest in which no losses to value are acceptable to medium-low in which loss to value is to be minimized). Caddo Lake supports wildlife species, such as wood duck, barred owl, gray squirrel, beaver, and green heron, at near optimal values. This is largely due to excellent and abundant habitat, including mast-bearing hardwood forest and extensive bald cypress stands. The river otter population at CL may be the densest in Texas. The lake supports among the richest fish assemblages in the state, with abundant gamefish, such as largemouth bass, black and white crappie, and channel catfish. Habitat is deemed outstanding for these species. Other less-common species include the American eel and paddlefish, migratory species that have been impacted by dams. Many fish species are near the western edge of their geographic ranges at CL. TPWD has estimated that there are only a half dozen bald cypress-tupelo wetland sites remaining in Texas, and CL is the largest. At CL, these forests are being impacted by timber harvest, oil/gas production, and housing development. CL has at least 189 species of trees and shrubs, 42 woody vines, 75 grasses, and 802 additional herbaceous plants. Of these, 48 are found in hardwood bottomlands, some even being restricted there. Bald cypress cannot regenerate on a flooded substrate, and seedlings do not tolerate prolonged submergence. The study by Klimas (1987) concludes that bald cypress can persist during changes in hydrological regimes, but growth, reproduction, and survival depend on frequency of substrate exposure to air. Under the current operating regime (water level stabilized at 168.5 ft msl), there is little bald cypress regeneration. This stabilization also has restricted establishment of many hardwood species that are unable to tolerate frequently flooded sites, because soil in the periphery of the lake is saturated with moisture or flooded during the growing season. Without some ability to control water level, it would be impossible to replace or restore impacted forested wetlands. The report appendix contains a list of rare species with their Nature Conservancy, TPWD, and TOES rankings.

USFWS. 1993. Waterfowl Technical Appendix for the Red River Waterway Shreveport to Daingerfield Reach Evaluation Study, USFWS, Atlanta, May 1993.

This report was submitted to the USACE-Vicksburg. The executive summary of this report discusses potential loss of migratory waterfowl habitat associated with barge alternative navigation channels in the Cypress Basin of east Texas and western Louisiana. A project authorized in 1989 provided for 76 miles of navigation channel, ca. 9 ft. deep and 200 ft. wide, with locks located at Caddo Lake and Lake O' the Pines and in the vicinity of Jefferson, TX. At least 18 stream bendways, containing 14 miles of natural stream channel, would be cut off

by the navigation channel. In 1992, the USACE stated in its Reevaluation Study that the project was neither economically nor environmentally feasible. Extension of navigation was deemed to have negative impacts on aquatic and terrestrial habitat in the project area. The Reevaluation Study proposed alternative projects. Under study in 1993 was the four barge alternative plan that would following existing water courses and channel construction through the Goose Prairie portion of CL. The report estimates wetland distribution and extent, summarizes population trends for waterfowl (1955-1991), summarizes some information on waterfowl ecology, estimates impacts of the project to waterfowl based on habitat productivity, food availability, and caloric requirements of ducks (i.e., decrease in available foraging habitat and duck-days for individual reaches). It is concluded that the proposed four barge navigation channel would result in severe adverse impacts to wintering migratory waterfowl, both on private and public lands.

Appendix 6 of the Reevaluation Study summarizes potential impacts on aquatic resources. Ecological guilds were constructed for the known ichthyofauna based on spawning and velocity preferences of individual fish species (summarized in Table 6-1). This table provided the basis for selecting evaluation species, but commercial and recreation importance, sensitivity to environmental disturbances, and availability of existing habitat models also were factors. The fish guilds were derived from categories along two dimensions: preferred velocity (swift water, slack water, generalist) and spawning substrate (open water, sand and gravel, vegetation, crevice). The study area for this assessment was from the mouth of Twelvemile Bayou to the upper reaches of Lake O' the Pines. Five evaluation species were selected for a reservoir impact analysis: spotted gar, threadfin shad, channel catfish, bluegill sunfish, and largemouth bass (the 5 species represent 4 ecological guilds that contain 34 species). Habitat models (miltiple regression models) were developed from field data reported in Ploskey et al. (1986). Independent variables were Secchi depth, nitrogen, phosphorus, growing season, alkalinity, chlorophyll a, and storage ratio. The analysis concluded that because no longterm project-related changes in water quality were anticipated, changes in fish habitat were undetectable. Eight evaluation species were chosen for the stream impact analysis: pickerels, blacktail shiner, ironcolor shiner, spotted sucker, flathead catfish, spotted bass, bluntnose darter, and blackside darter. These species represent 5 ecological guilds containing 56 species. Data for fish-habitat models were taken from a variety of literature sources. New field data were collected from 21 stations during April-August 1992. Fishes were collected with a seine (10 hauls through each habitat). In habitats > 6 ft. deep, gillnets were set overnight to sample fishes. The instream flow incremental methodology (IFIM) was used to project changes in habitat with changes in hydrology (Bovee 1982). The flow for 1985 was considered a typical water year in the region (near median discharge). Physical habitat for these fish species was simulated under a wide range of discharges in upper Big Cypress Bayou (5-5,000 cfs), lower Big Cypress Bayou (5-8,000 cfs), and Twelvemile Bayou (900-36,000 cfs). Suitability indices (S) for floodplains were created for 7 species as SI=(mean relative abundance in reach)/(mean relative abundance in system + one standard deviation). Several assumptions are

stated (e.g., all species use floodplain habitat). In general, high SI values were obtained for most species in slow, shallow water with cover. Tables present estimates of fish habitat losses under post-project conditions, and mitigation requirements are discussed. The report contains with a multiple regressioin analysis of stream fish habitat (independent variables include turbidity, velocity, temperature, conductivity, dissolved oxygen, width, and depth). The report concludes that habitat losses in the reservoir are not anticipated (0 acres), habitat losses in the streams will be minimal (0 acres), but habitat losses in floodplains will be substantial (3,646 acres) from the navigation project.

Invertebrate Community

Department of Commerce Bureau of Fisheries. 1913. The Mussel fisheries of Caddo Lake and the Cypress and Sulphur Rivers of Texas Louisiana. Economic Circular No 6.

Howells, Robert G. 1996. Preliminary Survey of freshwater Mussels of the Big Cypress Bayou System, Texas. Texas Parks & Wildlife Department, Ingram, Texas, July 1996. http://clidata.org/reports.htm.

This document summarizes distribution of 22 mussel taxa in the Cyprus Bayou System. In 1992, several taxa of mussel existed in Caddo Lake with harvesting by locals. While many taxa are still found and widely distributed, alteration of habitat has resulted in a decline of populations (no data was shown to support this). Suggested deleterious activities in the watershed included oil drilling (a 1913 report) and chicken farming, which needs to be investigated.

Howells, R. G. 1999. Distributional surveys of freshwater bivalves in Texas: Progress report for 1998. Management data series No 161. Texas Parks and Wildlife.

Mather, C. M. and J. A. Bergmann. 1994. Freshwater mussels of the Cypress Bayou system, Northeast Texas. Malacology Data Net 33 (5/6): 139-145.

Reynolds, E. K. 1989. The zooplankton community of Lake O' the Pines Reservoir, TX. M.S. Thesis Stephen F. Austin State University.

This study focuses on Lake O' The Pines, not Caddo Lake. The dominant species of rotifer, copepods and cladocera indicate this lake to be eutrophic. Zooplankton standing crop is higher than other lakes in east Texas. Rotifers dominated the zooplankton density. The maximum zooplankton density occurred in April and the minimum zooplankton density occurred in June. Low zooplankton densities in the headwaters of this lake might be due to metal toxicity.

U.S. Army Corps of Engineers. 1992. Mussel Survey. Red River Waterway Project Shreveport, LA, to Daingerfield, TX, Reach Reevaluation Study In-Progress Review. http://clidata.org/reports.htm).

This survey reports on mussel populations found along Lake O' The Pines, Big Cyprus Bayou, and Caddo Lake. The Shreveport,LA, to Daingerfield,TX, reach of the Red River Waterway Project begins upstream of Shreveport, LA, with an overland channel to Twelvemile Bayou and continues through Caddo Lake and Cypress Bayou, ending in Lake O' The Pines near Daingerfield, TX. The project includes three locks and one additional dam connected by a 9- by 200-foot

navigation channel. This 1992 survey was conducted because of concerns that construction and maintenance of this reach of the Red River Waterway project could have a negative impact on the native freshwater mussel communities. Twenty-one species plus the Asian clam *C. fluminea* were collected and identified. *Plectomerus dombevanus* was the most frequently encountered species, followed by *Corbicula fluminea,* and *Lampsilis teres.* With the exception of site 32 on Twelvemile Bayou, the study area did not support dense and diverse beds of freshwater mussels such as those usually found in gravel shoals in large rivers of the central United States. No evidence of low water quality that could negatively affected freshwater bivalves was observed, although it is likely that commercial shell fishermen have affected the resource in some areas. No uncommon or endangered species were found. Although the fauna is sparse,it can be characterized as healthy, with good species richness.

Venneman, T.E. 1984. The Zooplankton Community of Caddo Lake Texas and Louisiana, a Lake with Numerous Offshore Oil Wells. M.S. Thesis. Stephen F. Austin State, University: Nacogdoches, Texas.

The zooplankton community was found to be diverse, but the dominant zooplankton species in Caddo Lake are representaive of eutrophic conditions. Generally, zooplankton species of of smaller body size, possibly due to the lake being very shallow, therefore no refuge from grazing prevents heavy losses to zooplanktivorous fish. Species present seemed to be cosmopolitan. The broad niche tolerances may be due to rapidly changing physicochemical conditions in the lake. Higher conductivities in the oil-producing region (spilled brine water) might be responsible for the lower zooplankton densities found there.

WETLAND VEGETATION

This section provides summaries of available published and unpublished information on the swamp vegetation communities found in the greater Caddo Lake area. These communities are typically broken down into baldcypress and bottomland hardwood. The former is dominated by *Taxodium distichum* and occupies the lower elevation areas with longer periods of inundation. The latter community type includes hardwood species such as *Nyssa aquatica* and *Nyssa sylvatica* that are generally found in higher elevation areas of the bottomland and exposed to shorter periods of inundation. There are varying degrees of overlap in these swamp forest communities.

These communities are valued for their aesthetic qualities, the habitat they offer to fish and wildlife, as well as their contributions to water quality maintenance. Their dispersal and productivity are both intricately tied to the hydrology of Caddo Lake. Studies in this wetland system, as well as other similar wetlands, indicate that periodic drawdown is necessary for the regeneration of these forests. This is especially true for the baldcypress community that requires sufficient drawdown for seedling establishment. The results of a few of these studies also indicate that a “natural” hydrology (i.e. a pattern of seasonal pulsing of inflows and fluctuating water levels) stimulates production in these

forests in comparison to static conditions—conditions often found in managed water bodies.

Campo, J. J. 1986. The Big Cypress wildlife unit. A characterization of habitat and wildlife. Wildlife Division Texas Parks and Wildlife Department.

This report is one of a series that describes vegetation cover, land-use, and the plant and animal species of TX wildlife units. Appended to it are species lists of plants and animals discussed in the report and those that can be found throughout the Big Cypress Unit (BCU). It also gives detailed geographic descriptions of the location, topography & physiography, geology & soils, and climate of the BCU. Similar to the Changxiang et al. report, it uses 9 primary land cover classes (with a few subclasses for some), but seems to be more upland focused in that it has 4 upland forest categories (3 of which include pine associations). Using much more advanced techniques, Changxiang et al. (1992) only identified two pine associations (pure pine and pine-hardwood). 2 classes in Campo's report are lumped under the bottomland hardwood forest group. These include mixed hardwood bottomland forest and a bald cypress swamp/flooded hardwood forest category. The latter subclass, he mentions, is primarily limited to Caddo Lake. Each class/subclass also includes a description and location in the watershed.

The latter half of the report is devoted to important and common wildlife and fish species in BCU, including descriptions of their status and habitat requirements. Waterfowl occurring along stream prefer acorns and seeds, but these are variable from one year to the next. In open water reservoir areas, aquatic vegetation is the most important food source for waterfowl. However, water drawdown in the winter does not allow for the establishment of suitable food and cover for these organisms. As of the writing of this report, 6 species were considered endangered: the bald eagle, red-cockaded woodpecker, arctic peregrine falcon, interior least tern, shovelnose sturgeon, and paddlefish. 14 other species were considered threatened or protected and are described in the report.

Most of the land use effects on wildlife described pertain to upland areas; however, projected water resource needs and the impacts of possible measures to offset these needs are considered. In short, creating more open water area will result in significant loss of bottomland habitat for things like the American alligator, wood duck, and numerous other species that use these areas. The Caddo Lake system is considered both sensitive and unique (equates to rare?) and is dependent on adequate flows and periodic flooding (reflecting results of numerous past studies). Flood control and reservoir construction have the greatest impact on this area.

Changxiang, L J., Neal, A., Scofield, C., Chang, J., ludeke, A.K., and Frentress, C. 1992. Classification of land cover and assessment of forested wetlands in the Cypress Creek Watershed. Texas Parks & Wildlife Department, Austin, Texas. http://www.tpwd.state.tx.us/texaswater/sb1/terrestr/caddo/cypress_cr.phtml?print=true

This on-line report provides results of an image analysis/GIS study to classify wetlands and other land cover types in the Cypress Creek watershed.

They used ERDAS Imagine and principal components analyses to classify 14 land cover types that are described in depth in the report text. Groundtruthing of the site was done in 1996. Due to variance in GPS readings (10 m resolution), they went with a minimal patch size of 1 hectare (4X4 pixels).

There are three lakes in the watershed (Caddo Lake, Lake O' the Pines, and Lake Bob Sandlin). The western third of the watershed is mainly pasture. In the central region, mixed pine-oak and oak-hickory dominate. Bald cypress swamps and bottomland hardwoods dominate in the eastern third, which are mostly floodplain and shallow water systems.

Comparing their findings to a set of images shot in the early 1970s, they found that there has been a 33.9% reduction in the acreage of bottomland hardwood forests. This coincided with an increase in water bodies (e.g. Lake Bob Sandlin) and may also be the result of logging activity. There has also been a decline (8.3% drop) in pasture (perhaps conversion to forest) in this watershed.

Lastly, this HTML document has four linked PDF maps that illustrate a 3-D perspective of the watershed and land cover types, as well as figures showing more detail with regard to the eastern and western halves of the watershed.

EPA. 2004. Longhorn Army Ammunition Plant. EPA ID# TX6213820529.

This report provides an overview of the environmental assessment of the Longhorn Army Ammunition Plant (LAAP) and the adjacent lands that have been turned over to the USFWS as part of the Caddo Lake National Wildlife Refuge. It gives a general site description (location, population, setting, and hydrology) in addition to principal pollutants for this area. Methyl chloride and trichloroethylene seem to be the most significant problems; however other groundwater contaminants such as perchlorate, trinitrobenzene, and dichloromethane and soil/sediment contaminants such as dinitrotoluene and trinitrotoluene (TNT). This is of direct concern to Caddo Lake in that all water from these lands drains into Caddo Lake PLUS they are in the 100-yr floodplain of Caddo Lake. In a description of the present status and issues, the document claims that the LAAP does not pose an immediate threat to the public or the environment.

Keeland, B. D. 1996. Effects of flooding and herbivory on baldcypress seedlings planted at Caddo Lake, TX: first year results. Consortium for restoration on southern forested wetlands proceedings of the southern forested wetlands ecol and manag conf, Clemson, SC. Pg. 44 (5).

This appeared in a conference proceedings and reflected the first year of results from a study looking at inundation and herbivory effects on cypress seedling establishment. The study was conducted on the Longhorn Army Ammunition Plant in the Goose Prairie area of Caddo Lake. 567, 1-yr old seedlings were planted in each of three areas: upland (rarely inundated; 182 seedlings), periodically flooded (0-25 cm; 185 seedlings), and permanently flooded (20-75 cm; 200 seedlings). Half of all seedlings in each area were protected from herbivory with plastic tree shelters.

No herbivory was noticed under the flooded treatments, indicating that flooded or periodically flooded seedlings may be better protected from herbivores. Overall survival after 1 year was 61%. The periodically flooded area

had the greatest survival (>90%). Upland seedling survival ranged from 35-42%. Permanently flooded seedlings had survival rates of 42-55%. 48% of the unprotected seedlings were missing in the permanently inundated areas.

Growth rates in upland and periodically flooded areas were significantly greater than in permanently flooded areas. The upland growth rates were not expected and could not be explained, but combined with high mortality, periodically flooded areas did best overall. Lastly, protected plants grew faster than unprotected plants in each area. This has been documented by several others and is likely due to greenhouse effect that increases temperature, moisture, and CO2 around the seedling.

Keeland, B. D. and Conner, W.H. 1999. Natural regeneration and growth of *Taxodium distichum* (L.) Rich. In lake Chicot, Louisiana after 44 years of flooding. Wetlands 19(1): 149-155.

Lake Chicot is an 800 ha constructed lake near Ville Platte, LA. Before this area was impounded (in 1943), species such as N. aquatica, N. sylvatica, T. distichum, Cephalanthus occidentalis, Salix nigra, Planera aquatica, and Gleditsia aquatica were common as a result of spring flooding and summer drawdown along Chicot Bayou. Logging removed most of the trees before flooding and extended flooding thereafter kept most species from re-establishing, as high water during the re-generation period kept seedlings from establishing.

Immediately after drawdown, seven woody species became established, with T. distichum being the dominant. C. occidentalis and S. nigra were the next most abundant. Few N. aquatica were found, which was surprising due to the abundance of this species before the impoundment was constructed. This trend continued through the 1992 and 1996 samplings, except that more N. aquatica appeared in the plots. Another noteworthy finding was that there was essentially no under story development in the mature forest. The extent of the sapling coverage ended where the mature forest began. This phenomenon was unexplained.

They reiterated that T. distichum regenerates well during periods of low water that allow them to grow enough vertically to get photosynthetic tissues above the water during the growing season. Good seed crop from the previous growing season and little competition from other species are also key to successful bald cypress regeneration. Lastly, in situations where water levels are managed, draw downs need to be of sufficient length (a few weeks to a few months) to allow for seedling establishment and maximum water levels should not exceed average seedling height in order to have regeneration success.

Keeland, B. D. and Sharitz, R. R. 1995. Seasonal growth patterns of *Nyssa aquatica*, and *Taxodium distichum* as affected by hydrologic regime. Canadian Journal of Forest Restoration: 25: 1084-1095.

This study is similar to most others that Keeland is lead or co-author on. It addresses the importance of hydrologic regime in affecting seasonal growth rates of canopy and subcanopy forms of important bottomland woody species like N. aquatica, N. sylvatica, and T. distichum. Like other papers dealing with these issues, their findings have important implications with regard to growth responses to hydrologic change.

Water level, temperature, and precipitation were tracked and used to correlate with seasonal growth that was measured using dendrometer bands. The initiation of the growing season was identified as the first week of sustained growth that persists for at least 3 weeks. Few trees died during the study, but many showed no net growth. The latter seemed tied to species and specific sites. Canopy trees seemed more sensitive to the hydrologic gradient than subcanopy for all species. N. sylvatica occurred at the drier end of the spectrum and N. aquatica at the wetter end. T. distichum occupied the entire range of sites.

Where it occurred (i.e. at the drier end of the spectrum), N. sylvatica seemed least sensitive to changes in water levels. N. aquatica grew best under conditions of deep periodic flooding. T. distichum grew most in shallowly flooded sites, regardless of duration. The authors suggest that depth of flooding may be more important than duration in controlling growth of this species.

They reference models SWAMP and FORFLO by Phipps (1979; Ecological Modeling) and Pearlstine et al. (1985; Ecological Modeling) in which growth and reductions in growth are predicted relative to species-specific optimum growth curves measured in the field. They seem to agree with Pearlstine's optimum range of periodic flooding for T. distichum as being between 0.15 m below the surface to 1.2 m above the soil surface.

Keeland, B. D., Conner, W. H., and Sharitz, R. R. 1997. A comparison of wetland tree growth response to hydrologic regime in Louisiana and South Carolina. Forest Ecology and Management. 90: 237-250.

The authors reiterate the importance of flood duration and frequency in controlling species composition in forested wetlands. Work by Ariel Lugo and other also indicate that these factors are also critical in controlling forest structure and productivity in these wetlands. In this study, Keeland et al. look at the importance of hydrologic regime in controlling tree growth in different regions (ultimately 7 sites in coastal LA and 5 sites in coastal SC) and within each region, across hydrologic gradients.

Water levels (above and belowground), precipitation, and ET were measured at each site every week. Weekly DBH measurements were taken with dendrometer bands. LA growing season began in early May, a few weeks before most trees in SC initiated growth. In LA, N. aquatica stopped growing earliest and T. distichum ceased its growth later than all other species. Also, T. distichum showed greater growth at LA sites than SC sites. Overall, it appeared that the growing season was longer in LA than in SC.

In LA, there were no differences in N. sylvatica growth across a hydrologic gradient. N. aquatica varied across this gradient in LA, but was not related with mean growing season water levels. These characteristics for both species may have been an artifact of small sample sizes. T. distichum showed greater diameter growth with higher water levels in LA. In LA, much of this growth seemed to take place during the latter part of this growth phase. Growth curves of T. distichum in LA indicated less growth in permanently flooded areas than in periodically flooded areas.

Keeland, B. D. and Sharitz, R. R. 1997. The effects of water level fluctuations on weekly

tree growth in a southeastern USA swamp. American Journal of Botany 84(1): 131-139**.**

The objectives of this study were to: 1) determine the relationship between local water balance (rainfall minus ET) and growth (DBH) of Taxodium distichum, Nyssa sylvatica, and Nyssa aquatica; and 2) determine the pattern of these relationships across hydrologic gradients near Aiken, SC. Four study sites were chosen to represent a range of hydrologic conditions: RI (riverine, infrequent flooding), RS (riverine, periodic shallow flooding), RD (riverine, deep flooding), and BS (backwater, shallow permanent flooding). The modeling technique used (transfer function modeling) enabled them to describe the relationship between two time-series (weekly growth and weekly water balance).

The infrequently and periodically flooded sites (RI and RS) showed significant cross-correlations between water level and tree growth changes for N. sylvatica and T. distichum. Some reduced growth at these sites was attributable to re-structuring of roots as inundation patterns change. Maximum growth occurred in permanently flooded or saturated sites. Changes in water balance proved more important than changes in water level across a hydrologic gradient in terms of its cross-correlation with tree growth.

Keeland, B. D. and Young, P. J. 1997. Long-term growth trends of baldcypress (Taxodium distichum (L.) Rich.) at Caddo Lake, Texas. Wetlands 17(4): 559-566.

The overall conclusion of the study--as stated at the end of the abstract--is that water management (i.e. stabilization) has not resulted in an overall decline in baldcypress growth. However, evidence would suggest that stable water levels have resulted in little or no regeneration over the period of water management. Even during this study, no recruitment was observed. Five randomly sites were selected for this study, including two backwater sites (Pine Island Pond and Saw Mill Pond), a site located along a boat road through a former backwater area (Mossy Break) and two riverine sites located in old stream channels (Willowson Woodyard and Goat Island). These sites were all dominated by bald cypress. A control site at Pruitt Lake was established as an area that has not undergone the same level of water management as Caddo Lake.

Goat Island trees were the youngest, averaging 62 years, and possibly established during a drought after the dam had already been constructed. Some trees were older than 240 years, predating the original formation of the lake. Overall, T. distichum stands seem even-aged and a result of past changes in lake water levels (pre-raft/post-raft/post-dam) or as a result of inter-annual climatic variability (i.e. drought).

Key, Jennifer S. 1997. The Hydrologic and Biogeochemical Functions of 5 East Texas Bottomland Hardwood Wetlands using the U.S. Corps of Engineers Hydrogeomorphic Assessment Technique. Graduate Thesis, MS, Forestry, Stephen F. Austin State University, Nacogdoches, Texas. August 1997.

Five bottomland hardwood wetland sites in East Texas were selected for the purpose of assessing their functional characteristics using the United States Corps of Engineer's guidebook for the application of Hydrogeomorphic assessments to riverine wetlands. Functions assessed were: dynamic surface

water storage, removal of imported elements and compounds, organic carbon export, retention of particulates, and nutrient cycling. The assessment technique requires the selection of a normal or above normal functioning wetland, otherwise known as reference wetland. The reference wetland chosen was Harrison Bayou, which is located within the Longhorn Army Ammunition Plant, Karnack, Texas. Harrison Bayou was selected for use as reference wetland due to its undisturbed nature. The functional characteristics of the four target wetlands were compared (Big Cypress Bayou, Black Cypress Bayou, Cherokee Ridge, and Alazan Bayou) were compared against the functional characteristics found in Harrison Bayou. A Geographic Information System database was developed to give a visual relationship between function level and landscape position. Due to variation in flooding regimes between wetlands, Harrison bayou was determined to be an inappropriate reference. Three of the four target wetland sites had higher frequencies of flood events than the reference wetland, resulting in lower indices of function for those wetlands that actually functioned at a higher level. When more appropriate reference wetlands were used, estimations of function capacity were different and more accurate.

King, S L. and Keeland, B. D., 1999. Evaluation of reforestation in the lower Mississippi River alluvial valley. Restoration Ecology 7(4): 348-359.

Bottomland hardwood loss in the LMAV has been extensive over the past century as a result of drainage, conversion, and timber harvesting. Over the past few decades, there has been significant effort made to reforest and restore many of these original bottomland hardwood areas. The authors state that, to date, there has been no comprehensive survey of reforestation efforts in the LMAV, hence the need for this study. This paper does not directly pertain to Caddo Lake, but it does point to the importance of hydrologic restoration in ensuring long-term success of reforested or restored bottomland areas.

Sheffield, W.J. 1995. A summer-fall ecological reconnaissance of the Big Cypress Bayou watershed, Texas and Louisiana. Texas Parks and Wildlife Department, Austin, Texas.

During June-October 1994, an ecological survey of Big Cypress Bayou watershed was conducted (4,000 square miles, or 67% of the watershed was traversed). The purpose was to facilitate Army Corps of Engineers cover mapping and to provide ecological information for a comprehensive database for natural resource planning. Five land types, 18 cover types, 2 sub-types were identified. Five plant communities were considered in decline and in need of special attention, and two unique plant communities were identified. Vegetation diversity received strong emphasis in this study. The more structurally diverse and species-rich vegetation communities (e.g. waterbodies, hardwood forests, pine-hardwood uplands) supported greater numbers of animal species. Several conservation and restoration needs were discussed.

Tracy, Boyd D. 1997. The Planning Level Plant Community and Wetland Identification of Harrison Bayou within the boundaries of Longhorn Army Ammunition Plant, TX. Graduate Student Thesis for Degree of MS Forestry. Stephen F. Austin State University, Nacogdoches, Texas. May 1997.

Harrison Bayou is a unique remnant of the bottomland hardwood plant communities that once existed in the pre-settlement Caddo Lake region. This project focuses on Harrison Bayou within the confines of Longhorn Army Ammunition Plant (LHAAP) at Karnack, Texas. The project objectives were to identify and delineate major plant communities of Harrison Bayou and to identify which of these communities meet the requirements of a wetland according to the procedures outlined in the 1987 U. S. Corps of Engineers wetland delineation manual. Satellite imagery, aerial photos, and area maps have been utilized to create a GIS database. Classification routines were performed on this database, which identified and tentatively delineated the major vegetative communities within the study area. This delineation was used as the basis for sampling of the area. The sampling resulted in the identification of eleven community types in Harrison Bayou, six of which (51.25% of the total area) were identified as " wetland community types". The results of the plant community and wetland identification were entered into the GIS database and made available to assist the LHAAP administration in managing this unique and precious natural resource of the East Texas region.

U.S. Fish and Wildlife Service. 2000. Final environmental assessment for proposed establishment of the Caddo Lake National Wildlife Refuge through management agreement or transfer of Longhorn Army Ammunition Plant from the Department of the Army to the Department of the Interior, U.S. Fish and Wildlife Service: Harrison County, TX.

This is a copy of a final environmental assessment of the Longhorn Army Ammunition Plant (LAAP, 8500 acres in size) in order for it to be transferred over to the National Wildlife Refuge System (USFWS; Interior Department) from the Department of the Army. This will ultimately turn all jurisdictional responsibilities and resource management and conservation over to USFWS. The document provides a description of the location and purpose of the proposed refuge. It also includes responsibilities of each agency in terms of transfer, remediation, cleanup and acceptance of lands.

The document includes a section on the affected environment, which contains detailed information on the geology, climate, environmental condition (water and air quality), and biological resources of the LAAP lands. (There are clearly some human health concerns to be addressed, especially with respect to surface and groundwater contaminants.). 11 plant community types found within the LAAP are included and described, as are animal species of concern. There are also an extended sections on the archaeology and history of this area--up through its current status.

Appended to this document are things such as the MOA for establishment of the refuge, federal laws pertaining to protection of biological resources in LAAP lands, and a MOA between the Dept. of Army and Caddo Lake Institute for proposed lease of a portion of LAAP lands.

Van Kley, J.E. and D.N. Hines. 1998. The Wetland Vegetation of Caddo Lake. Texas Journal of Science 50:267-290.

This paper provides a nice history of Caddo Lake and review of studies done on hydrological and geomorphological controls on bottomland/swamp

vegetation. It also provides a nice classification scheme for herbaceous and woody vegetation communities at Caddo Lake.

The data for this study were collected along replicate transects, using a nested plot sampling design (large trees measured in large plots, smaller trees in medium-sized plots, and small, herbaceous plants in the smallest plots). Water level was measured at each site and tied to a water gauge with a level and sighting stick to allow for estimations of water level fluctuation at each site according to the gauge data. Aerial photographs were also used to identify distinct communities, and were used to corroborate with communities and zonation patterns identified in the field.

The first DCA axis (with r-squared of 0.74 and $p < 0.01$) based on the occurrence of ground layer species was strongly correlated with water levels at the plots. TWINSPAN separated these into 5 distinct groups (described in the abstract). The first DCA axis (with r-squared of 0.84 and $p < 0.01$) based on the log-transformed density of overstory trees was strongly correlated with water levels at the plots. TWINSPAN also separated these into 5 distinct groups (described in the abstract). The abundance ranks of overstory tree species showed a similar relationship to that of ground layer species.

They go on to describe each of the 6 community types identified using these field and remote sampling techniques, the species that make up them, and the general hydrologic conditions.

Walker, L. C., Brantley, T., Burkett, V. R. 1998. Characterization of an old-growth bottomland hardwood forest in northeast Texas; Harrison Bayou. pp 98-109, in: Wilderness and natural areas in Eastern North America: research, management, and planning.

This is a report of two surveys conducted in 1977 and 1993 to assess the vegetation structure and wildlife in the Longhorn Army Ammunition Plant (LAAP) lands along Harrison Bayou. The findings indicate no significant change overt the period of these records, but it does reveal some interesting facts about the wetland forest in this area. First, the report provides a nice history of the lake and LAAP lands, including information on hydrology, soils, climate, and archaeology. Apparently some of Harrison Bayou was subjected to cutting of old-growth forest between 1900 and 1941, but some virgin stands still remain. Water levels in Harrison Bayou are a function of Caddo Lake levels. Even with the dam, evidence indicates that Caddo Lake levels were up to 2 meters higher in its early, “natural” state.

The report describes the two main forest types in the Harrison Bayou area: bottomland hardwood forest (BLH)—which occupy the “higher” elevation areas that grade away from the stream edge—and baldcypress forest—a pioneer forest that develops in saturated soils, but can withstand extended periods of deep flooding at the adult phase. The report indicates two important pieces of information. First, that some BLH areas containing isolated (likely older baldcypress) individuals have likely experienced changes in hydrologic regimes. In other words, where conditions were once suitable for baldcypress establishment and growth, they are now relatively drier (i.e. shallower depth and more frequent soil exposure) and more suitable for BLH. The other important

piece of information presented is that baldcypress is essentially a pioneer species in that it establishes following a hydrologic disturbance (i.e. when water levels change dramatically)—in this case a drawdown. Although it can survive and persist under relatively stable conditions of flooding, it is a poor at the persistent, shallow water end of the hydrologic spectrum yet requires drawdown for establishment.

The report also covers some of the various biological controls (beavers, swamp rabbits, tent caterpillar, fungus, etc.) on baldcypress establishment and development; however, it appears that hydrology and other abiotic factors exert the greatest control on the success of this species at Harrison Bayou.

Young, P. J., B. D. Keeland, and R. R. Sharitz. 1995. Growth-response of baldcypress (Taxodium distichum (L.) Rich.) to an altered hydrologic regime. American Midland Naturalist 133:206-212.

This study was conducted along a tributary of the Savannah River (Aiken, SC) to address the importance of hydrologic change in controlling T. distichum growth. Construction of a road led to longer periods of inundation and greater inundation depths (around 85 cm). They assumed that downstream water levels were unchanged, and used this as a reference site for comparing with tree cores collected in the impacted area. 16 trees were cored in the impacted area and 15 were cored in the downstream (reference) area. Growth patterns at the upstream and reference sites were similar (within 1 SD of each other) until 1973, at which point the upstream site showed accelerated growth relative to the reference site. This corresponded with the construction of the road that led to prolonged inundation. After several years (5-10 yrs) of accelerated growth, this impacted site showed a marked decline in growth relative to the reference site. They suggest that this pattern of marked growth followed by consistent declines (as seen in the growth rings) may indicate large-scale hydrologic changes.

OTHER FAUNA

Autrey, B.C. 1997. Herpetofaunal assemblages of four vegetation types in the Caddo Lake area of northeast Texas. Master's Thesis, Stephen F. Austin State University, 95 pp.

The herpetofauna of the Longhorn Army Ammunition Plant (LHAAP), a 3,440 ha property bordered on the north by Big Cypress Bayou, was surveyed in 4 habitat types: bottomland hardwood forest, sideslope hardwood forest, mixed pine-hardwood forest, and pure pine forest. Several collecting methods were used in each habitat (drift fences, pitfall traps, boards, tubes (for tree frogs), and funnel traps (for aquatic species). During 1996 and 1997, 2,0028 amphibians (17 species) and 1,397 reptiles (28 species) were recorded at the site. Species richness and individual abundance in each habitat were as follows: bottomland hardwood- 38 spp, 1,188 indiv.; sideslope hardwood- 35 spp., 1,373 indiv.; mixed pine-hardwood- 28 spp., 526 indiv.; and pure pine- 28 spp., 338 indiv. Differences in assemblage composition seemed to be related to the moisture gradient across vegetation communities. The bottomland hardwood habitat had

high grass and herbaceous ground coverage but also the least little leaf litter depth or weight. The bottomland hardwood habitat also had relatively low vertical structure in the understory. In the pine and mixed pine-hardwood habitats, standing water was limited to shallow depressions, which limited the occurrence of water-dependent taxa (e.g., turtles, amphibians) and those reptiles that rely on amphibians as food resources. A severe drought from May through June 1996 further limited the occurrence of water-dependent taxa in upland habitats. Only 47% of species were found in all 4 habitat types, and it was recommended that future management at LHAAP attempt to maintain a diversity of vegetation communities.

Daniel, R. S. 1995. Bird and small mammal communities of four similar-aged forest types of the Caddo Lake area. Masters Thesis. Stephen F. Austin State University, Nacodoches, TX.

This was the result of a graduate-level research project conducted in 1996-97 to study the bird and small mammal community structure of four forest types (bottomland hardwood, sideslope hardwood, mixed pine-hardwood, and pure pine) found in the Longhorn Army Ammunition Plant (LAAP) lands. 70 species of birds and 10 species of small mammals were recorded that varied significantly among forest types. Bird diversity and abundance was greatest in the bottomland hardwood areas, mammal diversity was greatest in the pure pine areas, and mammal abundance was greatest in the mixed pine-hardwood. Birds seemed to be tied to tree species, canopy traits, and vertical structure. Small mammals were tied to ground cover and litter.

King, S L. and Keeland, B. D., and Moore, J. L. 1998. Beaver lodge distributions and damage assessments in a forested wetland ecosystem in southern United States. Forest Ecology and Management 108: 1-7.

The objectives of this study were 1) to gather information on the abundance of beaver in Caddo Lake, 2) determine the extent of beaver damage, especially to T. distichum, and 3) assess tree regeneration and discuss implications for long-term management. The abstract summarizes the study quite well. There ARE large mammalian herbivores (beaver and nutria), but their impact on T. distichum seems minimal. However, they suggest use of exclosures in different areas of the forest (high vs. low elevation and high vs. low light) and monitoring of these herbivores at 3-5 yr intervals to determine long-term effects.

Potential long-term implications of damage are not well discussed nor are the possible changes in # of beaver (or nutria) lodges over time. Questions arise as to whether numbers have been increasing over the past several decades or if their numbers have been stable. Also, I wonder whether beavers and nutria are prefer stable water levels as opposed to more natural, dynamics hydrologic conditions.Birds

Ingold, J.L. 1995. Checklist of the birds of the Caddo Lake watershed in Texas and Louisiana. Bulletin of the Museum of Sciences (Louisiana State University at Shreveport) No. 11: 1-46.

This document summarizes records of bird species for the Caddo Lake drainage (Figure 1). A master list of birds was obtained by reviewing records in Oberholster (1974). Records and bird specimens from 67 natural history

collections were examined to augment the Oberholster records. In addition, local bird banding, Christmas bird count and breeding bird survey data were included. Finally, a literature search added additional records of birds within the watershed. Oberholster listed 235 bird species in the Caddo Lake watershed. Addition records raised this total to 313 species. Historical changes in the local avifauna include species extinctions (passenger pigeon, ivory-billed woodpecker, Carolina parakeet) and local extirpations (greater prairie chicken, red-cockaded woodpecker). An account from the early 20th century (Cahn 1921) reported a blue heron rookery on Eagle Nest Island, but current records report no heron rookeries in the lake.

USFWS. 1993. Waterfowl Technical Appendix for the Red River Waterway Shreveport to Daingerfield Reach Evaluation Study, USFWS, Atlanta, May 1993.

This report was submitted to the USACE-Vicksburg. The executive summary of this report discusses potential loss of migratory waterfowl habitat associated with barge alternative navigation channels in the Cypress Basin of east Texas and western Louisiana.

RELEVANT INFORMATION TO THE CADDO LAKE SYSTEM

Fish

Fletcher, D. E. and B. M. Burr. 1992. Reproductive biology, larval description, and diet of the North American bluehead shiner, *Pteronotropis hubbsi* (Cypriniformes: Cyprinidae), with comments on conservation status. Ichthyological Exploration of Freshwaters 3: 193-218.

Killgore, K. J. and J. A. Baker. 1996. Patterns of larval fish abundance in a bottomland harwood wetland. Wetlands 19(3): 288-295.

Lemmons, R. P., et al. 1997. New Oklahoma localities for shortnose gar (*Lepisosteus platostomus*), largescale stoneroller (*Campostoma oligolepis*), and bluehead shiner (*Pteronotorpis hubbsi*).

Taylor, C. M. and S. M. Norris. 1992. Notes on the reproductive cycle of *Notropis hubbsi* (bluehead shiner) in southeastern Oklahoma

Wetlands vegetation

Lytle, D. A. and D. M. Merritt. 2004. Hydrologic regimes and riparian forests: a structured population model for cottonwood. Ecology 85(9): 2493-2503.

The Savannah River Annotated Bibliography Report has cited and summarized some information that is also applicable to the Caddo Lake System. Therefore, in this section of our report we want to list these references.

FLOODPLAIN ECOSYSTEMS: section review compiled by Rebecca Sharitz, Elizabeth A. Richardson, and Monica Plata we want to cite the following studies:

References **Page**

Vertebrates

Comparisons of forest community structure and wetland tree growth In response to hydrologic regime in South Carolina and Louisiana

Effects of river flow management on floodplain systems

Floodplain nutrient cycling

References **Page**

Floodplain wetland restoration

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- Freeman, M. C., et al. 2001 50
- Kinsolving, A. D. and M. B. Bain. 1993. 50
- Marchetti, M. P. and P. B. Moyle. 2001. 50
- Parasiewicz, P., et al. 1998. 50
- Scheidegger, K. J. and M. B. Bain. 1995. 51
- Schlosser, I. J. 1985. 51
- Travnichek, V. H., et al. 1995. 51

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- Bain, M. B. and J. M. Boltz. 1989. 52
- Baker, J. A., et al. 1991. 52
- Benke, A. C., et al. 2000. 52
- Finger, T. R. and E. M. Stewart. 1987. 52
- Killgore, K. J. and J. A. Baker. 1996. 53
- Paller, M. H. 1987. 54
- Ross, S. T. and J. A. Baker. 1983. 54
- Turner, T. F., et al. 1994. 54
- Ward, J. V. and J. A. Standford. 1995. 54
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Background

- Poff, N. L., et al. 1997 60
- Richter, B. D., et al. 1996. 60
- Sparks, R. E. 1992 60

MAPS

Texas Park and Wildlife Department maps**:** data listed below are archived at the GIS Lab, Texas Parks and Wildlife Department, Austin, Texas, and are available upon request. You can find more information at the GIS lab webpage. http://www.tpwd.state.tx.us/gis/downloads/

- Classified TM imagery of Cypress Creek land cover (vegtm.img, ERDAS Imagine v8.2)
- Classified MSS imagery from 1970's (vegmss.img, ERDAS Imagine v8.2)
- Road network and cities (road, ARC/INFO 7.0.3)
- Drainage system (stream, ARC/INFO 7.0.3)
- Contours (contour, ARC/INFO 7.0.3)
- Watershed boundary (boundary, ARC/INFO 7.0.3)
- Map compositions (cadoeast.map and cadowest.map, ERDAS Imagine v8.2)

Notes: all maps, imagery, and coverage are in UTM projection (zone 15, datum NAD27) and have units in meters. The whole watershed lies within UTM zone 15, therefore distortion of area is minimal.

Maps of Cypress Creek Watershed in PDF format:

http://www.tpwd.state.tx.us/texaswater/sb1/terrestr/caddo/cypress_cr.phtml?print=true: The following maps are part of the online paper written by Changxiang, L J et al.

- Map 1. 3D perspective view of Cypress Creek Watershed Vegetation
- Map 2. Vector and template layers used in Cypress Creek land cover analysis
- Map 3a. Land cover types in Cypress Creek Watershed (Eastern Portion)
- Map 3b. Land cover types in Cypress Creek Watershed (Western Portion)

Caddo Lake institute maps: http://clidata.org/maps.htm

- 1996 Caddo Lake Ramsar Site Map
- Thematic Mapper Data: Map shows Thematic Mapper Imagery of the Longhorn Army Ammunition Plant (LAAP). TM Bands 4,5,3 are shown
- Land Use/Land Cover Classification: Land Use/Land Cover classification of the LAAP. Data from the January 1992.
- Harrison Bayou Ecotones: Map shows the various ecotones present along Harrison Bayou (eg. Cypress-Water Elm -Swamp Privet-Button Willow, Water/Willow Oak-Overcup Oak-Cypress, etc.)
- Harrison Bayou Virgin Forest: Map shows the various virgin timber stands present along Harrison Bayou
- Species Sites: Map shows the location of endangered species and other species of importance spotted in the LAAP

The following maps are a series of overlays depicting different data of the LAAP.

- Plant Boundary
- Aerial Photo of Plant
- Topographic Quads of Plant
- Ground Truth Sites: Location of the various sites used to ground truth the land use/land cover map mentioned above.
- NWI Habitat Data: Map shows the location of lands classified as "wetlands" by the U.S. Fish & Wildlife Service National Wetlands Inventory (NWI).
- Species Sightings: Map shows the location of endangered species and other species of importance spotted in the LAAP
- Woodland Management Units Map show the woodland management units of LAAP.
- Longhorn Ecotone Map

These maps can be downloaded as PDF or JPEG formats

Caddo Lake Spill Response Maps: http://clidata.org/SpillMaps/default.htm

The following is a listing of the maps produced by the U.S. Geological Survey's National Wetlands Research Center for the Caddo Lake Institute Spill exercise

- Historical Photography: Map shows area boundaries, place names, and state line.
- Roads, Place Names, Boat Roads and Channel Markers: Map shows area boundaries, main channel, channel markers, boat roads, state line, place names, roads, and landmarks/businesses.
- Special Biological Areas: Map shows quad boundary, place names, roads, hydrology, and special biological areas.
- Ramsar Sites, State Park, and Special Cultural Areas
- Land Cover / Land Use
- Harrison Bayou: Map shows spill site polygon, place names, roads, hydrology, and special biological areas.
- These maps can also be downloaded as PDF or JPEG formats.