Appendix A
Firm Yield Sensitivity for the Sulphur River Basin Reservoir Sites

Freese and Nichols

MEMORANDUM

TO: Texas Water Development Board

FROM: Andres Salazar, Ph.D., P.E.

SUBJECT: Firm Yield Sensitivity for the Sulphur River Basin Reservoir Sites

DATE: December 15, 2006

The initial screening process of the Reservoir Site Acquisition Study prepared for the Texas Water Development Board recommended 16 reservoirs for further detailed evaluation. Four of the reservoirs are located in the Sulphur River Basin. These reservoirs are Ralph Hall, George Parkhouse I, George Parkhouse II, and Marvin Nichols IA, and are shown on Figure 1.

Firm yield analyses were performed for each of these four reservoirs assuming stand-alone operations and excluding other potential reservoir sites identified in this study. However, if more than one of the proposed reservoirs are built, the firm yield of the reservoirs permitted with junior priority relative to the others may decrease substantially. This memorandum summarizes the results of a sensitivity analysis performed to assess the relative priority effects of various Sulphur River Basin reservoirs upon one another. The results of the stand alone yield analyses are discussed in Section 3.4 of the main report.

For the recommended conservation capacities shown in Table 1, the yields of Ralph Hall, Parkhouse I, Parkhouse II, and Marvin Nichols IA were determined assuming that all four reservoirs are built. Each reservoir was analyzed as the most junior in relation to the other three in at least one combination.

Four priority combinations were analyzed, which are listed in Table 2. In each combination, the yield of each reservoir was calculated assuming that senior reservoirs are operating at their firm yield. Ralph Hall Lake is already in the permitting process and very likely would be permitted before any of the other proposed reservoirs. Therefore, Ralph Hall is included as the most senior reservoir in three of the four scenarios. Scenario 4 has Ralph Hall with the most junior priority to obtain the worst case scenario for this reservoir.

Parkhouse I, Parkhouse II, and Marvin Nichols IA reservoirs are assumed to be passing inflows for environmental protection in accordance with the Texas Water Development Board's Consensus Criteria for Environmental Flow Needs. Lake Ralph Hall is assumed to be passing flows calculated with the Lyons method because this was the method used in the permit application. Environmental flow restrictions for each reservoir are listed in Attachment 1.

Freese and Nichols, Inc. ◆ Engineers ◆ Environmental Scientists ◆ Architects
4055 International Plaza ◆ Suite 200 ◆ Fort Worth, Texas 76109-4895
(817) 735-7300 ◆ Metro (817) 429-1900 ◆ Fax (817) 735-7491

Figure 1. Location Map

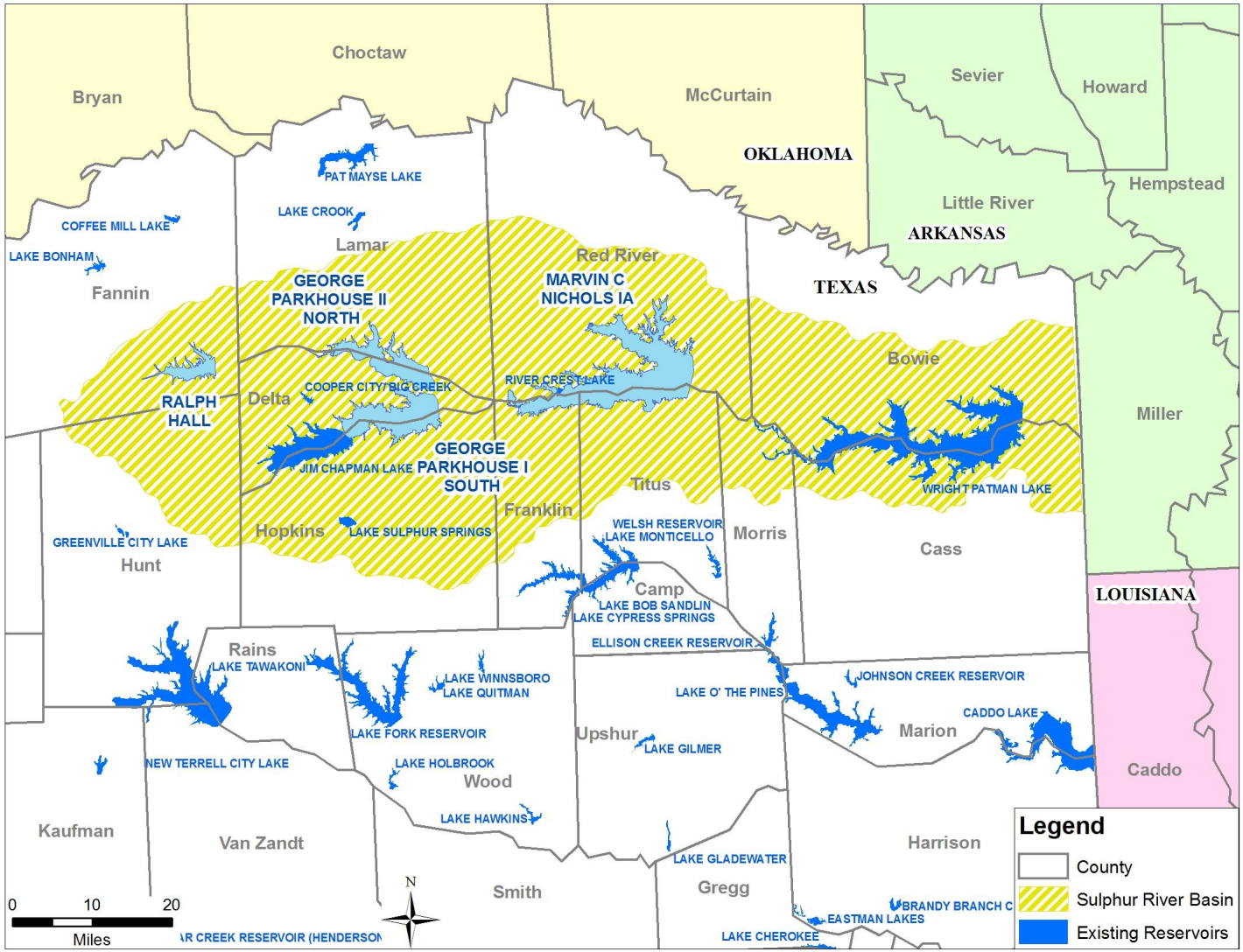

Table 1
Proposed Reservoirs in Sulphur River Basin

Reservoir	Conservation Elevation (msl)	Capacity (Acre-feet)	Area (Acres)
Ralph Hall	551.0	160,235	7,605
Parkhouse I	401.0	651,712	28,855
Parkhouse II	410.0	330,871	14,387
Marvin Nichols IA	328.0	1,562,669	67,392

Table 2
Relative Priority Combination Analyzed

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Most Senior	Ralph Hall	Ralph Hall	Ralph Hall	Parkhouse I
	Parkhouse I	Marvin Nichols IA	Parkhouse II	Parkhouse II
	Parkhouse II	Parkhouse I	Marvin Nichols IA	Marvin Nichols IA
Most Junior	Marvin Nichols IA	Parkhouse II	Parkhouse I	Ralph Hall

This sensitivity analysis used the permitting scenario (Run 3) of the Water Availability Model of the Sulphur River Basin (dated July 15, 2004) obtained from TCEQ (RJ Brandes 1999 and TCEQ 2006) and modified as necessary. A control point and reservoir were added at each dam location. These new control points were entered as primary control points, with known naturalized inflows.

In the WAM Models, flows at ungaged locations are usually calculated using the drainage area ratio method with known flows at gaged locations. The drainage areas of the Sulphur WAM were calculated by the University of Texas Center of Research in Water Resources (CRWR). These areas are different from values published from U.S. Geological Survey. In some cases, the difference is more than 10 percent. Preliminary yield studies conducted in this study determined that the flows calculated using the Sulphur WAM with the drainage area ratio method is different from previous hydrologic studies because of differences in the drainage areas. The USGS values are widely accepted and are more accurate than the CRWR values. Therefore, for purposes of estimating the firm yields under different priority scenarios, naturalized flows at the reservoir sites were calculated using the drainage area ratio method with drainage areas obtained from the USGS rather then CRWR.

The scope of work of this study does not include a verification or modification of the drainage areas of the Sulphur WAM Model. However, entering the naturalized flow at the reservoir sites is sufficient to produce accurate estimates of firm yields.

Evaporation rates are based on data from the Texas Water Development Board (2006), with adjustment to remove the portion of he precipitation on the surface area that is accounted for in

the naturalized flows. Attachment 2 shows the gages and equations used for calculating the naturalized flows and evaporation rates.

Results

Table 3 shows the firm yield of each reservoir under the different combinations of priority. These results present the impacts of relative priorities of potential future water rights in the Sulphur River Basin. This sensitivity analysis does not include evaluation of the potential for increased yields through system operations with existing reservoir or other future reservoirs. Key results are summarized as follows:

1. The yield of Ralph Hall Lake could be reduced to 2,700 acre-feet per year (or a total reduction of 92%) if it is junior to all other proposed reservoirs.
2. Ralph Hall Lake would have minimal impact on Parkhouse I Lake, reducing the yield by 400 acre-feet per year.
3. Ralph Hall Lake would have substantial impact on Parkhouse II Lake, reducing the yield by 26,900 acre-feet per year, which is 18% of the stand-alone yield.
4. Ralph Hall Lake would reduce the yield of Marvin Nichols IA by 17,900 acre-feet per year, which is 3% of the stand-alone yield. This result assumes Parkhouse I and Parkhouse II are not built or have junior priority.
5. If Parkhouse I Lake is built as the most junior reservoir, its yield would be 48,400 acre-feet per year, which is 73,600 acre-feet per year less than the stand-alone yield (a reduction of 60%).
6. If Parkhouse II Lake is built as the most junior reservoir, its yield would be 32,100 acre-feet per year, which is 112,200 acre-feet per year less than the stand-alone yield (a reduction of 78%).
7. The yield of Marvin Nichols IA Reservoir would be reduced by 141,200 acre-feet per year (or a reduction of 23%) if all of the proposed upstream reservoirs are built with senior priority.

In summary, sequential development of these four reservoir sites in an upstream to downstream priority order provides the greatest total firm yield among the scenarios evaluated. Cooperative development and system operations of reservoirs at some or all of these sites will maximize total firm yield.

Table 3
Firm Yield of the Proposed Reservoir under Different Combination of Priority
(Values are Acre-Feet per Year)

	Stand Alone Yield	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Ralph Hall	33,700	33,700	33,700	33,700	2,700
Parkhouse I	122,000	121,600	60,600	48,400	122,000
Parkhouse II	144,300	117,400	32,100	117,400	140,400
Marvin Nichols IA	602,000	460,800	584,100	503,800	465,500
Total	**NA***	**733,500**	**710,500**	**703,300**	**730,600**

* Total does not apply because only one reservoir is operating and others are excluded.

References

RJ Brandes Company. 1999. *Water Availability Modeling for the Sulphur River Basin.*

Texas Commission on Environmental Quality. 2006. Input File of the Water Availability Models. http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wam.html

Texas Water Development Board. 2006. Evaporation and Precipitation Data for the State of Texas. Available at http://hyper20.twdb.state.tx.us/Evaporation/evap.html

ATTACHMENT 1
Inflow Bypass for Environmental Protection

Table A1-1
Monthly Streamflow Statistics for Ralph Hall using the Lyons Method for Environmental Flow Needs

Month	AF	cfs
Jan	211	3.43
Feb	325	5.85
Mar	486	7.90
Apr	365	6.13
May	324	5.27
Jun	144	2.42
Jul	22	0.36
Aug	6	0.10
Sep	7	0.12
Oct	14	0.23
Nov	81	1.36
Dec	180	2.93
Total	2,164	
Average	180.4	3.00

Table A1-2
Monthly Streamflow Statistics for G. Parkhouse I (South) using the Consensus Criteria for Environmental Flow Needs

	Median		25th Percentile		7Q2	
Month	**AF**	**cfs**	**AF**	**cfs**	**AF**	**cfs**
Jan	1,919	31.2	318	5.2	0	0.0
Feb	3,596	64.2	794	14.2	0	0.0
Mar	3,748	60.9	800	13.0	0	0.0
Apr	2,697	45.3	638	10.7	0	0.0
May	4,687	76.2	741	12.0	0	0.0
Jun	1,854	31.1	294	4.9	0	0.0
Jul	233	3.8	22	0.4	0	0.0
Aug	47	0.8	0	0.0	0	0.0
Sep	72	1.2	0	0.0	0	0.0
Oct	180	2.9	9	0.2	0	0.0
Nov	696	11.7	88	1.5	0	0.0
Dec	1,916	31.1	177	2.9	0	0.0
Total	21,644		3,879		0	
Average	1,804	30.0	323	5.4	0	0.0

Table A1-3
Monthly Streamflow Statistics for G. Parkhouse II (North) using the Consensus Criteria for Environmental Flow Needs

	Median		25th Percentile		7Q2	
Month	**AF**	**cfs**	**AF**	**cfs**	**AF**	**cfs**
Jan	2,396	39.0	532	8.6	0	0.0
Feb	3,266	58.3	1,096	19.6	0	0.0
Mar	3,333	54.2	1,045	17.0	0	0.0
Apr	3,129	52.6	1,049	17.6	0	0.0
May	3,289	53.5	874	14.2	0	0.0
Jun	1,175	19.7	205	3.4	0	0.0
Jul	183	3.0	12	0.2	0	0.0
Aug	50	0.8	0	0.0	0	0.0
Sep	66	1.1	0	0.0	0	0.0
Oct	174	2.8	3	0.1	0	0.0
Nov	920	15.4	73	1.2	0	0.0
Dec	2,068	33.6	243	4.0	0	0.0
Total	20,046		5,132		0	
Average	1,671	27.8	428	7.2	0	0.0

Table A1-4
Monthly Streamflow Statistics for Marvin Nichols IA using the Consensus Criteria for Environmental Flow Needs

	Median		25th Percentile		7Q2	
Month	**AF**	**cfs**	**AF**	**cfs**	**AF**	**cfs**
Jan	13,845	225.1	3,419	55.6	69	1.1
Feb	21,947	391.6	6,659	118.8	63	1.1
Mar	31,133	506.2	8,975	145.9	69	1.1
Apr	19,656	330.2	6,143	103.2	67	1.1
May	32,113	522.1	6,092	99.0	69	1.1
Jun	11,994	201.5	3,110	52.3	67	1.1
Jul	2,564	41.7	552	9.0	69	1.1
Aug	911	14.8	220	3.6	69	1.1
Sep	1,011	17.0	123	2.1	67	1.1
Oct	1,562	25.4	251	4.1	69	1.1
Nov	5,055	84.9	1,083	18.2	67	1.1
Dec	11,641	189.3	2,201	35.8	69	1.1
Total	153,432		38,827		814	
Average	12,786	212.5	3,236	54.0	68	1.1

ATTACHMENT 2
Calculation of Naturalized Flows

Table A2-1 Gages Used in the Calculation of Naturalized Flows

Control Point	Name	USGS Drainage Area (sq. miles)	Sulphur WAM Drainage Area (sq. miles)
Existing Control Points			
A10	South Sulphur River near Cooper	527	541
B10	North Sulphur River near Cooper	276	311
C10	Sulphur River near Talco	1,365	1,381
D10	White Oak Creek near Talco	494	546
E10	Sulphur River near Darden	2,774	2,849
New Control Points			
B25	Ralph Hall	102	NA
C200	Parkhouse I	655	NA
C105	Parkhouse II	421	NA
E175	Marvin Nichols IA	1,889	NA

Derivation of Natural Flows and Evaporation Rates

1- Ralph Hall

Natural Flow (Calculated by the WRAP Model)

$$\text{Ralph Hall} = \frac{\text{B10}}{311\ \text{sq.miles}} \times 102\,\text{sq.miles}$$

Evaporation

Ralph Hall Evaporation = Control Point A70.
(Adjusted for effective runoff by the WRAP Model)

2- Parkhouse I

Natural Flow (Entered as primary control point)

$$\text{Parkhouse I} = \text{A10} + \frac{\text{C10} - \text{B10} - \text{A10}}{562\,\text{sq.miles}} \times 128\,\text{sq.miles}$$

Evaporation

Parkhouse I Evaporation = Net Quadrangle 412 + [Nat Flow C200] / 655

3- Parkhouse II

<u>Natural Flow</u> (Entered as primary control point)

$$\text{Parkhouse II} = \text{B10} + \frac{\text{C10} - \text{B10} - \text{A10}}{562\,\text{sq.miles}} \times 145\,\text{sq.miles}$$

<u>Evaporation</u>

Parkhouse II Evaporation = Net Quadrangle 412 + [Nat Flow C105] / 421

4- Marvin Nichols IA

<u>Natural Flow</u> (Entered as primary control point)

$$\text{Marvin Nichols IA} = \text{C10} + \frac{\text{E10} - \text{D10} - \text{C10}}{915\,\text{sq.miles}} \times 524\,\text{sq.miles}$$

<u>Evaporation</u>

Marvin Nichols Evaporation = 0.5 x (Net Quadrangle 412 + 413) + [Nat Flow E175] /1889

Appendix B
An Assessment of Potential Impacts to Archaeological and Cultural Sites Relating to Reservoir Site Acquisition Development

AN ASSESSMENT OF POTENTIAL IMPACTS TO ARCHEOLOGICAL AND CULTURAL SITES RELATING TO RESERVOIR SITE ACQUISITION AND DEVELOPMENT

by
Christopher J. Jurgens, Ph.D.
with contributions by Gene P. Davis and Diane B. Hyatt
Project Engineering and Review Division
Texas Water Development Board

INTRODUCTION

The Texas Water Development Board plans for systematic water resource development in the State of Texas and financially assists construction of resulting development. As part of current state-wide planning efforts, the development feasibility is being examined for sixteen localities across Texas. The State Water Plan designates these localities as unique sites with the highest priority for acquisition and development of future surface water reservoirs. The feasibility of developing these sites is being examined to enable acquisition that will prevent conflicts to their eventual development as water supply reservoirs.

One aspect of reservoir feasibility assessment is determining the potential for adverse impacts to cultural resources, including archeological sites and other historic properties. State and Federal historic preservation statutes require appropriate impacts assessment prior to facility development on public property or using public funds. Impacts assessment includes identification of historic properties and assessment of their historic or cultural significance. If impacts to significant historic properties are unavoidable, then data recovery must be undertaken to offset damage resulting from development.

CURRENT ASSESSMENT METHODOLOGY

Environmental review staff with the Board's Office of Project Construction and Financial Assistance (OPFCA) assisted the Office of Planning in the current assessment of reservoir sites.

Planning staff provided maps showing plotted locations for the sixteen designated unique reservoir sites. Three other sites were included that have not been designated as unique reservoir sites. The sites are shown in Figure 1. The OPFCA archeological staff developed quantitative measures of potential for impacts to historic properties that was specific to the regions of Texas where the reservoir sites are located.

To develop the quantitative measures of potential impacts to historic properties, OPFCA staff archeologists began with an examination of county-level summary data for the study area. This area included twenty seven counties that contain all or part of the proposed reservoir sites. Data in the Texas Historical Commission's (THC) on-line Archeological Sites Atlas were accessed to obtain summary statistics for historic property categories that might be potentially affected by reservoir development. These included both historic and prehistoric recorded archeological sites, historic cemeteries, and historic industrial or military sites. Communications with staff in the THC Archeology Division clarified details about the contents of existing data sets. The THC archeological staff also supplied their assumptions about the numeric relationship between total numbers of recorded archeological sites in counties and the percentage that is significant enough to be considered eligible for inclusion in the National Register of Historic Places.

Based on the THC assumptions and data about sensitive sites, the categories used to derive quantitative measures of potential for impacts to historic properties included sites potentially eligible for inclusion in the National Register of Historic Places, historic cemeteries, sawmills and military sites. The measures themselves were calculated averages of sensitive sites for regions and the study area. Variance of county-level data for the total number of sensitive sites was compared to both regional and study area averages.

A literature search focused on several syntheses published by the THC and the U. S. Army Corps of Engineers Southwest Region. Specific sources included Guy (1990); Kenmotsu and Perttula (1993); and Mercado-Allinger, *et al.* (1996). While a significant amount of archeological work has occurred in the decade since publication of the most-recent volume, the basic interpretations of these sources remain valid for the characteristics and context of historic properties in appropriate regions of Texas.

The literature search included geo-archeological publications that investigated the physiographic context of historic properties. The physical context includes the location of cultural resources in a landscape that has both physical and biological constituents. The biological constituents of the landscape provided a strong attraction for prehistoric or early historic residents who were intent on securing food and other resources. Physical constituents, such as water and clay sources, are also important attractions for those who must live close to the resources offered by a region.

For the current assessment, the physical constituents were viewed as most important. The association between soils and geomorphology is especially valuable as an indicator when determining the potential presence, characteristics, and long-term survival of historic properties. Physical conditions affect how archeological sites are formed and the probability of whether the contents of those sites will survive. Arguments supporting these points were developed by Collins and Bousman (1993) especially for an assessment of factors affecting archeological site formation and survival in Northeast Texas. Their conclusions remain valid and are incorporated into the methodology as devices that allow better interpretation of site distribution data aggregated at the county level.

RESULTS OF THE CURRENT ASSESSMENT

The nineteen reservoir sites identified by the Board's Planning staff were found to include parts of twenty seven counties. To efficiently make the best use of allotted time and resources, OPFCA archeologists used existing publications and available data sources to the maximum extent possible. A summary of previous archeological work and results reported by Guy (1990) is found in Table 1.

The literature search revealed the evolving scale and sophistication of previous archeological investigations in the central and eastern portions of Texas. These investigations were associated with planning for construction of fifty-four reservoirs in an area that partially overlaps with the current study area. The implications for the current study that the Guy (1990) summary bring to light concerning the evolving scale and sophistication of previous research will be discussed in

the Discussion section. Just over 5,000 archeological sites were recorded during reconnaissance or intensive surveys for these reservoirs between World War II and 1986. Of the sites recorded, only about 130 have been determined to be eligible for inclusion in the National Register of Historic Places. Table 2 aggregates Table 1's reservoir survey results by region.

The survey intensity and extent at each reservoir site cannot be determined from the secondary literature sources examined. The results of later surveys do indicate greater numbers of recorded sites. An example of change through time in archeological surveys necessary prior to reservoir construction and their results is the comparison between archeological work done during the quarter century between 1948 and 1984. No archeological sites were located at Lake Benbrook (Tarrant County) in 1948. The 1959 – 1961 archeological survey at Navarro Mills Reservoir in Hill and Navarro counties recorded 19 sites. One of these was subsequently excavated. The 1979 – 1984 investigations at Richland Creek Reservoir (Freestone and Navarro counties) recorded 1,001 sites, tested the significance of 270, and excavated the 53 found to be eligible for inclusion in the National Register of Historic Places.

Historic property categories identified during examination of county-level data in the THC's on-line Archeological Sites Atlas included archeological sites, State Archeological Landmarks, and sites listed on the National Register of Historic Places. Data from the twenty site counties included in the current examination are found in Table 3 for each of these categories. The existing data for these counties includes 7,250 recorded archeological sites, 298 State Archeological Landmarks, and 255 sites listed on the National Register of Historic Places.

For the purposes of the current study, significant other data are reported in the Archeological Sites Atlas for numerous historic sites that are typically not recorded as archeological sites. Most common are historic cemeteries. Sawmills also are numerous, especially in eastern parts of the state. Military sites are reported, but are less common. The Atlas data for the twenty seven counties included entries for 3,042 historic cemeteries, 907 sawmills, and 25 military sites.

Proposed reservoir sites and associated county-level data are aggregated into four regional groups on the basis of shared physiography and characteristics of historic properties. Frequency

data for the regional groups better illustrate the regional variation in individual data categories. The four groups are shown in Figure 2 and Table 4.

The northeast regional group contains 3,296 previously recorded archeological sites in its ten counties. These sites are 45 percent of the total reported in the Atlas for the twenty seven counties used in the current study. A similar percentage of historic properties found in northeastern Texas are listed on the National Register of Historic Places (118 properties). Over half of the historic cemeteries (1,634) reported in the current study are located in these ten counties. Reflecting the forested landscape found by early historic immigrants to the region, almost 81 percent of the historic sawmills are found in this regional group. They include 734 individual listings from the Texas Forestry Museum records that were compiled in the Atlas. Three of the 25 military sites (12 percent) reported in the study area are found in the counties making up this regional group.

The ten-county south central regional group contains 2,520 previously recorded archeological sites, or about 35 percent of the Atlas-reported total. A similar percentage of historic properties found in the region are listed on the National Register of Historic Places (94 properties). The 1,128 historic cemeteries in the ten-county south central regional group represent 37 percent of the total number listed in the Atlas for the current study. The 173 historic sawmills in this region are the remainder of those reported in the Atlas for counties in the current study area. Four of the 25 military sites (16 percent) reported in the study area are found in the counties making up this regional group.

Ten counties in the northwest regional group span the Rolling Plains and High Plains. They contain 1,231 previously recorded archeological sites, or about 17 percent of the Atlas-reported total. Most of these sites are clustered in Garza and Palo Pinto counties. Listed National Register-eligible sites in the region include 21 historic properties. Historic cemeteries are much fewer in number in this region, numbering 104. These represent 3.5 percent of the total number of historic cemeteries listed in the THC Atlas database for counties in the current study area. Nine of the 25 military sites (36 percent) reported in the study area are found in this regional group of counties.

Cameron County in far South Texas is the last county under consideration. The county's archeological sites include 203 previously recorded sites listed in the Archeological Sites Atlas. Twenty-two (22) historic properties from Cameron County are listed on the National Register of Historic Places. European settlement in the county since the mid-18th century is reflected in the 176 historic cemeteries within its borders, almost 6 percent of the total historic cemeteries in the 27 county study area. Nine of the 25 military sites (36 percent) reported in the study area are found in the county.

The THC's long experience in administering state and federal historic preservation programs gives its staff significant insight into the relationship among classes of historic properties. Its Archeology Division staff estimate a ratio of one site potentially significant enough to be eligible for listing in the National Register of Historic Places for every 5 recorded sites currently found in the Archeological Sites Atlas. While professional and avocational archeologists continue to record new archeological sites throughout Texas, the current value of 7,250 previously recorded sites in the 27 county study area would yield a value of 1,451 sites that would be potentially significant enough to be eligible for listing in the National Register. The northeast region contains 660 of the 1,451 archeological sites that are potentially eligible for listing. Just over 500 sites in the south central region would be potentially eligible for the National Register designation. About 250 sites in the northwest region would be eligible, as would 41 in the far south.

The 255 sites currently listed in the National Register of Historic Places in the study area represent less than 20 percent of the sites potentially eligible for listing in these counties. The difference between sites potentially eligible for listing and those actually listed is found Table 4. The value of the differential between actual listing and potential eligible for listing ranges between 8.5 and 53.6 percent for the four regions. This discrepancy between listed and potentially eligible sites has implications for reservoir development that will be discussed in the Discussion section.

DISCUSSION

The examination of frequency and distribution data for historic properties from the 27 county study area indicated that significant numbers of sensitive historic properties are present. Sensitive historic properties include archeological sites and historic structures that are eligible under national criteria of significance for listing in the National Register of Historic Places. While both archeological sites and historic structures may be listed on the National Register of Historic Places, most listed properties represent standing structures rather than archeological components. For both archeological site and National Register property categories in the THC's database, the reported frequencies represent a minimum number. A much higher frequency of sites significant enough to warrant listing is evident when the difference between currently listed National Register properties and all eligible sites is considered. Nearly 1,200 potential National Register sites remain unlisted in the study area. An important consideration for potential development projects is that state and federal historic preservation statutes grant National Register-eligible sites the same protections against unauthorized adverse impacts as listed sites. Historic preservation statutes apply to any public funding that enables development projects to be built and to any permitting necessary before construction. The protections insured by statute will require that the National Register-eligible sites be avoided by reservoir construction or that data recovery measures for them be included in development plans. Applicable statutes include the Texas Antiquities Code, (Title 9, Natural Resource Code, Chapter 191); the Archeological and Historic Preservation Act of 1974, Public Law 93-191; the Historic Sites Act; and the National Historic Preservation Act of 1966, Public Law 89-665, as amended.

Sensitive historic properties also include cemeteries. Over 3,000 cemeteries are reported in the Archeological Sites Atlas separately from archeological sites in the study area. These cemeteries are historic in age and contain the interred remains of Euro-Americans, Native Americans, or African-Americans. Within each regional area, some counties contain higher frequencies of recorded historic cemeteries. In the northeast region, Anderson, Fannin, and Smith each contain over 300 cemeteries. Red River, Lamar, and Cherokee counties each contain between 100 and 135 cemeteries. In south central Texas, Austin County is the oldest county in its region. This former seat of the Austin Colony contains 315 cemeteries, the highest number of any county in

the region. Freestone and Grimes counties also contain between about 150 and 225 cemeteries. Except for sparsely populated Live Oak County, other counties in this region contain between 50 and 100 recorded cemeteries. The northwest region has one county that contains almost 40 percent of its historic cemeteries, Palo Pinto. Clay and Haskell counties also contain between 15 and 25 recorded historic cemeteries. The centuries-old Hispanic settlement in Cameron County of far southern Texas contains well over 150 historic cemeteries.

Any reservoir construction affecting historic cemeteries will be required by statute to consider adverse impacts to them. At least two state statutes apply to construction that may impact historic cemeteries: Title 8 of the Health and Safety Code, Chapters 694 – 715 (relating to regulation of cemeteries); and Title 9 of the Natural Resource Code, Chapter 191 (the Antiquities Code of Texas). In addition, several federal statutes and executive orders apply. These include the Archeological and Historic Preservation Act of 1974, Public Law 93-191; the Historic Sites Act; the National Historic Preservation Act of 1966, Public Law 89-665, as amended; and Executive Order 11953, Protection and Enhancement of the Cultural Environment. The Native American Graves Protection and Repatriation Act of 1990, Public Law 101-601, will also apply if any historic Native American cemeteries or identified individual graves are to be affected. This act requires consultation with current Native American tribes before impacts to Native American cemeteries or graves may occur during planned construction. Similar requirements apply to previously unknown graves discovered during construction.

The total frequency and distribution of prehistoric Native American graves is unknown in the study area and is not represented in the Archeological Sites Atlas data for cemeteries. In many prehistoric Native American graves, most human skeletal material has deteriorated, especially in eastern Texas. Only associated grave offerings, such as pottery or stone tools, remain as sensitive, identifiable contents. Prehistoric Native American graves represent a culturally-sensitive issue that is subject to the protections of federal statute under the Native American Graves Protection and Repatriation Act of 1990, Public Law 101-601. The consultation requirements imposed by this statute were discussed under historic cemeteries and will apply to any reservoir construction contemplated for the sites under consideration.

The effect of advancements in archeological field methods during the past 60 years on survey results was briefly mentioned in the Results section. The total number of sites found during surveys has increased as methods came into use that allowed detection of sites that were previously overlooked. The advancements in methodology have been accompanied by significant increases in the standards necessary to insure statutory compliance.

Archeological surveys still do not completely examine large project areas, but rely on systematic or statistical sampling to insure that a large enough area is thoroughly examined to record most sites and to assess the impacts to significant historic properties that are protected by statutes. The sampling surveys replace reconnaissance survey typically used up until about the mid-1980s. Archeologists now use geomorphic characterization to develop probability models that guide sampling for survey efforts, to date landforms within survey efforts, and to assess the extent and scope of prior disturbance.

Geomorphic characterization allows survey to be concentrated within portions of a project's landscape. Appropriate use of this method allows specific survey techniques to be used where they are most productive. Resources can be allocated using geomorphic characterization into areas best suited for trenching to locate deeply buried sites or systematic pedestrian survey and shovel-testing to locate shallowly buried sites. Use of geomorphic characterization also allows areas that may be much less productive or extensively disturbed by natural causes to be deemphasized.

A recent example is the Phase Ia sample survey of about 10% at the proposed Lake Columbia site in 2006 (Owens, *et al.*, in preparation). Geomorphic characterization helped project archeologists to stratify the project area and focus initial survey efforts onto landforms containing historic properties that could be located quickly using the basic pedestrian walkover and shovel testing survey techniques typically used to find and record sites. Previous to the Phase Ia archeological survey, no archeological sites or historic structures had been recorded in the area and no professional archeological survey had ever been done within the lake basin. The results from archeological survey of almost 1,300 acres recorded 37 new archeological sites, 25 occurrences of isolated artifacts, and 7 historic properties recorded on the basis of standing

structures only. The historic properties with standing structures included a significant late-19th century African-American freedmen's community. The rate of about 3 sites recorded in each 100 acres surveyed within the reservoir area compares closely with data from archeological survey of Lake Gilmer in Upshur County in the early 1990s reported by Parsons, *et al.* (1992).

Large development projects implemented in the 1980s and 1990s included reservoirs and surface mines that provide fuel to power plants in eastern Texas. The results of archeological surveys conducted within portions of the current study area during this era show the effects of more stringent methodologies and regulatory compliance standards. Increasing numbers of archeological sites were recorded, tested, and excavated to mitigate impacts to significant sites.

Data are readily available for the ten counties in northeast Texas that fall within the Texas Historical Commission's northeast planning region. Perttula and Kenmotsu (1993:Table 2.1.1) report that these counties had a total of 1,527 archeological sites recorded in 1991. That total did not include all sites reported from the Cooper Lake survey. The sites in northeast Texas included 128 that were listed as significant and that would warrant state and federal statutory protections. Research for the current 2006 reservoir site feasibility study found an increase of 215 percent in the total number of recorded archeological sites in the northeast region. A five-fold increase in the number of significant sites is also evident in a comparison of data for sites that would potentially be eligible for listing in the National Register of Historic Places.

Partial data from 1991 are available for the south central region from Perttula and Kenmotsu (1993:Table 2.1.1). Their data are specifically for Madison and Walker counties at the region's eastern edge. Recorded archeological sites have increased since 1991 in Madison County by over 500 percent and by 200 percent in Walker County. No significant sites were reported in 1991 for these counties.

Quantitative measures of potential impacts were derived for the study area and the regional subsets of counties within it. The measures are averages calculated for the total number of sensitive sites in each county, allowing comparison between the study area and regions (see Table 5). Degree of variation from both the regional and study area averages is also presented in

Table 5. Counties and regions that have a higher potential for impacts to sensitive cultural resources are identifiable in Table 5 using the degree of variation and the difference between regional and study group averages.

On a regional basis, the northeastern region has the highest potential for reservoir site acquisition and eventual construction to cause impacts to sensitive sites. The northeast regional average is 50 percent higher than that for all twenty-seven counties in the study area. Within this region, the values for three counties greatly exceed both regional and study area averages. The values for Anderson, Cherokee, and Smith counties indicate a very strong potential for impacts to sensitive cultural resources that would be caused by development projects. While considerably lower, values for Red River and Titus counties also exceed the study area average. These values indicate a potential for impacts to sensitive cultural resources that correlates well with the results from previous archeological work. Caddoan sites and historic cemeteries are very frequent in the region, as are sawmills.

The far southern region has the next highest potential for potential impacts to sensitive cultural resources. Cameron County, the single county within the region, has a potential similar to Titus County in the northeastern region. Cameron County's values are based primarily on the historic cemeteries that can be used to indicate a potential frequency for other sensitive historic period sites occupied over the past 250 years.

The south central region has a lower potential for impacts to sensitive cultural resources. The value for its regional average is about 10 percent below the average for the study area average. Within the region, four counties have a much stronger potential. Austin and Freestone counties greatly exceed both the regional and study area average for sensitive sites, primarily due to a large number of historic cemeteries. Grimes County also has similar characteristics. Walker County's large number of recorded historic saw mills yields a strong tendency for impacts to sensitive cultural resources.

The northwest region has the lowest potential impacts to cultural resources that may be sensitive. Four of its counties have had few archeological sites or cemeteries recorded. Two counties have

a stronger potential, mainly due a larger number of sites that may be eligible for listing on the National Register of Historic Preservation. Garza and Palo Pinto counties have many more recorded archeological sites, most likely due to factors related to their physiographic settings.

The scope and cost of future water resource development projects historic preservation compliance is problematic. Large archeological projects are usually driven by the need for development projects to comply with historic preservation statutes. Their project budgets focus on work within the area of affect defined by the development project. While systematic academic archeological research projects have been undertaken throughout Texas for over a century, they are usually focused on much smaller areas. Some research projects are carried out over a span of decades. A good example of these focused, long-term research projects is the excavation of the George C. Davis site. This is an important complex of Caddoan ceremonial mounds within Caddo Mounds State Park in Cherokee County. Excavations at this location have been undertaken periodically by research archeologists from the University of Texas at Austin since the 1930s.

The frequency, characteristics, and significance of archeological sites are currently unknown in much of the state because these areas have never received any professional archeological attention. An example of this type of data gap is the Lake Columbia site where initial archeological surveys occurred recently and only sampled a small percentage of the reservoir basin. Many areas of the state also suffer from incomplete data where professional archeological work occurred decades ago under less stringent statutory or regulatory standards. Additional work will be necessary to comply with current statutory requirements where development projects have not yet been built.

Archeological work is labor-intensive and destroys its primary data during excavations, whether the work is undertaken as pure research or to comply with statutory requirements. Sophisticated techniques, such as geomorphic characterization and ground-penetrating radar, help guide archeological field survey, testing, and excavation efforts. Use of such sophisticated techniques can be expensive in their own right because of equipment or consultant costs. They can limit the unnecessary destruction of the historic properties that make up the archeological record. Judi-

cious use of these techniques focuses work on productive problems where such effort is not wasted. Cost estimates for archeological field projects are based on a specification of survey rates per day or excavation rates of 10-cm levels per day. Appropriate use of sophisticated techniques controls project costs when it allows archeological project managers to focus labor on productive problem areas. It also allows them to be more sophisticated in their interpretation of results from archeological fieldwork.

CONCLUSIONS

Feasibility assessment for systematic water resource development at nineteen sites across the state must include a complete assessment of the potential impacts to historic properties protected under state and federal law. Statutory requirements for permitting and public funding of reservoir construction mandate identification, assessment of significance against national criteria, and data recovery at historic properties meeting those significance criteria if impacts to the properties cannot be avoided. The twenty-seven county project area now contains a total of 7,250 recorded archeological sites. If THC estimates are correct, then their existing data significantly underreports historic properties potentially eligible for listing on the National Register of Historic Places. Less than 20 percent of 1,451 sites meeting eligibility criteria are now listed within the study area for the current assessment. Within this area, a potential of almost 1,200 sites that could meet these criteria may remain, based strictly on the total number of sites now reported. Most of the nineteen reservoir basins under consideration have never had an archeological survey or at best have been incompletely examined. Without adequate archeological fieldwork, an unknown number of very significant sites are left within the reservoir basins. The importance for the current assessment is that these are the sites that will be subject to the bulk of historic preservation statutory compliance requirements. Compliance will require avoidance of impacts or expensive and time-consuming data recovery.

The characteristics of historic period sites vary widely. Many are not recorded separately as archeological sites because they have standing structures. Texas Historical Commission data indicate that historic period cemeteries and sawmills are present in large numbers in several regions. The northeast, south central, and far southern regions contain counties with a long

period of substantial Euro-American occupation. Existing data indicate that these counties have a higher probability of containing significant historic properties not recorded as archeological sites that will receive protection under state and federal historic preservation statutes.

The final consideration in this assessment is that extensive consultation with Native American tribes will be necessary to comply with the requirements of federal statutes. Before they may authorize construction permits or financial assistance for reservoir construction, federal agencies are obligated to consult with tribes to insure that Native American graves are protected. State agencies building or financially assisting construction of major construction projects, such as highways, are already operating within these requirements.

The object of an agency's tribal consultation is to develop agreed-upon protocols for determining cultural affinity within a project area for human skeletal remains or grave goods from interments that are not obviously Euro-American. The consultation process also develops treatment protocols for Native American graves that might be encountered during archeological work or subsequent construction. Potential scopes and costs of Native American consultation for the nineteen reservoir sites under consideration will remain an unknown for the immediate future.

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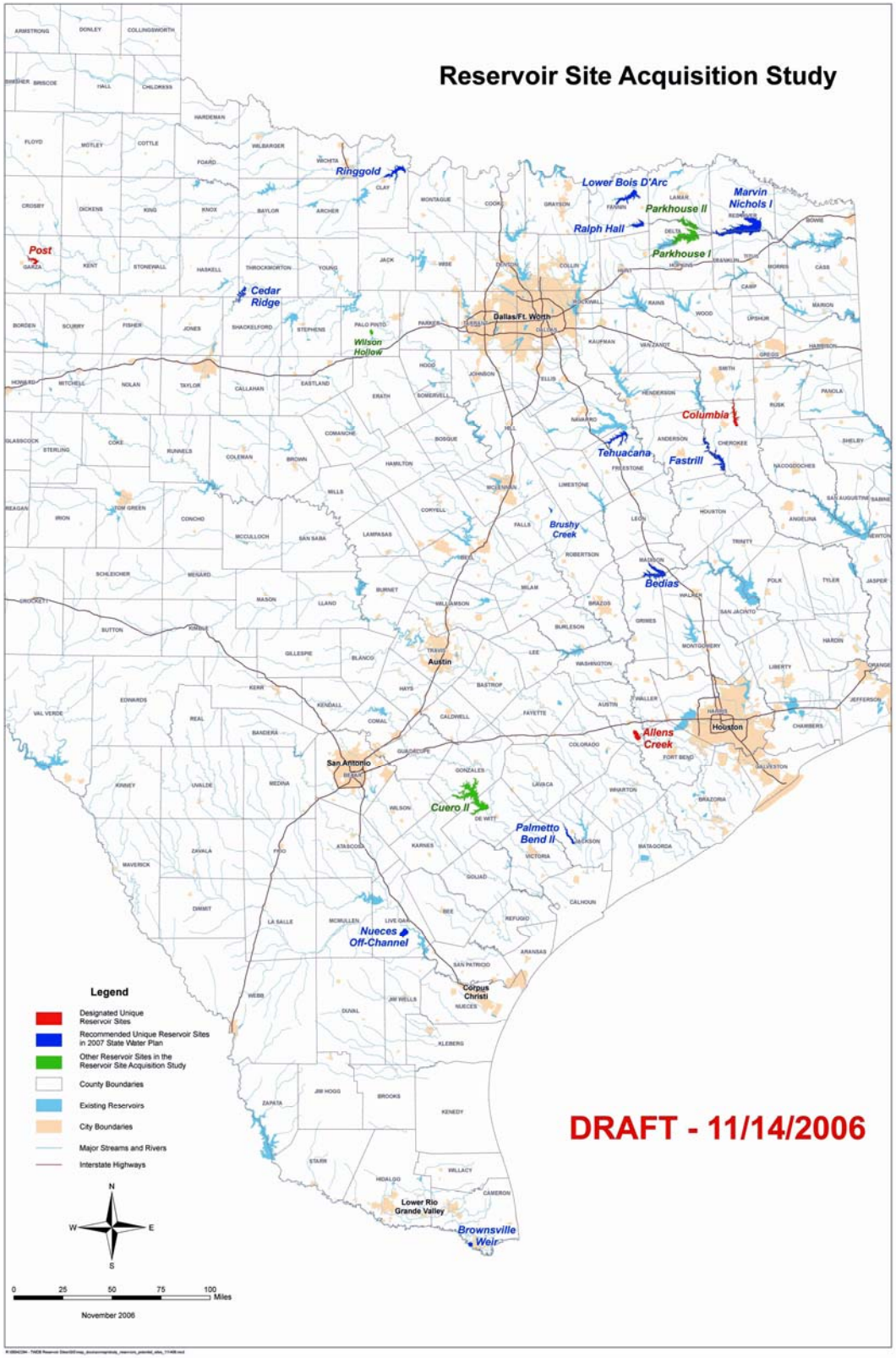

Figure 1: Location of Proposed Reservoir Sites Considered in the Current Study.

Table 1: Synopsis of Previous Reservoir Archeological Investigations in Eastern and Central Texas.

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Addicks	Harris	1947, 1964, 1982 - 86	76 (1982 - 86 only)			36
Aquilla	Hill	1972 - 1975, 1977 - 80, 1982 - 83	131	43	19	
Aubrey (Lake Ray Roberts)	Cooke, Denton, Grayson	1972 - 73, 1980 - 83, 1985 - 86	381	60	13	31
Bardwell	Ellis	1963, 1965	15	6	1	1
Barker	Fort Bend, Harris	1983 - 1985	75	6	3	33
B. A. Steinhagen	Jasper, Tyler	1947 - 48	7			
Bayou Loco (Nacogdoches)	Nacogdoches	1972, 1975 - 76	16	4	2	1
Bedias	Grimes, Madison, Walker	1985 - 86	11			
Benbrook	Tarrant	1948	0			
Big Cow Creek	Jasper, Newton	1975 - 76	7			
Big Pine	Lamar, Red River	1971 - 72, 1974 - 75	116	8	2	2
Big Sandy	Upshur, Wood	1980, 1985	129	12		
Blackburn Crossing (Lake Palestine)	Anderson, Cherokee, Henderson, Smith	1957, 1969 - 70, 1975	133		12	
Bois D'Arc	Fannin	1968	13			
Bosque	Bosque	1986	146			
Brushy Creek	Fannin, Grayson	1960	10			
Caddo	Harrison, Marion	1920, 1931, 1950s, 1957, 1968, 1974, 1977, 1983	60	1	2	
Cedar Creek	Henderson, Kaufman	1961, 1963 - 64	33	1	1	
Cleveland	San Jacinto	1985	4			
Cooper	Delta, Hopkins	1951, 1953, 1955, 1959, 1964, 1970, 1972 - 76, 1986	160	32	17	
Cypress Springs	Franklin	1968 - 69	17			

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Denison Dam (Lake Texoma)	Cooke, Grayson	1972	158	11		
Ferrels Bridge (Lake O' the Pines)	Camp, Harrison, Marion, Morris, Upshur	1951, 1957 - 60, 1974	75	25	11	
Flat Creek	Henderson	1959	1			
Forney (Lake Ray Hubbard)	Collin, Dallas, Kaufman, Rockwall	1940s, 1950s, 1963 - 65	33	6	3	
Garza-Little Elm (Lake Lewisville)	Denton	1940s, 1950s, 1948 , 1951, 1956, 1973, 1979 - 80, 1986				
Grapevine	Denton, Tarrant	1948, 1975	12	2		
Honea (Lake Conroe)	Montgomery, Walker	1965, 1967	34		4	
Iron Bridge (Lake Tawakoni)	Hunt, Rains, Van Zandt	1957, 1958, 1960	22		3	
Lake Creek	Montgomery	1985 - 86	46			
Lake Fork	Hopkins, Rains, Wood	1975 - 76, 1978 - 79	130	67	11	
Lakeview (Joe Pool Lake)	Dallas, Ellis, Tarrant	1977 - 81, 1984 - 86	42	23	19	14
Lake Lavon	Collin	1940s, 1948, 1950 - 51, 1959 - 60, 1964, 1969, 1973 - 74	34	9	5	
Lake Livingston	Polk, San Jacinto, Trinity, Walker	1961 - 66, 1968 - 69	160	3	6	
Marshall (Little Cypress)	Harrison, Upshur	1981, 1986	18			
McGee Bend (Lake Sam Rayburn)	Angelina, Jasper, Nacogdoches, Sabine, San Augustine	1948, 1956 - 58, 1960 - 62	81	11	10	
Millican	Brazos, Grimes, Leon, Madison	1971, 1973, 1981 - 82	188			
Mineola	Rains, Van Zandt, Wood	1971	91			

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Navarro Mills	Hill, Navarro	1959, 1961	19		1	
Pat Mayse	Lamar	1965, 1967	23	5	4	
Ponta	Cherokee, Nacogdoches, Rusk	1968	10			
Richland Creek	Freestone, Navarro	1979 - 84	1001	270	53	
Rockland	Angelina, Polk, Trinity, Tyler	1954	10			
Somerville	Burleson, Lee, Washington	1961, 1963 - 64	29		1	
Tennessee Colony	Anderson, Freestone, Henderson, Navarro	1971 - 72, 1974 - 77	326	14		
Texarkana (Lake Wright Patman)	Bowie, Cass	1949, 1952, 1963, 1970	190		4	
Timber Creek	Fannin	1968	2			
Titus County (Lake Bob Sandlin)	Camp, Franklin, Titus	1968 - 69, 1974 - 75, 1977 - 78	150	13	5	
Toledo Bend	Newton, Panola, Sabine, Shelby	1961 - 68	139	20	7	
Upper Navasota (Lake Limestone)	Leon, Limestone, Robertson	1974 - 77	52	22	4	
Waco Lake	McLennan	1959, 1963 - 65, 1984 - 85	115	13	2	
Wallisville Lake	Chambers, Liberty	1965 - 73, 1979, 1981, 1985 - 86	171	32	9	11
Water's Bluff	Smith, Upshur	1985 - 86	32			1
Lake Whitney	Bosque, Hill, Johnson	1947 - 52, 1956 - 60, 1971 - 72, 1976, 1984	101	29	14	3
Total:			**5035**	**748**	**252**	**133**

Note: The data within this table is primarily abstracted from Guy (1990). The data in this reference only encompasses work up to and including the year 1986.

Table 2: A Synopsis of Previous Reservoir Archeological Investigations in Eastern and Central Texas, Aggregated by Region.

Northeast Region

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Bayou Loco (Nacogdoches)	Nacogdoches	1972, 1975 - 76	16	4	2	1
Big Pine	Lamar, Red River	1971 - 72, 1974 - 75	116	8	2	2
Big Sandy	Upshur, Wood	1980, 1985	129	12		
Blackburn Crossing (Lake Palestine)	Anderson, Cherokee, Henderson, Smith	1957, 1969 - 70, 1975	133		12	
Bois D'Arc	Fannin	1968	13			
Caddo	Harrison, Marion	1920, 1931, 1950s, 1957, 1968, 1974, 1977, 1983	60	1	2	
Cedar Creek	Henderson, Kaufman	1961, 1963 - 64	33	1	1	
Cooper	Delta, Hopkins	1951, 1953, 1955, 1959, 1964, 1970, 1972 - 76, 1986	160	32	17	
Cypress Springs	Franklin	1968 - 69	17			
Ferrels Bridge (Lake O' the Pines)	Camp, Harrison, Marion, Morris, Upshur	1951, 1957 - 60, 1974	75	25	11	
Flat Creek	Henderson	1959	1			
Iron Bridge (Lake Tawakoni)	Hunt, Rains, Van Zandt	1957, 1958, 1960	22		3	
Lake Fork	Hopkins, Rains, Wood	1975 - 76, 1978 - 79	130	67	11	
Marshall (Little Cypress)	Harrison, Upshur	1981, 1986	18			
McGee Bend (Lake Sam Rayburn)	Angelina, Jasper, Nacogdoches, Sabine, San Augustine	1948, 1956 - 58, 1960 - 62	81	11	10	
Mineola	Rains, Van Zandt, Wood	1971	91			
Pat Mayse	Lamar	1965, 1967	23	5	4	

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Ponta	Cherokee, Nacogdoches, Rusk	1968	10			
Tennessee Colony	Anderson, Freestone, Henderson, Navarro	1971 - 72, 1974 - 77	326	14		
Texarkana (Lake Wright Patman)	Bowie, Cass	1949, 1952, 1963, 1970	190		4	
Timber Creek	Fannin	1968	2			
Titus County (Lake Bob Sandlin)	Camp, Franklin, Titus	1968 - 69, 1974 - 75, 1977 - 78	150	13	5	
Water's Bluff	Smith, Upshur	1985 - 86	32			1
Subtotal:			**1828**	**193**	**84**	**4**

Southeast Region

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Addicks	Harris	1947, 1964, 1982 - 86	76 (1982 - 86 only)			36
Barker	Fort Bend, Harris	1983 - 1985	75	6	3	33
B. A. Steinhagen	Jasper, Tyler	1947 - 48	7			
Big Cow Creek	Jasper, Newton	1975 - 76	7			
Cleveland	San Jacinto	1985	4			
Honea (Lake Conroe)	Montgomery, Walker	1965, 1967	34		4	
Lake Creek	Montgomery	1985 - 86	46			
Lake Livingston	Polk, San Jacinto, Trinity, Walker	1961 - 66, 1968 - 69	160	3	6	
Rockland	Angelina, Polk, Trinity, Tyler	1954	10			
Toledo Bend	Newton, Panola, Sabine, Shelby	1961 - 68	139	20	7	
Wallisville Lake	Chambers, Liberty	1965 - 73, 1979, 1981, 1985 - 86	171	32	9	11
Subtotal:			**729**	**61**	**33**	**80**

North Central Region

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Aquilla	Hill	1972 - 1975, 1977 - 80, 1982 - 83	131	43	19	
Aubrey (Lake Ray Roberts)	Cooke, Denton, Grayson	1972 - 73, 1980 - 83, 1985 - 86	381	60	13	31
Bardwell	Ellis	1963, 1965	15	6	1	1
Benbrook	Tarrant	1948	0			
Bosque	Bosque	1986	146			
Brushy Creek	Fannin, Grayson	1960	10			
Denison Dam (Lake Texoma)	Cooke, Grayson	1972	158	11		
Forney (Lake Ray Hubbard)	Collin, Dallas, Kaufman, Rockwall	1940s, 1950s, 1963 - 65	33	6	3	
Garza-Little Elm (Lake Lewisville)	Denton	1940s, 1950s, 1948, 1951, 1956, 1973, 1979 - 80, 1986				
Grapevine	Denton, Tarrant	1948, 1975	12	2		
Lakeview (Joe Pool Lake)	Dallas, Ellis, Tarrant	1977 - 81, 1984 - 86	42	23	19	14
Lake Lavon	Collin	1940s, 1948, 1950 - 51, 1959 - 60, 1964, 1969, 1973 - 74	34	9	5	
Navarro Mills	Hill, Navarro	1959, 1961	19		1	
Waco Lake	McLennan	1959, 1963 - 65, 1984 - 85	115	13	2	
Lake Whitney	Bosque, Hill, Johnson	1947 - 52, 1956 - 60, 1971 - 72, 1976, 1984	101	29	14	3
Subtotal:			**1197**	**202**	**77**	**49**

South Central Region

Reservoir	County	Years Investigated	Recorded Sites	Sites Tested	Sites Excavated	Sites NHRP - Eligible or Potentially Eligible
Bedias	Grimes, Madison, Walker	1985 - 86	11			
Millican	Brazos, Grimes, Leon, Madison	1971, 1973, 1981 - 82	188			
Richland Creek	Freestone, Navarro	1979 - 84	1001	270	53	
Somerville	Burleson, Lee, Washington	1961, 1963 - 64	29		1	
Upper Navasota (Lake Limestone)	Leon, Limestone, Robertson	1974 - 77	52	22	4	
Subtotal:			**1281**	**292**	**58**	

Table 3: Comparison of Recorded Archeological and Cultural Sites for Counties Containing Proposed Reservoir Sites.

County	Historic Cemeteries	Sawmills	Military Sites	Archeological Sites	State Archeological Landmarks	National Register of Historic Places-Listed Sites	Potential Total of National Register of Historic Places-Eligible Sites
Anderson	367	83	2	240	11	25	48
Austin	315	0	2	94	5	7	19
Cameron	176	0	9	203	195	22	41
Cherokee	134	409	0	444	2	6	89
Clay	25	0	0	11	1	2	2
De Witt	62	0	0	283	1	59	57
Delta	31	5	0	283	0	0	57
Falls	77	0	0	80	1	2	16
Fannin	331	10	0	74	1	8	15
Franklin	75	9	0	144	0	2	28
Freestone	226	1	0	617	4	1	123
Garza	4	0	0	694	2	7	139
Gonzales	74	0	3	221	5	9	44
Grimes	151	43	0	431	2	6	86
Haskell	15	0	0	37	0	0	7
Hopkins	70	12	0	251	1	1	50
Jackson	51	0	1	230	1	2	46
Lamar	100	12	1	317	3	40	64
Live Oak	15	0	1	333	2	3	67
Madison	96	3	1	31	0	1	6
Palo Pinto	40	0	0	384	4	6	77
Red River	102	109	0	309	2	6	62
Shackelford	9	0	2	78	5	5	16
Smith	367	85	1	333	22	29	67
Throckmorton	11	0	1	27	1	1	5
Titus	57	0	0	901	12	1	180
Walker	61	126	1	200	15	4	40
TOTAL	**3042**	**907**	**25**	**7250**	**298**	**255**	**1451**

(Source: Texas Historical Commission On-Line Archeological Sites Atlas, November, 2006)

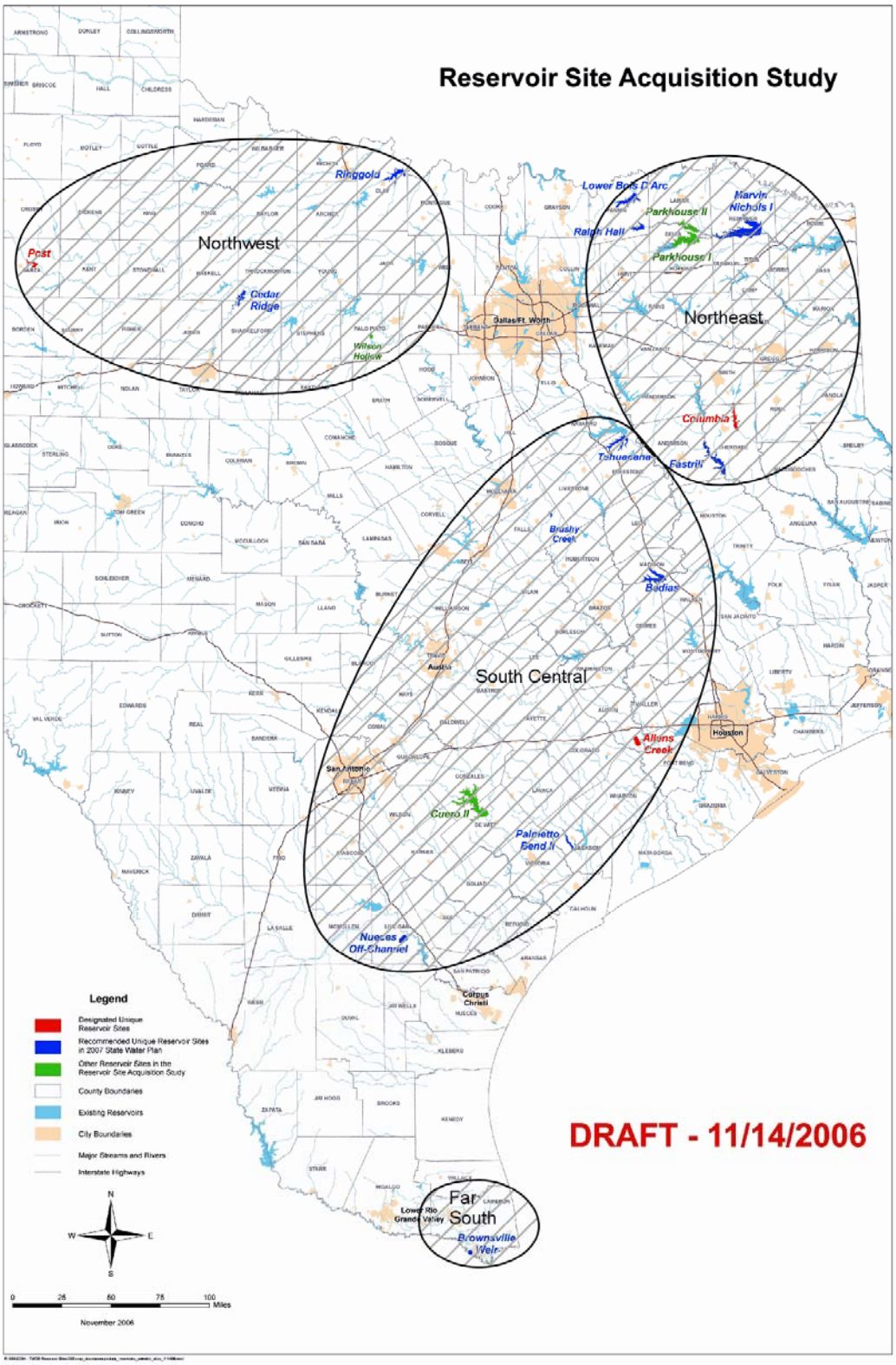

Figure 2: Location of Regional Groups Used in Study, Aggregated on the Basis of Physiography and Characteristics of Historic Properties.

Table 4: Comparison of Recorded Archeological and Cultural Sites for Counties Containing Proposed Reservoir Sites, Aggregated by Regional Group.

County	Historic Cemeteries	Sawmills	Military Sites	Archeological Sites	State Archeological Landmarks	National Register of Historic Places-Listed Sites	Potential Total of National Register of Historic Places-Eligible Sites
Northwest							
Clay	25	0	0	11	1	2	2
Garza	4	0	0	694	2	7	139
Haskell	15	0	0	37	0	0	7
Palo Pinto	40	0	0	384	4	6	77
Shackelford	9	0	2	78	5	5	16
Throckmorton	11	0	1	27	1	1	5
Group Subtotal	**104**	**0**	**3**	**1231**	**13**	**21**	**246**
Northeast							
Anderson	367	83	2	240	11	25	48
Cherokee	134	409	0	444	2	6	89
Delta	31	5	0	283	0	0	57
Fannin	331	10	0	74	1	8	15
Franklin	75	9	0	144	0	2	28
Hopkins	70	12	0	251	1	1	50
Lamar	100	12	1	317	3	40	64
Red River	102	109	0	309	2	6	62
Smith	367	85	1	333	22	29	67
Titus	57	0	0	901	12	1	180
Group Subtotal	**1634**	**734**	**4**	**3296**	**54**	**118**	**660**
South Central							
Austin	315	0	2	94	5	7	19
De Witt	62	0	0	283	1	59	57
Falls	77	0	0	80	1	2	16
Freestone	226	1	0	617	4	1	123
Gonzales	74	0	3	221	5	9	44
Grimes	151	43	0	431	2	6	86
Jackson	51	0	1	230	1	2	46
Live Oak	15	0	1	333	2	3	67
Madison	96	3	1	31	0	1	6

County	Historic Cemeteries	Sawmills	Military Sites	Archeological Sites	State Archeological Landmarks	National Register of Historic Places-Listed Sites	Potential Total of National Register of Historic Places-Eligible Sites
Walker	61	126	1	200	15	4	40
Group Subtotal	**1128**	**173**	**9**	**2520**	**36**	**94**	**504**
Far South							
Cameron	176	0	9	203	195	22	41
Group Subtotal	**176**	**0**	**9**	**203**	**195**	**22**	**41**
TOTAL	**3042**	**907**	**25**	**7250**	**298**	**255**	**1451**

(Source: Texas Historical Commission On-Line Archeological Sites Atlas, November, 2006)

Regional Groups include the Following Proposed Reservoir Sites:

Northwest: Cedar Ridge, Post, Ringgold, and Wilson Hollow.
Northeast: Columbia, Fastrill, Lower Bois D'Arc, Marvin Nichols I, Parkhouse I, Parkhouse II, and Ralph Hall.
South Central: Allens Creek, Bedias, Brushy Creek, Cuero II, Nueces Off-Channel, Palmetto Bend II, and Tehuacana.
Far South: Brownsville Weir.

Table 5: Comparison of Sensitive Cultural Resources for Counties Containing Proposed Reservoir Sites, Aggregated by Regional Group.

County	Historic Cemeteries	Sawmills	Military Sites	Potential Total of National Register of Historic Places-Eligible Sites	Total Sensitive Sites	Regional Avg. (Total Sites / Counties in Region)	Variance from Regional Avg.	Study Area Avg. (Total Sites / Counties)	Variance from Study Area Avg.
Northwest									
Clay	25	0	0	2	27		-31.8		-173.9
Garza	4	0	0	139	143		+84.2		-57.9
Haskell	15	0	0	7	22		-36.8		-178.9
Palo Pinto	40	0	0	77	117		+58.2		-83.9
Shackelford	9	0	2	16	27		-31.8		-173.9
Throckmorton	11	0	1	5	17		-41.8		-183.9
Group Subtotal	**104**	**0**	**3**	**246**	**353**	**58.8**			**-151.1**
Northeast									
Anderson	367	83	2	48	500		+196.8		+299.1

County	Historic Cemeteries	Sawmills	Military Sites	Potential Total of National Register of Historic Places-Eligible Sites	Total Sensitive Sites	Regional Avg. (Total Sites / Counties in Region)	Variance from Regional Avg.	Study Area Avg. (Total Sites / Counties)	Variance from Study Area Avg.
Cherokee	134	409	0	89	632		+328.8		+431.1
Delta	31	5	0	57	93		-210.2		-107.9
Fannin	331	10	0	15	356		+52.8		-144.9
Franklin	75	9	0	28	112		-191.2		-88.9
Hopkins	70	12	0	50	132		-171.2		-68.9
Lamar	100	12	1	64	177		-126.2		-23.9
Red River	102	109	0	62	273		-30.2		+72.1
Smith	367	85	1	67	520		+216.8		+319.1
Titus	57	0	0	180	237		-66.2		+36.1
Group Subtotal	**1634**	**734**	**4**	**660**	**3032**	**303.2**			**+102.3**
South Central									
Austin	315	0	2	19	336		+154.6		+135.1
De Witt	62	0	0	57	119		-62.4		-81.9
Falls	77	0	0	16	93		-88.4		-107.9
Freestone	226	1	0	123	350		+168.6		+149.1
Gonzales	74	0	3	44	121		-60.4		-79.9
Grimes	151	43	0	86	280		+98.6		+79.1
Jackson	51	0	1	46	98		-83.4		-102.9
Live Oak	15	0	1	67	83		-98.4		-117.9
Madison	96	3	1	6	106		-75.4		-94.9
Walker	61	126	1	40	228		+46.6		+27.1
Group Subtotal	**1128**	**173**	**9**	**504**	**1814**	**181.4**			**-19.5**
Far South									
Cameron	176	0	9	41	226		0		+25.1
Group Subtotal	**176**	**0**	**9**	**41**		**226**			**+25.1**
TOTAL	**3042**	**907**	**25**	**1451**	**5425**			**200.9**	

Appendix C
Report on the Creation of a Land Cover / Land Use Database for Select Proposed Reservoir Sites In Texas

Report on
The Creation of a Land Cover / Land Use Database for Select Proposed Reservoir Sites in Texas

Texas Parks & Wildlife GIS Lab

November 16, 2006

Statement of Need

Texas Water Development Board is tasked with evaluating proposed reservoir sites. Land cover information is needed to evaluate sites with respect to possible wetland impacts and other mitigation needs. Land cover information allows efficient evaluation of relative costs and risks associated with reservoir development on a particular site. The most recent ground verified land cover / vegetation database for Texas is The Vegetation Types of Texas – Including Cropland, McMahan, et.al. 1984, PWD Bulletin 7000-120. The most recent unverified database is the 1992 National Land Cover Dataset (USGS). These dataset are unsuitable for site evaluation due to age, lack of resolution, and / or unverified accuracy and a new database needs to be developed.

Proposed Methodology

All proposed reservoir sites will be mapped using a modified version of the Texas Land Classification System (Appendix B). This classification system is an expansion of the National Land Cover Database (NLCD) Classification System (Appendix A) and is a standard land cover / land use classification system for Texas. The modified version will use all classes considered necessary to quickly evaluate potential reservoir sites as to relative risk of impacts to wetlands and other land resources subject to mitigation. The classification system is a generalization and is intended to allow rapid mapping to a level of detail considered sufficient for planning level evaluation of reservoir sites. The classes included in the system are (using NLCD / Texas Land Classification nomenclature):

Land Cover Type	Definition
1.1 Open Water	All areas of open water, generally with less than 25 percent cover of vegetation or soil.
2.0 Developed	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-100 % of total cover
4.111 Deciduous Forest	Areas dominated by trees where 75% or more of the canopy cover can be determined to be trees which loose all their leaves for a specific season of the year.
4.112 Evergreen Forest	Areas dominated by trees where 50% or more of the canopy cover can be determined to be trees which maintain their leaves / needles all year. All mixed Pine / Oak forests in this class. Includes Pine plantations and other evergreen dominated silvaculture operations.
4.1121 Broad-leaf Evergreen Forest	Areas dominated by evergreen trees that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus virginicus, Quercus fusiformis*.
4.12 Shrubland	Areas where trees have less than 25% canopy cover and the existing vegetation is dominated by plants that have persistent woody stems, a relatively low growth habit (generally less than 4 m), and which generally produce several basal shoots instead of a single shoot. Includes true shrubs, trees that are small or stunted because of environmental conditions, desert scrub, and chaparral. In the eastern US, includes former cropland or pasture lands which are now covered by brush to the extent that they are no longer identifiable or usable as cropland or pasture. Clear-cut areas will exhibit a stage of shrub cover during the regrowth cycle. Some common species which would be classified as shrub land are mountain mahogany, sagebrush, and scrub oaks.
4.21 Natural Herbaceous	Areas dominated by native or naturalized grasses, forbs, ferns and weeds. They can be managed, maintained, or improved for ecological purposes such as weed/brush control or soil erosion. Includes vegetated vacant lots and areas where it cannot be determined whether the vegetation was planted or cultivated such as in areas of dispersed grazing by

Land Cover Type	Definition
	feral or domesticated animals. Includes landscapes dominated by grass-like plants such as bunch grasses, palouse grass, palmetto prairie areas, and tundra vegetation, as well as true prairie grasses.
4.22 Planted / Cultivated Herbaceous	Areas of herbaceous vegetation planted and/or cultivated by humans for agronomic purposes in developed settings. The majority of vegetation in these areas is planted and/or maintained for the production of food, feed, fiber, pasture, or seed. Temporarily flooded are included in this category. Does not include harvested areas of naturally occurring plants such as wild rice and cattails.
4.31111 Seasonally Flooded Forest	Tree dominated areas on which surface water or soil saturation is present for extended periods during the growing season, but is absent by the end of the growing season in most years. Example species include: *Quercus laurifolia, Fraxinus pennsylvanica, Nyssa sp., Acer rubrum, Liquidambar styraciflua, Ulmus americana*
4.3112 Swamp	Tree dominated areas on which surface water persists throughout the growing season, except during drought years. Example species include: *Nyssa aquatica, Taxodium distichum*.
4.312 Shrub Wetland	Wetlands with greater 25% shrub cover and less than 25% tree cover. Usually fresh water inundation, includes seasonal and greater flooding regimes. Example species include: *Arundinaria gigantea, Baccharis salicifolia, Salix Sp., Cephalanthus occidentalis, Planera aquatica and Forestiera acuminata*
4.32 Emergent Herbaceous Wetlands	Areas dominated by wetland herbaceous vegetation which is present for most of the growing season. Includes fresh-water, brackish-water, and salt-water marshes, tidal marshes, mountain meadows, wet prairies, and open bogs.

Table 1. Reservoir Site Land Cover Classification System

Land cover will be mapped using Landsat ETM+ and TM data from the most current suitable datasets available in the State of Texas imagery archive, December 1999 to March 2003 (Table 1). Imagery collected during and out of the growing season will be used. Data will be combined and an unsupervised clustering routine (Isodata) in Leica Geosystems Erdas Imagine 9.0 will be run. Data will be grouped statistically into 30 clusters and these will be assigned to one of the land cover classes. Using the national hydric soils list from the Natural Resources Conservation Service (NRCS) and the Soil Survey Geographic (SSURGO) database from the same source to develop a map of the hydric soils in the area of interest and then using this to modify the land cover classes. Only soils map units classified as Sloughs, flood plains, or salt marshes with greater than 70% hydric inclusions are included for analysis. Classes 4.111 Deciduous Forest, 4.112 Evergreen Forest and 4.1121 Broad-leaf Evergreen Forest areas that intersect the hydric soils area will be reclassified to 4.31111 Seasonally Flooded Forest. Class 4.21 Natural Herbaceous areas that intersect the hydric soil area will be reclassified to 4.32 Emergent Herbaceous Wetlands. Class 4.12 Shrubland areas will be reclassified to 4.312 Shrub Wetland. Minimum mapping unit is 1 hectare.

Row / Path	Date
25-37	1/10/2000
25-37	4/18/2001
25-38	9/6/2000
25-38	11/3/2001
25-39	1/10/2000
25-39	7/20/2000
26-37	4/25/2001
26-37	12/14/2001
26-38	2/4/2001
26-38	4/25/2001
26-39	12/16/1999
26-39	4/25/2001
26-40	2/4/2001
26-40	4/25/2001
26-42	6/12/2001
26-42	3/30/2003
27-40	7/21/2001
27-40	12/31/2002
28-36	4/4/2000
28-36	2/2/2001
28-37	4/4/2000
28-37	3/9/2002
29-37	5/29/2000
29-37	1/8/2001

Table 1

Boundary information for each potential reservoir site, provided by Texas Natural Resource Information System, will be intersected with land cover data. No buffer was applied because the small size of some sites would lead make comparison of areas difficult as relatively large percentages of total area would be outside the footprint of the reservoir sites.

Random points are selected from each class and DOQQ imagery evaluation will be conducted to get a limited amount of verification of accuracy. Points will be overlaid on 2004 National Agricultural Imagery Program DOQ mosaics displayed at 1:10,000 scale and will be evaluated as to accuracy of land cover class.

Deliverables

1. Land cover database for priority potential reservoir sites (see Appendix C). Data delivered in ESRI personal geodatabase format. UTM WGS84 Meters projection. 11x17 proof maps in both paper and Adobe Acrobat formats.

2. DOQ imagery verification report and database. Data delivered in ESRI personal geodatabase format. Geographic WGS84 Decimal Degree (change due to locations crossing UTM boundaries) projection.

Results

Overall accuracy of the classification is 91%. Errors of omission and commission were computed for each class (Table 2). Classification accuracy is grouped for all landcover classes. Class 4.31111 Seasonally Flooded Forest is mapped conservatively and may occupy a larger percentage of the landscape than mapped. Small inclusions into matrix soils or soils that had smaller percentages of hydric soil types / areas may have this class present and not be mapped.

Class	1	2	3	4	5	6	7	8	9	10	11	12	Error of Omission
1	36												**0.000**
2		9											**0.000**
3			44	2			1						**0.064**
4				9				2					**0.182**
5					12								**0.000**
6			1	1		42	2						**0.087**
7						3	42	10					**0.236**
8	1							23					**0.042**
9									24		1	1	**0.077**
10										8			**0.000**
11											15		**0.000**
12										1	1	22	**0.083**
Error of Commission	**0.027**	**0.000**	**0.022**	**0.250**	**0.000**	**0.067**	**0.067**	**0.343**	**0.000**	**0.111**	**0.118**	**0.043**	

Table 2

Appendix A – NLCD Land Cover Classification System[1]

11. Open Water—All areas of open water, generally with less than 25 percent cover of vegetation or soil.
12. Perennial Ice/Snow—All areas characterized by a perennial cover of ice and/or snow, generally greater than 25 percent of total cover.
21. Developed, Open Space—Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes
22. Developed, Low Intensity—Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49 percent of total cover. These areas most commonly include single-family housing units.
23. Developed, Medium Intensity—Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50–79 percent of the total cover. These areas most commonly include single-family housing units.
24. Developed, High Intensity—Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
31. Barren Land (Rock/Sand/Clay)—Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.
32. Unconsolidated Shore*—Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.
41. Deciduous Forest—Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
42. Evergreen Forest—Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
43. Mixed Forest—Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
51. Dwarf Scrub—Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20 percent of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
52. Shrub/Scrub—Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes true shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
71. Grassland/Herbaceous—Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
72. Sedge/Herbaceous—Alaska only areas dominated by sedges and forbs, generally greater than 80 percent of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
73. Lichens—Alaska only areas dominated by fruticose or foliose lichens generally greater than 80 percent of total vegetation.

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[1] Homer, C., Haung, C., Yang, L., Wylie, B., and Coan, M. Development of a 2001 Nation Land-Cover Database for the United States. Photogrammetric Engineering and Remote Sensing. Vol 70. No. 7, July 2004, pp.829-840.

74. Moss—Alaska only areas dominated by mosses, generally greater than 80 percent of total vegetation.
81. Pasture/Hay—Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
82. Cultivated Crops—Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
90. Woody Wetlands—Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

> **91. Palustrine Forested Wetland***—Includes all tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.
> **92. Palustrine Scrub/Shrub Wetland***—Includes all tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs or trees that are small or stunted due to environmental conditions.
> **93. Estuarine Forested Wetland***—Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts are equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
> **94. Estuarine Scrub/Shrub Wetland***—Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

95. Emergent Herbaceous Wetlands—Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

> **96. Palustrine Emergent Wetland (Persistent)***—Includes all tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season.
> **97. Estuarine Emergent Wetland***—Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands.
> **98. Palustrine Aquatic Bed***—The Palustrine Aquatic Bed class includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages.

99. Estuarine Aquatic Bed*—Includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages.

Appendix B – Texas Land Classification System[2]

Expand the USGS MRLC classification categories to include the following new vegetative categories unique to Texas and call the new classification scheme the Texas Land Classification System. The new categories to MRLC are highlighted in blue.

VEGETATED - areas having generally 25% or more of the land or water with vegetation. Arid or semi-arid areas may have as little as 5% vegetation cover.

4.1 Woody Vegetation - land with at least 25% tree and (or) shrub canopy cover.

4.11 Forested – trees with crowns overlapping (generally 60-100% cover)

4.111 Deciduous Forest - area dominated by trees where 75% or more of the canopy cover can be determined to be trees which loose all their leaves for a specific season of the year.

4.1111 Cold Deciduous Forest – area dominated by trees that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus stellata , Quercus marilandica.*

4.112 Evergreen Forest - area dominated by trees where 75% or more of the canopy cover can be determined to be trees which maintain their leaves all year.

4.1121 Broad-leafed Evergreen Forest - area dominated by evergreen trees that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus virginicus, Quercus fusiformis.*

4.1122 Needle-leafed Evergreen Forest – area dominated by evergreen trees with slender elongated leaves. Example species include: *Pinus echinata, Pinus palustris, Pinus taeda, Juniperus virginiana.*

4.113 Mixed Forest - areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the canopy cover.

4.12 Shrubland - areas where trees have less than 25% canopy cover and the existing vegetation is dominated by plants that have persistent woody stems, a relatively low growth habit (generally less than 4 m), and which generally produce several basal shoots instead of a single shoot. Includes true shrubs, trees that are small or stunted because of environmental conditions, desert scrub, and chaparral. In the eastern US, include former cropland or pasture lands which are now covered by brush to the extent that they are no longer identifiable or usable as cropland or pasture. Clear-cut areas will exhibit a stage of shrub cover during the regrowth cycle. Some common species which would be classified as shrub land are mountain mahogany, sagebrush, and scrub oaks.

4.121 Deciduous Shrubland - areas where 75% or more of the land cover can be determined to be shrubs which loose all their leaves for a specific season of the year.

4.1211 Cold Deciduous Shrubland - area dominated by shrubs that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus sinuata, Rubis sp., Smilax Sp.*

4.1212 Drought Deciduous

4.122 Evergreen Shrubland - areas where 75% or more of the land cover can be determined to be shrubs which keep their leaves year round.

4.1221 Broad-leafed Evergreen Shrubland - area dominated by evergreen shrubs that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus havardii, Quercus fusiformis.*

4.1222 Needle-leafed Evergreen Shrubland – area dominated by evergreen shrubs with slender elongated leaves. Example species include: *Juniperus ashei, Juniperus virginiana.*

4.123 Mixed Shrubland - areas dominated by shrubs where neither deciduous nor evergreen species represent more than 75% of the land cover.

4.124 Desert Scrub - land areas predominantly in arid and semi-arid portions of the southwestern U.S. Existing vegetation is sparse and often covers only 5-25% of the land. Example species include sagebrush, creosote, saltbush, greasewood, and cacti.

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[2] Interagency LULC Working Group, GIS Managers Committee, Texas Geographic Information Council. Texas Land Classification System. October 1999.

4.13 Planted/Cultivated Woody (Orchards/Vineyards/Groves) – areas containing plantings of evenly spaced trees, shrubs, bushes, or other cultivated climbing plants usually supported and arranged evenly in rows. Includes orchards, groves, vineyards, cranberry bogs, berry vines, and hops. Includes tree plantations planted for the production of fruit, nuts, Christmas tree farms, and commercial tree nurseries. Exclude pine plantations and other lumber or pulp wood plantings, which will be classified as Forest.

4.131 Irrigated Planted/Cultivated Woody - orchards, groves, or vineyards where a visible irrigation system is in place to supply water

4.132 Citrus - trees or shrubs cultivated in orchards or groves that bear edible fruit such as orange, lemon, lime, grapefruit, and pineapple.

4.133 Non-managed Citrus - orchards or groves containing fruit bearing trees or shrubs which are no longer maintained or harvested by humans.

Evidence of non-managed citrus includes the growth of non citrus shrubs, trees, and grasses within an orchard or grove.

4.14 Woodland – Open stands of trees with crowns not usually touching (25- 59% cover).

4.141 Deciduous Woodland - area dominated by trees where 75% or more of the canopy cover can be determined to be trees which loose all their leaves for a specific season of the year.

4.1411 Cold Deciduous Woodland – area dominated by trees that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus stellata, Quercus marilandica, Juglans nigra, Quercus alba.*

4.142 Evergreen Woodland - area dominated by trees where 75% or more of the canopy cover can be determined to be trees which maintain their leaves all year.

4.1421 Broad-leafed Evergreen Woodland - area dominated by evergreen trees that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus virginicus, Quercus fusiformis.*

4.1422 Needle-leafed Evergreen Woodland - area dominated by evergreen trees with slender elongated leaves. Example species include: *Pinus palustris, Pinus taeda, Juniperus virginiana*.

4.143 Mixed Woodland - areas dominated by trees where neither deciduous nor evergreen species represent more than 75% of the canopy cover.

4.2 Herbaceous Vegetation - areas dominated by non-woody plants such as grasses, forbs, ferns and weeds, either native, naturalized, or planted. Trees must account for less than 25% canopy cover while herbaceous plants dominate all existing vegetation.

4.21 Natural Herbaceous - areas dominated by native or naturalized grasses, forbs, ferns and weeds. It can be managed, maintained, or improved for ecological purposes such as weed/brush control or soil erosion. Includes vegetated vacant lots and areas where it cannot be determined whether the vegetation was planted or cultivated such as in areas of dispersed grazing by feral or domesticated animals. Includes landscapes dominated by grass-like plants such as bunch grasses, palouse grass, palmetto prairie areas, and tundra vegetation, as well as true prairie grasses.

4.211 Natural Grasslands - natural areas dominated by true grasses. Includes undisturbed tall-grass and short-grass prairie in the Great Plains of the U.S.

4.2111 Short Grasslands – natural areas dominated by Graminoid vegetation usually less than 0.5 meters tall when inflorescences are fully developed. Example species include:
Bouteloua eriopoda,
Bouteloua gracilis, Buchloe dactyloides.

4.2112 Medium – Tall Grasslands – natural areas dominated by graminoid vegetation usually more than 0.5 meters tall when inflorescences are fully developed. Example species include:
Paspalum sp., Schizachyrium scoparium, Andropogon gerardii, Panicum virgatum.

4.212 Natural Forb – natural areas dominated by broad-leaved herbaceous plants. Example species include: *Giant Ragweed, Bigelowia nuttallii.*

4.22 Planted/Cultivated Herbaceous - areas of herbaceous vegetation planted and/or cultivated by humans for agronomic purposes in developed settings. The majority of vegetation in these areas is planted and/or maintained for the production of food, feed, fiber, pasture, or seed. Temporarily flooded are included in this category. Do not include harvested areas of naturally occurring plants such as wild rice and cattails.

4.221 Fallow/Bare Fields - areas within planted or cultivated regions that have been tilled or plowed and do not exhibit any visible vegetation cover.

4.222 Small Grains - areas used for the production of grain crops such as wheat, oats, barley, graham, and rice. Category is difficult to distinguish
from cultivated grasses grown for hay and pasture. Indicators of small grains may be a less than 10% slope, annual plowing and seeding, distinctive field patterns and sizes, different timing of green-up and harvest, different harvesting practices, a very "even" texture and tone, or regional variations discovered during field checks.

4.2221 Irrigated Small Grains - areas used for the production of small grain crops where a visible irrigation system is in place to supply water including the flooding of entire fields. Category includes rice fields. Presence of irrigation system does not guarantee that the field is irrigated. The specific small grain crops that follow while difficult to classify compared to specific row crops were included for sake of completion.

4.2222 Non-Irrigated Small Grains – Denotes fields without any visible sign of irrigation system.

4.223 Row Crops - areas used for the production of crops or plants such as corn, soybeans, vegetables, tobacco, flowers and cotton. Fields which exhibit characteristics similar to row crops, but that do not have any other distinguishing features for a more specific category may be included.

4.224 Specialty Crops - includes vegetables such as potatoes, tomatoes and fruits such as cantaloupe, and watermelon.

4.225 Cultivated Grasses - areas of herbaceous vegetation, including perennial grasses, legumes, or grass-legume mixtures that are planted by humans and used for erosion control, for seed or hay crops, for grazing animals, or for landscaping purposes

4.2251 Irrigated

4.22511 Pasture/Hay - areas of cultivated perennial grasses and/or legumes (e.g., alfalfa) used for grazing livestock or for seed or hay crops. Pasturelands can have a wide range of cultivation levels. It can be managed by seeding, fertilizing, application of herbicides, plowing, mowing, or baling. Pastureland has often been cleared of trees and shrubs, is generally on steeper slopes than cropland, and is intended to graze animals at a higher density than open rangeland, and is often fenced and divided into smaller parcels than rangeland or cropland. Hay fields may be more mottled than small grain fields as they are not plowed annually and may be harvested and baled two or three times a year in some locations.

4.22512 Turf - areas growing grasses such as St. Augustine for yards.

4.2252 Non-irrigated Cultivated Grasses

4.22521 Pasture

4.22522 Turf

4.226 Other cultivated

4.3 Vegetated Wetland - areas where the water table is at, near, or above the land surface for a significant part of most years and vegetation indicative of this covers more than 25% of the land surface. Wetlands can include marshes, swamps situated on the shallow margins of bays, lakes, ponds, streams, or reservoirs; wet meadows or perched bogs in high mountain valleys, or seasonally wet or flooded low spots or basins. Do not include agricultural land, which is flooded for cultivation purposes.

4.31 Woody Wetland - areas dominated by woody vegetation. Includes seasonally flooded bottomland, mangrove swamps, shrub swamps, and wooded swamps including those around bogs. Wooded swamps and southern flood plains contain primarily cypress, tupelo, oaks, and red maple. Central and northern flood plains are dominated by cottonwoods, ash, alder, and willow. Flood plains of the Southwest may be dominated by mesquite, salt cedar, seepwillow, and arrowweed. Northern bogs typically contain tamarack or larch, black spruce, and heath shrubs. Shrub swamp vegetation includes alder, willow, and buttonbush.

4.311 Forested Wetland – area with tree canopy greater than 25%, surface water present or saturated soils present for variable periods, which may or may not have detectable seasonality.

4.3111 Riparian Forest – tree dominated wetlands along river or stream courses.

4.31111 Seasonally flooded - tree dominated area on which surface water or soil saturation is present for extended periods during the growing season, but is absent by the end of the growing season in most years. Example species include: *Quercus*

laurifolia, Fraxinus pennsylvanica, Nyssa sp., Acer rubrum, Liquidambar styraciflua, Ulmus americana

4.31112 Temporarily Flooded – tree dominated area on which surface water is present for brief periods during the growing season. Example species include: *Quercus virginiana, Celtis laevigata, Carya illinoinensis, Ulmus crassifolia, and Platanus occidentalis.*

4.3112 Swamp – tree dominated area on which surface water persists throughout the growing season, except during drought years. Example species include: *Nyssa aquatica, Taxodium distichum.*

4.312 Shrub Wetland – wetland with shrub canopy cover greater than 25%.

4.3121 Tidal – shrub dominated wetlands with less than 25% tree canopy cover, tidal (usually saline to some extent) water covers land surface, usually on a daily cycle. Example species include: *Tamarix Sp., Baccharis halimifolia, Avicennia germinans.*

4.3122 Non-Tidal – wetlands with greater 25% shrub cover and less than 25% tree cover. Usually fresh water inundation, includes seasonal and greater flooding regimes. Example species include: *Arundinaria gigantea, Baccharis salicifolia, Salix Sp.*

4.32 Emergent Herbaceous Wetlands - areas dominated by wetland herbaceous vegetation which is present for most of the growing season. Includes fresh-water, brackish-water, and salt-water marshes, tidal marshes, mountain meadows, wet prairies, and open bogs.

4.321 Marsh – Herbaceous fresh water wetlands, dominated by rooted vascular emergent herbaceous vegetation. Example species include: *Typha sp., Juncus effusus, Rhynchospora sp., Scirpus americanus, Colocasia esculenta, Ludwigia Sp., Sagitaria Sp.*

4.3211 Prairie Pothole – off channel, isolated wetlands. Usually depressions in the landscape. Common in the panhandle region of Texas.

4.322 Tidal Marsh - wetland areas dominated by saline herbaceous vegetation, water depth and/or inundation usually changing on a daily cycle. Example species include: *Spartina patens, Spartina alternaflora, Scirpus pungens, Juncus roemerianus, and Phragmites australis.*

Appendix C – Reservoir List

Bedias
Brownsville Weir
Brushy Creek
Cedar Ridge
Cuero 2
Fastrill 274
George Parkhouse 1
George Parkhouse 2
Lower Bois D'Arc
Marvin Nichols 1
Nueces Off Channel
Palmetto Bend 2
Ralph Hall
Ringgold
Tehaucana
Wilson Hollow