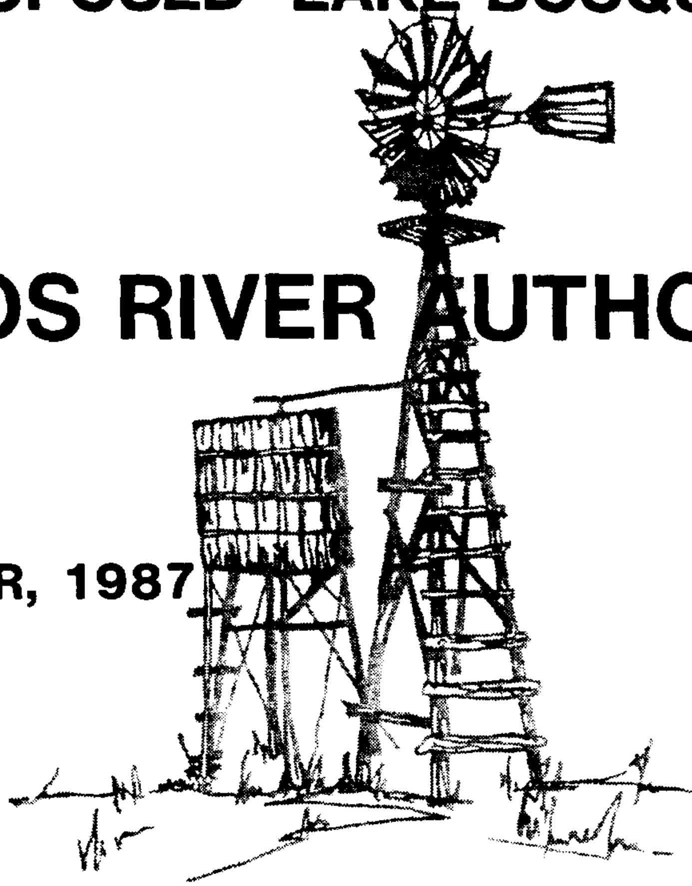
8-483-522

REPORT TO BRAZOS RIVER AUTHORITY
& LAKE BOSQUE PROJECT PARTICIPANTS

ANALYSIS OF PROJECT ALTERNATIVES FOR PROPOSED LAKE BOSQUE PROJECT



BRAZOS RIVER AUTHORITY

SEPTEMBER, 1987

HDR Infrastructure, Inc.
A Centerra Company

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Water Resources
Wastewater
Hazardous Waste
Bridges
Transportation
Industrial
Geoprocessing

September 15, 1987

Mr. Carson Hoge
General Manager
Brazos River Authority
4400 Cobbs Drive
Waco, Texas 76714-7555

Dear Mr. Hoge:

HDR Infrastructure, Inc., is pleased to submit this report that analyzes project alternatives for the Lake Bosque Project. Since the Lake Bosque Project is linked with operation of Lake Waco, where enlargement is planned, the report also addresses water demand as influenced by water conservation in all of Bosque and McLennan Counties where the project participants are located.

The demand for water supply in the two-county area, after accounting for reasonable levels of water conservation, clearly supports the need for construction of Lake Bosque as well as the planned Lake Waco Enlargement. Long-term water demands could grow to more than 110,000 acre-feet per year by the yer 2040. Lake Waco's long-term supply of 65,574 acre-feet per year is committed to the City of Waco. According to projections of the City's growth in municipal water demand and their role as the region's supplier to manufacturing water uses, the existing yield of Lake Waco is inadequate to serve additional municipal customers or more than a near-term amount of additional manufacturing use.

Alternatives for water supply in the area must envision the development of new surface-water sources. Groundwater pumpage has overdrafted the available supply from the Trinity Aquifer underlying the area. This has been recognized by the Texas Water Commission in its inclusion of Bosque and McLennan Counties in a designated Critical Groundwater Management Area. Surface water supplies in the area are influenced by existing water supply projects and periodic high levels of total dissolved solids in the Brazos River.

Five alternatives were fitted within the setting of available surface water resources in the area to determine the most economically feasible and environmentally acceptable project to supply water for the eight participants' long-term water demands. The alternatives are:

- Bosque River Reservoir
- Leon River Reservoir
- Diversion and Off-Channel Storage, Brazos River
- Wastewater Reuse
- Lake Whitney

Each alternative delivers the same amount of treated water, 17,900 acre-feet per year, to the same delivery points for the customers. Treated water costs were selected as a basis of comparison because total dissolved solids levels in the raw water from the Lake Whitney alternative and the Brazos River alternative require a higher level of water treatment than the other alternatives to be suitable sources of supply.

This alternatives analysis found that all five alternatives appeared technically feasible and environmentally acceptable. Therefore, the participants' costs for development of the alternative supply sources was used as a basis for selecting the recommended project. Lake Bosque, sited on the North Bosque River four miles north of the City of Meridian and storing 102,909 acre-feet of water at conservation pool level, is the least costly alternative for the participants. The alternatives can be compared as follows:

- Bosque River Reservoir	$1.42/1,000 gallons
- Leon River Reservoir	$2.43/1,000 gallons
- Diversion and Off-Channel Storage, Brazos River	$2.69/1,000 gallons
- Wastewater Reuse	$1.72/1,000 gallons
- Lake Whitney	$2.66/1,000 gallons

Unit water costs shown are weighted averages for all eight participants.

Our analysis shows that construction of Lake Bosque is the best alternative project to serve the participants. The assistance that you and your staff have provided has been most helpful as we have worked toward completing this project.

Sincerely,

HDR Infrastructure, Inc.

G.E. Kretzschmar, Jr., P.E.
Project Manager

GEK:bb

REPORT CERTIFICATION

I certify that this report was prepared by me or under my direct supervision.

STATE OF TEXAS
G. E. KRETZSCHMAR, JR.
45637
REGISTERED
PROFESSIONAL ENGINEER

G.E. Kretzschmar, Jr., P.E.

Registered Professional Engineer,
Texas, No. 45637

Date: September 15, 1987

HDR Infrastructure, Inc.
3000 South IH-35, Suite 400
Austin, Texas 78704

ANALYSIS OF PROJECT ALTERNATIVES

FOR

PROPOSED LAKE BOSQUE PROJECT

Prepared for

BRAZOS RIVER AUTHORITY

By

HDR Infrastructure, Inc.

September, 1987

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SECTION 1 - INTRODUCTION

A dependable water supply source capable of meeting their long range (50 year) water requirements is needed by the Cities of Clifton and Meridian in Bosque County, Texas; by the Cities of Lacy-Lakeview, Hewitt, Woodway, Bellmead, and Waco in McLennan County, Texas; and by McLennan County WCID (Elm Mott) in McLennan County. The seven cities and the district have agreed to participate in a regional water supply project sponsored by the Brazos River Autority. At present, all these participants, except the City of Waco, meet nearly all of their water supply needs from groundwater.

The City of Waco has an adequate amount of surface water from Lake Waco to meet its near term needs, but since the water supply demands for Bosque and McLennan Counties far exceed the current yield of Lake Waco, the City has agreed to participate in the Lake Bosque project to enable optimum development of that reservoir site for long-term municipal needs of the area. This action also assures the availability of water supply for further industrial development in McLennan County. The other cities realize that expansion of groundwater supply capacity would be the most economical alternative water supply for them if the local groundwater aquifer could meet their needs. However, the characteristics of the aquifer inhibit transmissivity and recharge rates. Due to the aquifer's characteristics and prolonged overdrafting, groundwater cannot continue to meet their needs. Existing surface water sources with suitable water quality within reasonable distance to the project participants are already contractually committed to other entities and are, therefore, not available. Additionally, any uncommitted surface water available from the implementation of water conservation measures and a more extensive use of groundwater supplies, discussed in Sections 2 and 3 respectively. Neither of these two alternatives individually nor both combined provide an adequate, reliable supply to meet the demands of the project participants. However, water conservation is expected to reduce the long range water needs of the participants and its impact is included in water demand projections for the entities.

Section 4 describes the various surface water alternatives that were evaluated. These include four variations on the location of the Lake Bosque site, an alternative for use of Leon River water, diversion and off-channel storage of Brazos River flood waters, reuse of wastewater, and use of Lake Whitney water. The various alternatives are compared and discussed in Section 5. The recommended alternative is the Lake Bosque reservoir project located at river mile 58.3 on the North Bosque River, 4 miles north of the City of Meridian. A detailed description of the project follows in Section 4.1.4.

population growth versus projected high population growth and the related difference in manufacturing water demands. Estimates of population growth available from other sources, as discussed in the PPA Report, generally track or exceed the TWDB's high population growth projection. The TWDB low population growth projection indicates a 43% increase by 2040, while the TWDB high growth projection indicates a 73% increase.

A review of per capita water use (in gallons per capita per day, GPCD) by the Lake Bosque participants in 1980 indicates a wide disparity in consumption rates according to TWDB data:

Participant	Year 1980 Water Use (GPCD)
Clifton	197
Meridian	77
Lacy-Lakeview	207
Hewitt	144
Woodway	213
Bellmead	177
Waco	261
McLennan Co. WCID No. 2	126

Of the participants, the City of Waco has the best developed supply and distribution system and since its water is not unreasonably costly, its citizens were able to use essentially all of the water they needed. During this same period, the City of Meridian's supply and distribution sytems reached the maximum they were capable of delivering and water use was restricted. In the 1984 short-term drought, some of the participants experienced water shortages and had to implement emergency water use restrictions.

With regard to future per capita demands, TWDB has projected that per capita water use of all the participants will increase until about the year 2000 and then should remain constant due to the influence of water conservation. The TWDB projected conservation influenced rates and the rates without conservation after the year 2000 are as follows:

Participant	Normal/Drought Water Demand (GPCD) With Conservation	Normal/Drought Water Demand (GPCD) Without Conservation
Clifton	166/224	182/240
Meridian	117/175	133/191
Lacy-Lakeview	127/185	143/201
Hewitt	110/168	126/184
Woodway	148/206	164/222
Bellmead	106/164	122/180
Waco	227/285	243/301
McLennan County WCID No. 2	135/182	151/198

These conservation-influenced per capita water use rates have been adopted for projecting water demand for the Bosque project.

The rates reflected as normal demands in the TWDB projections should occur in most years and the drought demand rate will occur only in those periods of severe rainfall reduction when water is needed most. The demands presented earlier for 1980 were for a drought-like period extending only slightly longer than one year. The drought of record for this area is about five years, so water use can be expected to be greater than in 1980. Note, however, that TWDB's drought usage projection for the City of Waco for year 2040 is only 9% greater than actual usage in 1980 according to their record of 261 gpcd. The City reports slightly greater average annual per capita usage for 1980. High per capita use in 1980 is due, in large part, to the City having water system capacity adequate to meet all demands at that time.

The water demand projections presented in the PPA Report incorporate drought per capita demands.

2.2 Water Conservation Effects

As increased water supplies become available to those participants now depending on inadequate water supplies, increased water usage will occur, since the influence of supply shortages will be removed. The trend toward increasing per capita usage will necessitate a concerted water conservation program to ensure that water is used wisely.

The Brazos River Authority (BRA), in accordance with its Water Conservation Policy, is developing and will implement a specific water conservation program for the recommended alternative project to ensure the wise and efficient use of existing and future water supplies. The applicable water conservation measures of the BRA, as a regional raw water supplier, will be somewhat different from the specific water conservation measures applicable within the participants' water systems. Implementation of the participants' water conservation programs will be their individual responsibilities.

The expected influence of water conservation programs incorporated into the demand projections is shown below:

	With/Without Water Conservation	Conservation Reduction Effect
McLennan County		
Normal Demand	185/201 GPCD	8.0%
Drought Demand	242/258 GPCD	6.2%
Bosque County		
Normal Demand	133/149 GPCD	10.7%
Drought Demand	187/203 GPCD	7.9%

The above figures are based on county-wide projections that include the project participants as well as other entities.

TABLE 2-1

PROJECTED 2040 MUNICIPAL AND MANUFACTURING WATER NEEDS

PARTICIPANTS	POPULATION	DROUGHT WATER DEMAND WITH CONSERVATION (gpcd)	PROJECTED WATER DEMAND (AF/Year)	(mgd)
Project Participants				
Bellmead	16,183	164	2,973	2.65
Clifton	7,388	224	1,854	1.65
Hewitt	8,838	168	1,663	1.48
Lacy-Lakeview	5,012	185	1,039	0.93
Northcrest *	5,169	165	955	0.85
McLennan Co. WCID #2	1,777	182	362	0.32
Meridian	3,303	175	647	0.58
Waco	160,199	285	51,142	45.66
Beverly Hills *	4,006	308	1,382	1.23
Woodway	19,858	206	4,582	4.09
Subtotal	231,733		66,599	59.46
Potential Municipal Customers				
Bruceville-Eddy	1,851	168	348	0.31
Mart	3,758	252	1,061	0.95
Moody	2,643	167	494	0.44
West	4,059	192	873	0.78
Rural Bosque County	17,575	166	3,268	2.92
Rural McLennan County	32,266	180	6,505	5.81
Subtotal	62,152		12,549	11.20
Manufacturing				
Bosque County			356	0.32
McLennan County			26,231	23.42
Subtotal			26,587	23.74
TOTAL	293,885		105,735	94.40

* Water currently being supplied through a participant.

Authority's permitted yield from the above percentage of Lake Whitney's storage space is presently committed to meet the Brazos River Basin water supply needs. Use of the remaining storage space in Lake Whitney for future water supply needs would be contingent on the approval of the U.S. Congress and the acquiring of a water right permit from the Texas Water Commission. The storage is now used by the Corps of Engineers to generate hydroelectric energy, which is marketed through the Southwestern Power Administration to the Brazos Electric Power Cooperative. An additional major factor to be considered is the fact that the waters of Lake Whitney contain high levels of dissolved solids that represent an expensive water treatment problem. Therefore, the allocation of existing and planned Lake Whitney supplies to meet future demands in the Bosque-McLennan County region by TWDB is probably not a viable alternative at this time.

The principal problem recognized by the project participants in the TWDB's long-range projections is that of almost total reliance on Lake Whitney for supplying manufacturing water demands. Due to the apparent problems with using Lake Whitney as a supply source, it must be dismissed if another source of fresh water is reasonably available.

TWDB's long-range projections also assign the water supply yield of Aquilla Reservoir to meet demands in the project area. The total dependable yield of Aquilla Reservoir has been contractually committed by the Brazos River Authority to other entities in the Brazos River Basin.

Based on the information presented above concerning water supply sources and demands for water supply presented in Table 2-1, Table 2-2 has been developed to show the realistic allocation of the two county project area's year 2040 high water demand projections for municipal use and manufacturing use to an existing or proposed water supply source.

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The expected influence of water conservation programs incorporated into the demand projections is shown below:

	With/Without Water Conservation	Conservation Reduction Effect
McLennan County		
Normal Demand	185/201 GPCD	8.0%
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Bosque County		
Normal Demand	133/149 GPCD	10.7%
Drought Demand	187/203 GPCD	7.9%

The above figures are based on county-wide projections that include the project participants as well as other entities.

According to guidelines for water conservation programs issued by TWDB an effective program will normally reduce water demands from 5% to 15%, with maximum reductions seldom exceeding 25%. The conservation reductions shown above reduced the total water demand in Section 2.1 that would otherwise be projected at the year 2040 by 5,266 AF/Year (4.70 MGD) or 4.8%. On a municipal water demand basis, the reduction is 6.4%.

2.3 Selected Water Demand

Long-term water supply project alternatives often have fixed, rather than variable, ultimate capacities. Therefore, it is necessary to establish a selected design water demand to guide the development of alternative projects and project capacities. Several characteristics of raw water supply projects should be considered in the process of determining the appropriate level of design water demand. These are:

1) Project works are durable and long-lived, requiring substantial capital outlays of public funds. The public's investment should purchase an efficient, long-term water supply.

2) Ultimate capacities of facilities, particularly dams and withdrawal structures, are built-in at construction and modification is difficult and costly, if not impossible. The initial facilities should be fully adequate for long-term service.

3) Surface water development reservoirs are normally sized to deliver a dependable yield of water supply during a repeat of the drought of record. Dependable yield for the proposed Lake Bosque project means the maximum amount of water that can be withdrawn from the reservoir every year without ever completely depleting reservoir storage. The same below-average rainfall conditions that created the critical period of low water runoff used to determine dependable or firm yield also drive per capita water demand upward. Therefore, drought condition water demands are appropriate for evaluating municipal water demand projections.

4) Optimal development of water supply projects results in lowest, long-term water costs and best serves the public interest. Therefore, facilities should be designed for optimum capacity whenever possible.

5) The raw water supply increment of a total water system's capital outlays varies widely, but is generally about one-third of the

total cost. Other increments of the total system are dependent on the adequacy of the raw water supply and can be implemented in phases. Therefore, more conservative estimates of future demands are more suitable for sizing treatment and some distribution facilities, while more optimistic demands are appropriate for sizing raw water facilities.

Based on the above characteristics, the adoption of high/optimistic water demand projections is justified as a design goal for developing a surface water supply source. Table 2-1 presents the high water demand projection for the year 2040 for the project participants, other potential municipal customers and manufacturing uses in the two county area. Section 5.0, below, discusses the recommended project alternative and justifies its development as a surface water supply project in order to meet projected future water demands in the Bosque and McLennan County areas.

2.4 Existing Supplies

The TWDB's long-range projections allocate existing and planned surface and ground water supply sources to the meeting of present and projected water demands. According to TWDB projections, which now extend only to the year 2030, Lake Waco is to supply nearly all of the municipal water use for the area and Lake Whitney is to supply essentially all of the area's manufacturing water use. Aquilla Creek Reservoir, the Trinity Aquifer and other local supply sources (direct diversion) account for the balance of the projected water supply to meet water demands. TWDB also includes some unmet shortages. Sources other than Lake Waco and Lake Whitney, combined with the shortage in supply, or demand for other new projects, amount to approximately 6.2% of the total supply (and demand) as projected to the year 2040.

The Brazos River Authority has contracted with the Corps of Engineers to use 22.017% of the usable storage space in Lake Whitney. The

TABLE 2-1

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Bosque County			356	0.32
McLennan County			26,231	23.42
Subtotal			26,587	23.74
TOTAL	293,885		105,735	94.40

* Water currently being supplied through a participant.

Authority's permitted yield from the above percentage of Lake Whitney's storage space is presently committed to meet the Brazos River Basin water supply needs. Use of the remaining storage space in Lake Whitney for future water supply needs would be contingent on the approval of the U.S. Congress and the acquiring of a water right permit from the Texas Water Commission. The storage is now used by the Corps of Engineers to generate hydroelectric energy, which is marketed through the Southwestern Power Administration to the Brazos Electric Power Cooperative. An additional major factor to be considered is the fact that the waters of Lake Whitney contain high levels of dissolved solids that represent an expensive water treatment problem. Therefore, the allocation of existing and planned Lake Whitney supplies to meet future demands in the Bosque-McLennan County region by TWDB is probably not a viable alternative at this time.

The principal problem recognized by the project participants in the TWDB's long-range projections is that of almost total reliance on Lake Whitney for supplying manufacturing water demands. Due to the apparent problems with using Lake Whitney as a supply source, it must be dismissed if another source of fresh water is reasonably available.

TWDB's long-range projections also assign the water supply yield of Aquilla Reservoir to meet demands in the project area. The total dependable yield of Aquilla Reservoir has been contractually committed by the Brazos River Authority to other entities in the Brazos River Basin.

Based on the information presented above concerning water supply sources and demands for water supply presented in Table 2-1, Table 2-2 has been developed to show the realistic allocation of the two county project area's year 2040 high water demand projections for municipal use and manufacturing use to an existing or proposed water supply source.

TABLE 2-2

SUPPLY SOURCES PLANNED TO MEET PROJECTED 2040 MUNICIPAL AND MANUFACTURING WATER NEEDS (AF/year)

PARTICIPANT	TRINITY AQUIFER	EXISTING LAKE WACO	PROPOSED LAKE WACO ENLARGEMENT	PROPOSED LAKE BOSQUE	PLANNED LOCAL PROJECTS	UNMET FUTURE DEMANDS	TOTAL SUPPLY
Municipal Customers							
Bellmead	0	0	0	2,973	0	0	2,973
Clifton	0	0	0	1,854	0	0	1,854
Hewitt	0	0	0	1,663	0	0	1,663
Lacy-Lakeview	0	0	0	1,039	0	0	1,039
Northcrest *	0	0	0	955	0	0	955
McLennan Co. WCID #2	0	0	0	362	0	0	362
Meridian	0	0	0	647	0	0	647
Waco	0	51,142	0	0	0	0	51,142
Beverly Hills *	0	1,382	0	0	0	0	1,382
Woodway	0	0	0	4,582	0	0	4,582
Subtotal	0	52,524	0	14,075	0	0	66,599
Potential Municipal Customers							
Bruceville-Eddy	0	0	348	0	0	0	348
Mart	0	0	0	1,061	0	0	1,061
Moody	0	0	0	494	0	0	494
West	0	0	873	0	0	0	873
Rural Bosque County	1,354	0	0	1,914	0	0	3,268
Rural McLennan County	566	5,939	0	0	0	0	6,505
Subtotal	1,920	5,939	1,221	3,469	0	0	12,549
Non-Customer Municipalities							
McGregor	1,538	0	0	0	0	0	1,538
Robinson	0	0	0	0	2,698	0	2,698
Valley Mills	591	0	0	0	0	0	591
Subtotal	2,129	0	0	0	2,698	0	4,827
Manufacturing							
Bosque County	0	0	0	356	0	0	356
McLennan County	143	6,211	13,075	0	0	6,802	26,231
Subtotal	143	6,211	13,075	356	0	6,802	26,587
TOTAL MUNICIPAL & MANUFACTURING	4,192	64,674	14,296	17,900	2,698	6,802	110,562
Existing Irrigation Permit		900					
TOTAL		65,574					

* Water currently being supplied through a participant.

As indicated in Section 1, above, the recommended alternative is the Lake Bosque Reservoir Project which is described in Section 4.1.4. The participating entities listed below have recognized the need for this project and have agreed to share the dependable yield of the project and the associated project costs on the following basis:

Participant	Project Share %
Clifton	10.92
Meridian	7.71
Lacy-Lakeview	12.68
Hewitt	17.76
Woodway	18.16
Bellmead	17.52
Waco	12.33
McLennan County WCID No. 2	2.92
	100%

The practical aspect of adjusting contracted water supply with future demands of potential municipal customers, as is suggested by Table 2-2, is addressed in the participants' contracts for constructing and operating the proposed project. According to their contracts, participants may buy and sell treated water from Lake Bosque among themselves and to new customer entities. This provision assures that this important supply project will provide water service when and where it is needed.

2.5 Water Demand for Lake Bosque Alternatives Analyses

The 2040 projected water use of the participants, based on drought per capita use rates, the projected demands of other potential surface water users (immediate neighbors) who will eventually need to share in this planned water supply project, and the projected manufacturing demands of Bosque and McLennan Counties total 105,735 AF/Yr (94.41 mgd). This is the quantity of water that is associated with the upper range of projections in the previously mentioned Paul Price Associates Report, after adjustments for supplying the Cities of Beverly Hills and West, and was identified as a design demand goal for sizing alternative projects. A comparison of 2040 water supply demands with existing and future surface water supplies is shown in tabular form below:

2040 Project Area Water Demands		105,735 AF/Year
Less;		
2040 Lake Waco (w/o enlargement) Supply	65,574 AF/Year	
less existing irrigation permit	900 AF/Year	
		-64,674 AF/Year
2040 Demand for New Supplies		41,061 AF/Year
Less;		
Proposed 2040 Lake Bosque Supply		-17,900 AF/Year
Proposed 2040 Lake Waco Enlargement Supply		-14,296 AF/Year
Unmet 2040 Demand		8,865 AF/Year

It is assumed that the unmet demands for water in 2040, totalling 8,865 AF/Year, will be met from safe pumpage of groundwater resources and future, more expensive surface water development projects.

When the participant's project shares shown in Section 2.4, above, are summed on a county-wide basis, the results show that 18.63% of the project is contracted for by Bosque County entities and 81.37% by McLennan County entities. Applying these percentages to the estimated firm yield of the proposed Lake Bosque Project results in the following:

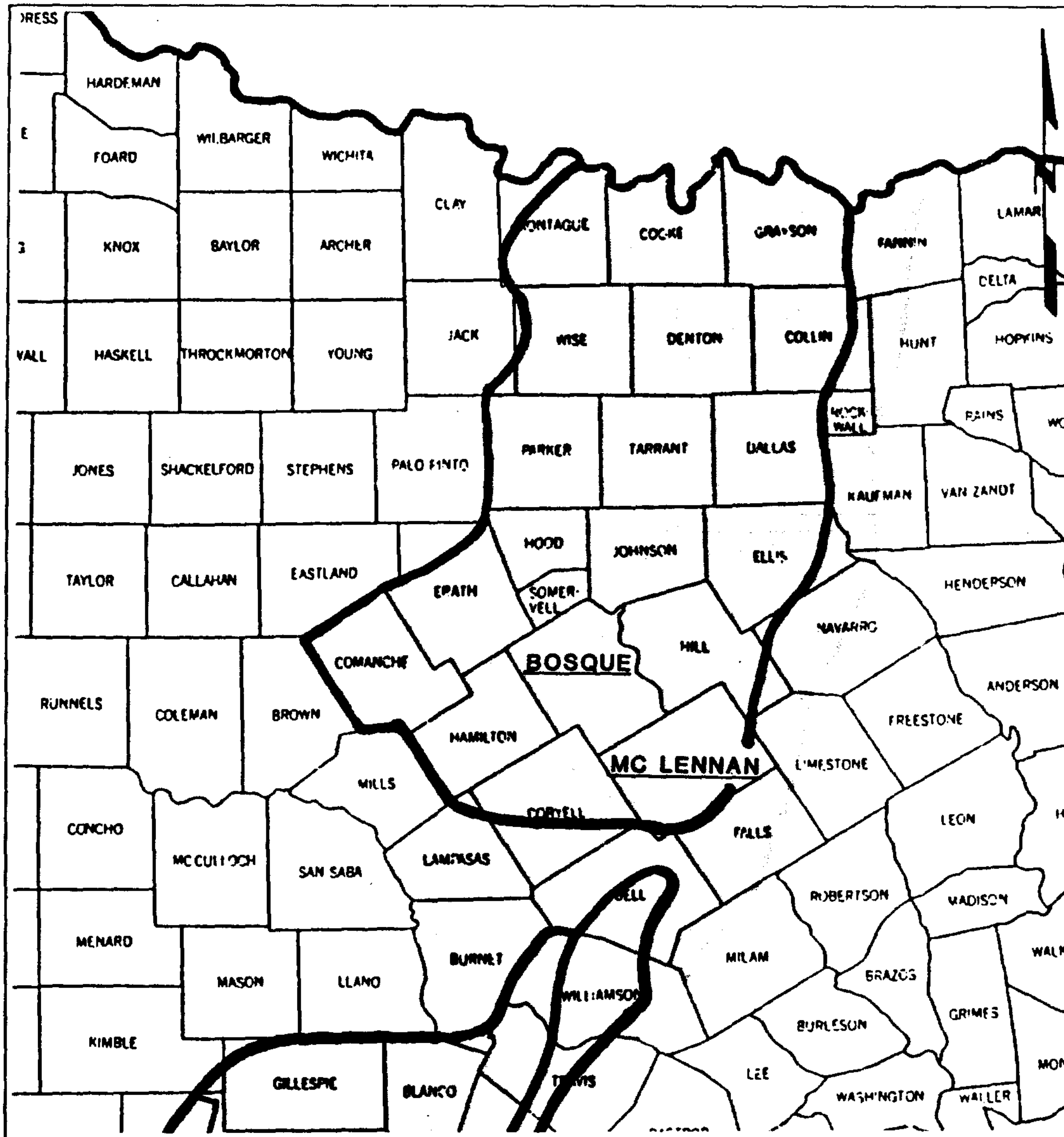
		Equivalent Water Needs	
	%	AF/Year	MGD
Bosque County	18.63	3,335	2.98
McLennan County	81.37	14,565	13.00
Total	100.00	17,900	15.98

In subsequent discussions of Lake Bosque alternatives to meet the participants' needs, those quantities listed above will be uniformly used to evaluate various project alternatives.

SECTION 3 - GROUNDWATER DEVELOPMENT

The economical development of existing groundwater resources within proximity of the participants is the first water supply alternative to be considered. All of the Lake Bosque participants, except for the City of Waco, now rely almost wholly on groundwater for their water supplies. Their well fields in Bosque and McLennan Counties are withdrawing water much faster than the natural recharge into the Trinity Group Aquifer that the area has been included in the Texas Water Commission's (TWC's) recently designated Critical Groundwater Management Area (see Figure 3-1). The TWC defines a critical area as one "that is experiencing serious groundwater problems or is expected to during the next 20 years."

Bosque and McLennan Counties are underlain by the Travis Peak formation of the aquifer. The Hensell and Hosston members of the Travis Peak formation have a fresh water thickness of 50 to 120 feet and are the primary source of groundwater throughout this portion of Central Texas. The Texas Water Development Board (TWDB), in their report, "Ground Water Resources of Central Texas, With Emphasis on the Antlers and Travis Peak Formations," studied the aquifer over a 15-county area which included Bosque and McLennan Counties. They used a computer model to determine the availability of water in the aquifer based on 1966 pumpage rates. Their findings regarding fully or overdeveloped areas of the aquifer and those areas which they found to be available for further development are illustrated in Figure 3-2. As can be seen from this map, the nearest possible area for developing additional groundwater supplies for the smaller cities surrounding the City of Waco is a strip along the eastern edge of the aquifer's fresh water zone. At the time of the report in 1966,



Areas proposed for detailed study by TWC/TWDB

Critical areas proposed by TWC July, 1986

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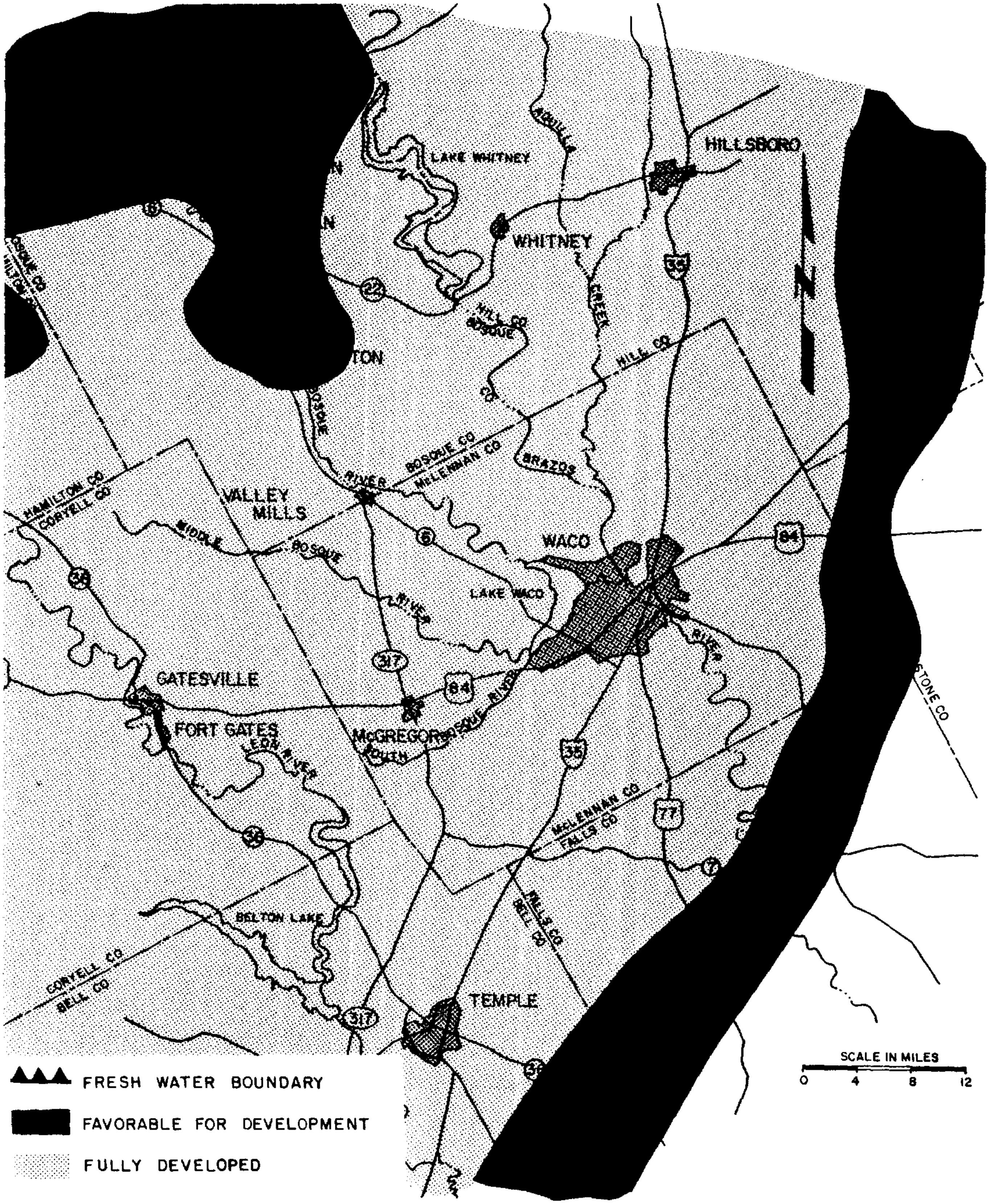
TRINITY GROUP AQUIFER

FIGURE 3-1



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TRINITY GROUP AQUIFER
AREAS FAVORABLE FOR
DEVELOPMENT
TWDB 1966

FIGURE
3-2

the TWDB determined that there was an additional 10,000 acre-feet per year (8.9 MGD) of groundwater available in the study area.

Based on continued declines in water levels in McLennan County water wells and an increase in pumpage since 1966, it can be assumed that at least part of this additional supply is now being used. For example, the water level in the TWDB's monitoring well at Waco (#40-32-501) has declined 217 feet since 1965. Another well near Robinson (#40-40-401) has declined 347 feet in the last 20 years, from 375 ft. msl to 28 ft. msl.

Bosque County currently derives almost all of its water supply from groundwater sources. The Hensell and Hosston members provide over 95% of municipal and industrial water supply in the county. Projections of water level decline for the Cities of Meridian and Clifton show that they have a potential groundwater supply for the next 20 to 30 years. These projections are based on the rate of water level declines since 1965 and on the assumption that further demands will be met by additional groundwater development. The conclusion that groundwater will meet Bosque County needs for 20 to 30 years assumes that continued pumpage of existing wells, expansion of well fields, and groundwater withdrawal in excess of safe pumpage levels will continue to be permissible.

The previous water supply study HDR performed for the Bosque County Water Committee evaluated groundwater recharge using spreading ponds and injection wells. Spreading ponds to recharge the Paluxy Aquifer outcrop north of the City of Meridian appeared to be feasible. However, field tests utilizing in situ pressure tests indicated that aquifer transmissivity characteristics were not adequate for an economically feasible recharge project. Injection wells into the Travis Peak formation were also considered as an alternative, however, capital costs and recurring operation and maintenance costs caused it to be more expensive than other alternatives, including the Lake Bosque alternative.

This study of injecting groundwater for future recovery addressed meeting only the needs of Bosque County, and while an evaluation of injection of groundwater to meet the needs of the McLennan County entities has not been performed, it can be assumed that the process would be at least as expensive to meet their needs as it would be to meet the Bosque County needs. Therefore, this alternative must be discarded since it would be more expensive than the Lake Bosque alternative. Also, this alternative, while technically feasible, would require extensive testing to assure it would be workable in the Travis Peak formation.

The cumulative total of water supply sought by the participating entities is 15.98 MGD. The existing supply available from the aquifer is probably no more than one-half of this amount. Therefore, it must be concluded that groundwater is not a dependable nor feasible long-term source to meet the participants' projected water needs.

SECTION 4 - SURFACE WATER DEVELOPMENT ALTERNATIVES

In order to evaluate the potential to provide the project participants with a long-term water supply, a wide range of surface water development alternatives were studied. These alternatives varied from the development of conservation storage reservoirs to the reuse of wastewater effluent. More specifically, the five alternatives considered were: (1) Bosque River Reservoir, (2) use of water diverted from a new Leon River reservoir identified as the Gatesville Reservoir, (3) diversion and off-channel storage of unappropriated Brazos River water, (4) wastewater reuse, and (5) release of stored Lake Whitney water and subsequent downstream diversion.

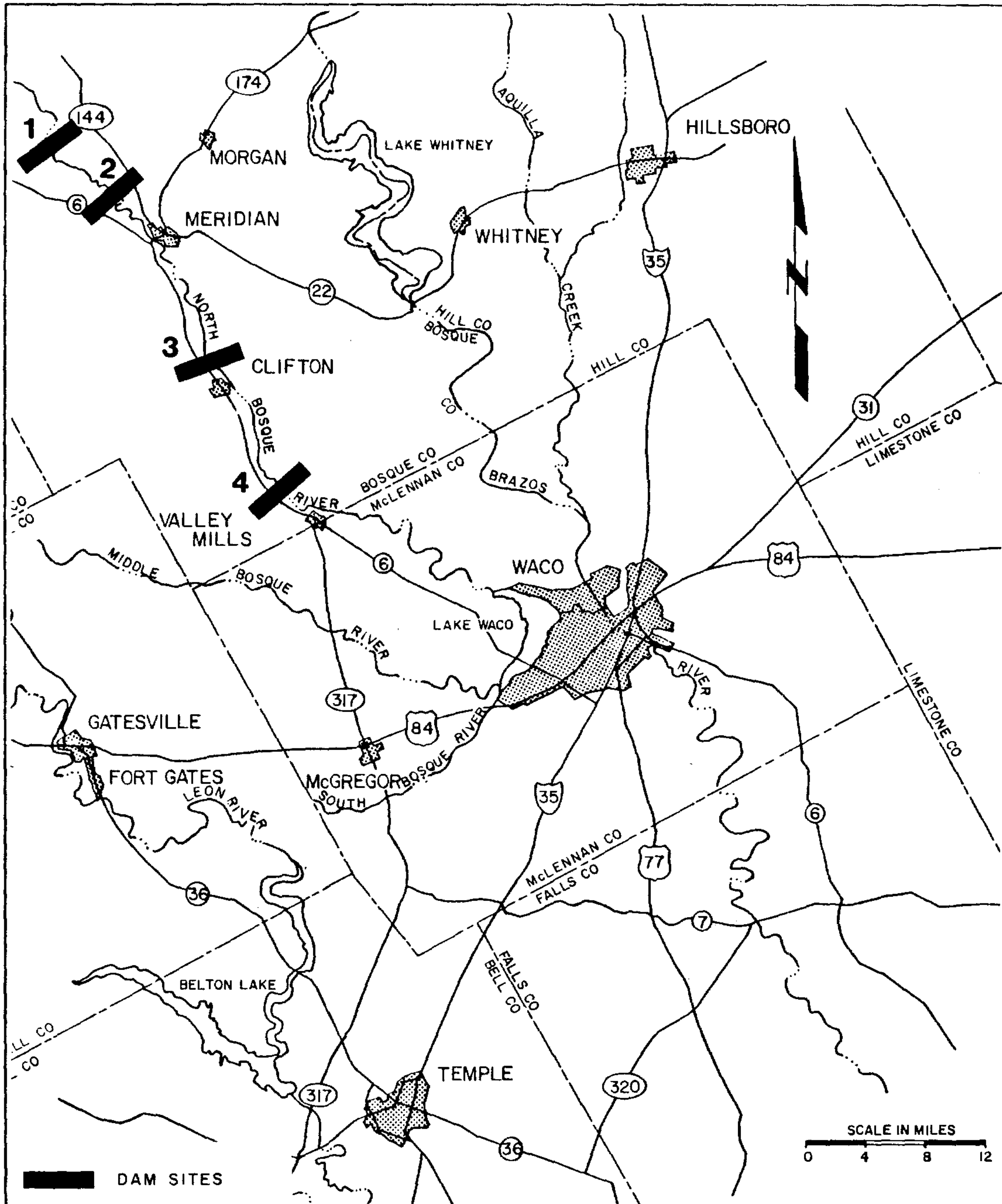
Raw water costs, treatment costs, and transmission costs were developed for each alternative and these costs serve as the basis for comparing the economic feasibility of the various alternatives. In all cases, capital costs have been assumed to be financed at 8% interest for a period of 25 years with uniform annual debt service payments. Costs associated with issuing debt, capitalized interest, management fees, and reserve fund requirement have not been included in calculations. For each alternative, costs were calculated for treated water delivered to appropriate distribution points for the project participants. It was assumed that the McLennan County participants' water would be treated and delivered through the City of Waco's expanded facilities for all alternatives. For some alternatives, the Bosque County entities would also use the City of Waco's treatment facilities. Each alternative project, including water treatment, is described in the following sections.

4.1 BOSQUE RIVER RESERVOIR ALTERNATIVE

The Bosque River sub-basin is controlled by Lake Waco very near its confluence with the Brazos River at Waco. Analysis of the hydrology of the basin shows that existing conservation storage in Lake Waco at elevation 455 feet above mean sea level (msl) or at the proposed enlargement to 462 feet msl does not fully develop the yield of the basin. Three tributaries of the Bosque River, the North, Middle, and South Bosque Rivers, converge in Lake Waco. Since the North Bosque River is the largest basin tributary, development of additional conservation storage on this stream was studied.

A previous study, "Water Supply Alternatives for Bosque County" (May, 1982) by HDR, showed that a reservoir on the North Bosque River was the most economical water supply project to meet the long term needs of Bosque County. That study evaluated various reservoir sites and found a site now identified as Lake Bosque to be the most economical. This study evaluated three additional sites on the North Bosque River that have favorable topographic characteristics while avoiding extensive relocations and compares them with the originally recommended site. These sites were selected after a thorough review of USGS maps which indicated these are the only sites that can develop reasonable storage without incurring extensive relocation costs. All of the selected sites are in Bosque County. (see Figure 4-1) The conservation storage volumes for these sites range from 29,200 acre-feet to 102,909 acre-feet. Areal yields after 50 years of sediment accumulation range from 17,500 (15.6 mgd) to 35,000 (31.25 mgd) acre-feet per year.

The firm yield for each site was estimated and these ranged from a low of 9.0 mgd to a high of 17.9 mgd. The estimates of firm yield were derived assuming that the same ratio between areal and firm yield exists for the



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NORTH BOSQUE RIVER DAM SITES

FIGURE 4-1

three new sites as was found through detailed studies for the recommended Lake Bosque (Site 2) site. Since all four sites will require similar treatment of the water before distribution, these costs will not be addressed until the sites are compared for raw water costs and environmental impacts. A cursory review (see Figure 4-1) does indicate that the two most northerly sites are upstream of Meridian and Clifton and will have lower transmission costs to serve those two cities.

4.1.1 Comparison Of Reservoir Sites

Table 4-1 presents a summary of statistics, yields, and costs for each of the sites. Based on estimates of firm yield, a unit cost was computed for each 1000 gallons of yield developed. The project costs for each site include an estimate of major relocations plus an estimate for dam and spillway construction.

4.1.2 Feasibility

As shown in Table 4-1, Site 2 offers the lowest cost per unit of yield and is the most economically feasible of the four reservoir sites on the North Bosque River. Its location is advantageous since all project participants are located downstream from the reservoir and water can be supplied with minimal capital investments and minimal operating costs for diversion and transmission facilities. The site impounds water without exposure to unreasonable evaporation and seepage losses. Furthermore, the construction requirements are not unusual.

The McLennan County participants' releases from the reservoir will flow down the North Bosque River for diversion from Lake Waco. While in transit, the releases will be depleted by channel losses. These losses are accounted for in yield calculations.

TABLE 4-1

COST COMPARISONS FOR

BOSQUE RIVER SITES

	SITE 1	SITE 2*	SITE 3	SITE 4
Normal Pool Elevation (Ft. MSL)	860	830	680	620
Initial Capacity at Normal Pool (Ac-Ft)	65,400	102,909	29,200	91,500
Surface Area (Ac)	3,083	4,564	2,018	4,938
50-Year Capacity at Normal Pool (Ac-Ft)	62,777	100,509	19,879	71,826
Drainage Area at Dam (Sq. mi.)	646	707	943	1,146
Initial Areal Yield (Ac-Ft/Yr)	26,000	32,100	21,500	40,000
50-Year Areal Yield (Ac-Ft/Yr)	25,000	31,800	17,500	35,000
50-Year Estimated Firm Yield Ac-Ft/Yr (mgd)	14,672 (13.1)	17,900 (15.98)	10,080 (9.0)	20,048 (17.9)
Project Cost Including Relocations (1987 $)	$46,670,000	$37,529,000	$51,200,000	$52,260,000
Annual Debt Service **	$4,372,050	$3,515,340	$4,796,420	$2,895,720
Annual Operation & Maintenance Costs ($)	160,000	200,000	110,000	220,000
Total Annual Cost ($)	$4,532,050	$3,715,340	$4,906,420	$5,115,720
Unit Cost of Raw Water (Per 1000 Gallons)	$0.95	$0.64	$1.49	$0.78

* Proposed Lake Bosque

** Assumed 8% interest for 25 years
Excludes financing costs, capitalized interest, management fees, and reserve funds.

Site 2 has been thoroughly investigated. Reports analyzing developing this site into the recommended Lake Bosque project are "Baseline Ecology Report: Lake Bosque Reservoir Site", October, 1985 prepared by Technical Consulting Associates, "Geotechnical Investigation, Bosque Reservoir Site, Bosque County, Texas" June 1983, NFS Services, Inc., and "Reservoir Operation Studies for Proposed Lake Bosque Project and Lake Waco Enlargement", June 1985, HDR Infrastructure, Inc.

4.1.3 Environmental Assessment

All four potential reservoir sites identified on the North Bosque River encompass the same range of vegetational types and habitats: bottomland, or mesic, woodland, cropland, native pasture, improved pasture and upland woodland. The mesic woodlands in all four sites are confined to narrow riparian strips along the North Bosque River and major tributaries. These riparian strips are remnants of an essentially eastern hardwood woodland that once covered much of the valley floor. The wooded valleys of rivers such as the Bosque and Leon to the west were important components of the transitional nature of the Texan Biotic Province. These valleys represent a more eastern, mesic assemblage of plants and animals. Since the valleys are interdigitated with the plains environment of the adjacent uplands, a transitional environment existed.

All the cropland and most of the improved pasture on these sites has been developed by clearing the mesic woodlands. Unlike East Texas bottomlands, these areas experience flooding on only a two to five year return interval; consequently they are not wetlands and, are well suited to intensive agricultural development without extensive drainage, diking, or other water management measures.

Since these reservoir sites are located in areas that are very similar in terms of soils, topography and vegetation, the primary predictor of terrestrial impact is area of the conservation pool. Reservoirs at Sites 2 and 4 would have similar surface acreages (4,500 to 4,900 ac.), which is substantially larger than the acreage of the remaining two sites. Site 3 at 2,000 acres would have by far the smallest conservation pool of the four alternative reservoirs, followed by Site 1 (3,000 ac). Site 4 occupies a reach of the North Bosque that may have undergone somewhat more extensive agricultural development than Site 2, and consequently would presumably have a lower wildlife value than a similar area of the Site 2 reach. As a group, the four sites encompass a major tributary confluence (East Bosque, Meridian Creek, Neils Creek), so are similar with respect to the complex of fish and wildlife resources common to that situation.

Longitudinal migration in the North Bosque River does not appear to be of particular importance to any of the resident species. For example, Texas Parks and Wildlife biologists in Waco report only limited use of either the river or the North Bosque arm of Lake Waco by white bass (Roccus chrysops). Local fisherman in Valley Mills say white bass do not run above the China Springs crossing (about 15 river miles below Site 4).

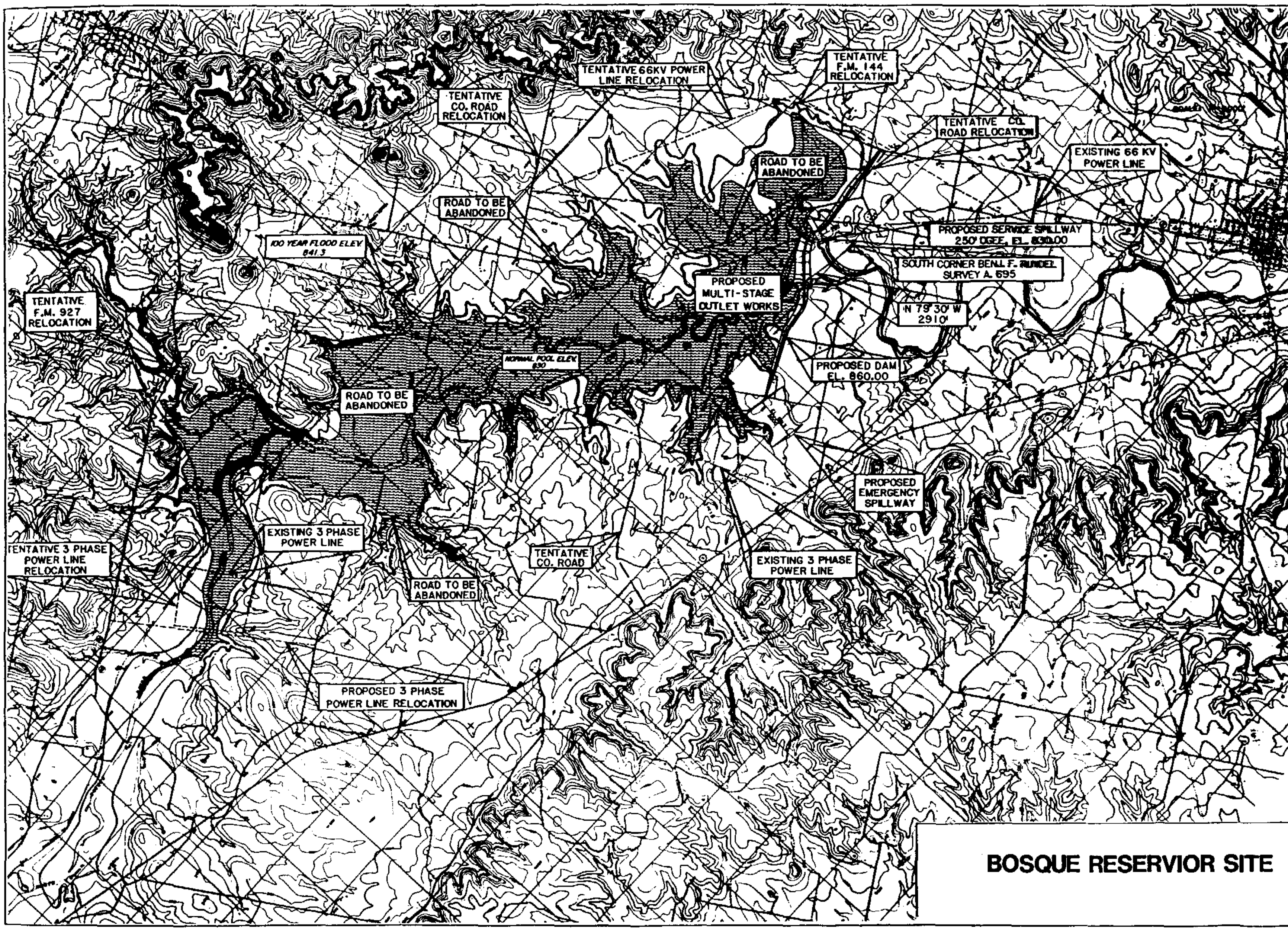
Tailwater effects would be a function of reservoir storage capacity and operation. Since all four alternative reservoirs would be operated as a system with Lake Waco to optimize yield, some similarity in release regime can be assumed, except as site specific inflows and reservoir capacity dictate more or less frequent spills. It is also assumed that all four alternative dams would be equipped with multilevel outlets to avoid impacts due to low dissolved oxygen levels in releases and drastic changes in temperature regime. On the basis of the relative magnitude of change in existing hydrologic regime as a result of reservoir operation, it is logical that larger reservoirs and those higher in the basin would tend to exert greater impacts.

It appears that the four alternative Bosque River reservoir sites can be ranked in ascending order of probable fish and wildlife habitat impact as follows: Site 3 < Site 1 < Site 4 = Site 2. The lesser impacts of Sites 1 and 3 are primarily due to their smaller size, thus inundating shorter reaches of the North Bosque River.

4.1.4 Detailed Description of The Recommended Lake Bosque Site and Estimated Costs

The Lake Bosque project will impound water from 707.6 square miles of the North and East Bosque River Drainage Basins (see Figure 4-2). The impoundment will be located between the City of Meridian and the town of Iredell in northwestern Bosque County at river mile 58.3 on the North Bosque River, 4 miles north of the City of Meridian. The conservation pool formed by the dam will inundate approximately 4,564 acres at an elevation of 830 ft. above mean sea level (msl). An additional 192 acres will be directly impacted by the dam and by the primary and emergency spillways. Also, there are 1,387 acres between the conservation pool elevation of 830 ft. msl and the 100-year flood elevation of 841.3 feet, which will be intermittently inundated.

The dam will be an earth-filled embankment approximately 14,000 feet in length. The primary spillway, with crest set at an elevation of 830 ft. msl, will be an ungated, concrete ogee structure with 250 feet of crest width. Flows greater than the 100-year flood will also flow through a 2000



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BOSQUE RESERVIOR SITE

FIGURE 4-2

foot-wide emergency spillway with a crest elevation of 841.3 ft. msl. The dam crest elevation is 860 ft. msl, which provides adequate freeboard above the stage of the Probable Maximum Flood in the reservoir.

The yield of the proposed project has been determined on the basis that Lake Bosque and Lake Waco will be operated as a two-reservoir system. The Bosque County project participants are located on the North Bosque River between the two reservoirs and can divert their allocation either directly from Lake Bosque or from the North Bosque River. The McLennan County project participants can divert their allocation directly from Lake Waco. In system operation, releases from Lake Bosque for the McLennan County participants will be managed in concert with operation of Lake Waco to curtail evaporation and other losses for the two-reservoir system, consistent with water supply and environmental mitigation needs.

The results of system operation are evident in the following comparison of estimated reservoir yields at the year 2040. By contractual agreement, the benefit of system operation yield increase is attributed to Lake Bosque.

Reservoir	Independent Yield	System Operation Yield
Lake Waco, enlarged	79,870 AF/Year	79,870 AF/Year
Lake Bosque	10,570 AF/Year	17,900 AF/Year
Total	90,440 AF/Year	97,770 AF/Year

The yield increase of 7,330 AF/Year (6.54 MGD) is attributable to system operation which is a "practice....that will....improve the efficiency in the use of water........so that a water supply is made available for future or alternative uses" as water conservation is defined, in part, in the Texas Water Code (V.T.C.A., Water Code § 11.002). This yield increase is 6.6% of the total water demand for the area at year 2040 as presented in Table 2.2.

With Lake Bosque operated as a system with Lake Waco at 462 ft. msl, the combined yield for the system in the year 2040 will be 97,770 ac-ft/yr (87.29 mgd) with 17,900 ac-ft/yr (15.98 mgd) attributable to Lake Bosque. Of the 15.98 mgd, 2.98 mgd will be diverted for use in Bosque County, and the remaining yield will be released from Lake Bosque for diversion from Lake Waco for use in McLennan County. It is anticipated that a diversion averaging 13.00 mgd for these entities will be made from Lake Waco via the City of Waco's water system.

The estimated construction cost of the Lake Bosque Project is $37,525,000 (see Table 4-2). This sum includes acquisition of land, dam construction, construction of all relocations, professional services for permitting, design, and construction management work, and contingencies. Estimated costs for the delivery and treatment systems for the 2040 needs of the participants amount to $32,329,000.

The cost of facilities to treat and deliver the total yield of Lake Bosque are being presented for this and all other alternatives, since ultimate total costs provide the only equitable means of uniformly comparing alternative projects. Of course, the treatment and transmission facilities may actually be constructed in phases, but presenting data on phasing at this time unneccesarily complicates the comparison of alternatives.

Since the McLennan County participants will receive Lake Bosque water through Lake Waco via the City of Waco's water system, minimal raw water delivery facilities are necessary for them, and these costs have been included in the cost for the treatment plant expansion. Ultimate costs for

TABLE 4-2

COSTS FOR LAKE BOSQUE ALTERNATIVE
(1987 DOLLARS)

Lake Bosque	Capital Cost	Annual Operation and Maintenance Cost
Embankment	$11,600,000	$200,000
Spillway & Outlet Works	4,912,000	
Land Acquisition	8,520,000	
Relocations	3,342,000	
Subtotal	$28,374,000	
Contingencies @ 15%	4,256,000	
Subtotal	$32,630,000	
Services @ 15%	4,895,000	
TOTAL COST	$37,525,000	$200,000

Bosque County Treatment and Transmission System	Capital Cost	Annual Operation and Maintenance Cost
Intake/Pump Station	$ 745,000	$167,000
6 MGD Treatment Plant	4,500,000	329,000
Pipelines	3,200,000	
Subtotal	$ 8,445,000	
Contingencies @ 15%	1,267,000	
Subtotal	$ 9,712,000	
Professional Services @ 15%	1,457,000	
TOTAL COST	$11,169,000	$496,000

McLennan County Treatment System	Capital Cost	Annual Operation and Maintenance Cost
26 MGD Treatment Plant	$16,000,000	$1,044,000
Contingencies @ 15%	2,400,000	
Subtotal	$18,400,000	
Professional Services @ 15%	2,760,000	
TOTAL COST	$21,160,000	$1,044,000

adding 26 MGD of capacity to the City's existing plant or constructing a new 26 MGD plant are estimated to be comparable. Treatment plant capacities for the participants have been sized assuming that required peak treatment capacity will be twice the average-day water use of the participants. A peaking factor of 2.0 is typical for communities similar to the project participants. Thus the Bosque County participants will need a 6 MGD plant and the McLennan County participants will need a 26 MGD plant. The McLennan County customers will receive treated water from the City of Waco's expanded treatment facilities in the near future via the City's expanded distribution system. Water distribution costs for the McLennan County participants are equal for all alternatives, so treated water distribution costs are not included for the McLennan County customers. Unit treated water costs are shown in Table 4-3, assuming the entire yield of Lake Bosque is treated and delivered.

TABLE 4-3

SUMMARY OF TREATED WATER UNIT COSTS (1987 DOLLARS)
FOR LAKE BOSQUE ALTERNATIVE, ASSUMING ALL FACILITIES
CONSTRUCTED INITIALLY

	Total Shared Cost	Bosque Participants	McLennan Participants
Capital Cost for Lake Bosque	$ 37,525,000	$ 6,998,000	$30,527,000
Capital Cost for Treatment and Transmission Systems		11,169,000	21,160,000
Total Capital Cost		$18,167,000	$51,687,000
Annual Debt Service *		$ 1,702,000	$ 4,842,000
Annual Reservoir O&M	200,000	37,000	163,000
Annual Treatment and Transmission System O&M		496,000	1,044,000
Total Annual Cost		$ 2,235,000	$ 6,049,000
Yield (MGD)		2.98	13.00
Unit Cost for Treating and Delivering Yield ($/1000 gallons)		$2.05	$1.27

* Assumed 8% interest for 25 years
Excludes financing costs, capitalized interest management fees, and reserve funds

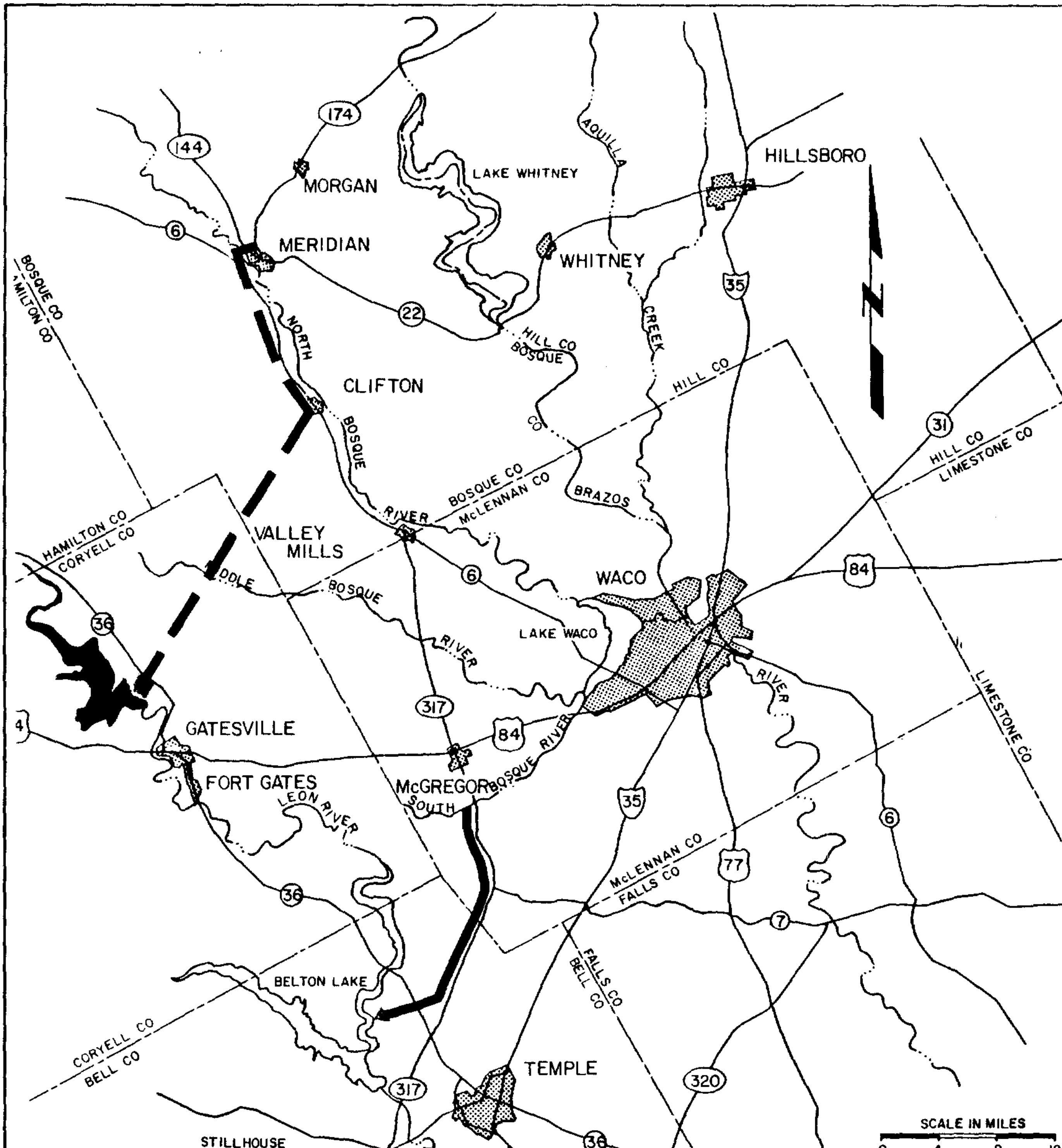
4.2 GATESVILLE RESERVOIR ALTERNATIVE

The Leon River drains the sub-basin immediately south and west of the Bosque River sub-basin. Although the runoff from the Leon River watershed is currently developed with conservation storage capacity at Lakes Proctor and Belton, it is estimated that additional storage could develop additional water supply on a firm yield basis.

The Leon River site selected for study is located approximately 4 river miles upstream of the City of Gatesville in Coryell County, Texas (see Figure 4-3). The selection of the Gatesville site is based on close proximity to the Bosque County project participants without inundating federal lands or impacting population centers.

The proposed Gatesville Reservoir would have an optimum conservation pool elevation of 864 ft msl. At this elevation, the reservoir would have an initial conservation storage space of 500,000 acre-feet and a surface area of 14,400 acres. The dam would be an earth-filled embankment approximately 17,000 feet long with a 400-foot concrete primary spillway and a 3,000 foot-wide emergency spillway. Approximately 10.0 million cubic yards of material would be required to construct the embankment.

The construction of the proposed Gatesville Reservoir would result in a third major reservoir on the Leon River. Proctor Lake, constructed in 1964, is located approximately 75 miles upstream of the Gatesville site, while Lake Belton, constructed in 1954, is located approximately 40 miles downstream of the site. There are significant benefits associated with system operation of Gatesville Reservoir with Lake Belton. These benefits parallel those for system operation of Lake Bosque with Lake Waco discussed previously in Section 4.1.4.



WATER TREATMENT PLANT

RAW WATER INTAKE/PUMP STATION

RAW WATER TRANSMISSION LINE

TREATED WATER TRANAMISSION LINE

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GATESVILLE RESERVOIR SITE

FIGURE
4-3

In the analysis of the ability of the proposed Leon River system to meet the demands of the project participants, it was assumed that the 2.98 mgd demand for the Bosque County entities would be met through direct withdrawals from the proposed Gatesville Reservoir, whereas the 13.00 mgd demand for the McLennan County entities would be met through withdrawals from Lake Belton of water released to it from Gatesville Reservoir. Separate raw water transmission systems are proposed for the two withdrawal points and their respective destinations.

Reservoir operation studies were performed for the Leon River basin with and without the Gatesville Reservoir for the critical drought period of 1945 through 1957. The yield of Lake Proctor was held constant at its permitted yield of 19,658 AF/Year in all cases. Gatesville Reservoir and Lake Belton were operated as a two-reservoir system. Yield increases attributable to the Gatesville Reservoir were determined by subtracting the system yield without the Gatesville reservoir from the system yield with the new reservoir.

The selection of an optimal size for the Gatesville Reservoir was determined by varying the storage capacity of the proposed reservoir and computing the incremental system yield associated with each size reservoir. Review of yield computations for various storage capacities shows a 500,000 acre-feet reservoir to be about the optimum for the Gatesville site. At this capacity, an incremental system yield of 27,409 AF/Year (24.47 MGD) is obtainable for 2040 conditions.

Since the Gatesville Reservoir is sized for site and hydrologic conditions, and not merely to meet the demands of the participants, excess yield is available from the system. Table 4-4 gives a yield summary for the system for year 2040 conditions.

TABLE 4-4

YIELD SUMMARY FOR GATESVILLE RESERVOIR ALTERNATIVE

	2040 CONDITIONS AF/Year	(MGD)
Without Gatesville		
Lake Proctor Yield	19,658	(17.55)
Lake Belton Yield	96,568	(86.21)
Total System Yield	116,226	(103.75)
With Gatesville		
Lake Proctor Yield	19,658	(17.55)
Lake Gatesville Yield	3,394	(3.03)
Lake Belton Yield	120,583	(107.64)
Total System Yield	143,635	(128.22)

Yield Increase Attributable To Gatesville	27,409	(24.47)
Bosque County Supply	3,338	(2.98)
McLennan County Supply	15,568	(13.90)*
Total Supply	18,906	(16.88)
Excess System Yield	8,503	(7.59)

* Includes additional yield to account for channel losses in delivery to Lake Waco.

4.2.1 Costs

Costs to construct the Leon River alternative and deliver treated water to the participants are divided into three components: Gatesville Reservoir, Bosque County treatment and transmission system, and McLennan County treatment and transmission system. Reservoir costs include capital costs for site preparation, diversion facilities, embankment, outlet works, spillways, and relocations as well as operation and maintenance costs. These costs are summarized in Table 4-5.

The Bosque County transmission system would include an intake, pump station, and treatment plant at the proposed Gatesville Reservoir and approximately 40 miles of transmission pipeline for delivery of treated water to the Cities of Meridian and Clifton. The Lake Waco transmission system includes an intake and pump station at Lake Belton and approximately 20 miles of transmission pipeline to deliver raw water to the South Bosque River. The pipeline would discharge into the South Bosque River approximately 12 river miles upstream of Lake Waco. It is assumed the Cities of Lacy-Lakeview, Hewitt, Woodway, Bellmeade, and Waco, and McLennan County WCID would have their water treated and delivered through the City of Waco expanded water plant and distribution system.

TABLE 4-5

SUMMARY OF COSTS FOR GATESVILLE RESERVOIR ALTERNATIVE
(1987 Dollars)

	Capital Costs	Annual Operation and Maintenance Cost
Gatesville Reservoir		
Embankment	$ 34,650,000	$ 300,000
Spillways	7,000,000	
Outlet Works	800,000	
Land Acquisition	21,478,000	
Relocations	22,435,000	
Subtotal	$ 86,363,000	
Contingencies @ 15%	12,955,000	
Subtotal	$ 99,318,000	
Professional Services @ 15%	14,898,000	
Total Cost	$114,216,000	$ 300,000
Bosque County Transmission System		
Intake/Pump Station	$ 745,000	$ 200,000
6 MGD Treatment Plant	4,500,000	329,000
Pipeline	7,758,000	
Subtotal	$ 13,003,000	
Contingencies @ 15%	1,950,000	
Subtotal	$ 14,953,000	
Professional Services @ 15%	2,243,000	
Total Cost	$ 17,196,000	$ 529,000
McLennan County Transmission System		
Intake/Pump Station	$ 1,211,000	
26 MGD Treatment Plant	16,000,000	$1,044,000
Pipeline	5,177,000	600,000
Subtotal	$ 22,388,000	
Contingencies @ 15%	3,358,000	
Subtotal	$ 25,746,000	
Professional Services @ 15%	3,862,000	
Total Cost	$ 29,608,000	$1,644,000

4.2.2 Feasibility

Table 4-6 presents unit water costs for Bosque County and McLennan County participants for the Leon River Alternative. This alternative appears to be feasible based on currently available information. Technical issues which need to be addressed in a more detailed study of the Gatesville Reservoir are dam foundation adequacy, local availability of suitable borrow material, and the current and future status of water rights in this portion of the Brazos River Basin.

4.2.3 Environmental Assessment

This reservoir would be situated in an area very similar to that of the Lake Bosque project; both are in the Western Cross Timbers Vegetational Region, on the border between the Balconian and Texan Biotic Provinces, in the Lampasas Cut-Plain Physiographic Region and have similar valley and channel morphologies. Available information indicates the same vegetation and wildlife habitat to be present and that a similar degree and type of agricultural development have impacted those resources. Land use is dominated by pasture and cropland, and woodlands are largely restricted to riparian strips and juniper-oak uplands. The Gatesville site is larger than any of the Bosque sites, by factors of 3 (Site 2) to 8 (Site 3). Like the Bosque River, the Leon River is being affected by nutrient and sediment loading and appears to support a similar fish community.

Habitat values impacted by the construction and operation of Gatesville Reservoir would be greater than the impacts expected for the Bosque River sites because of the much larger area inundated. Tailwater effects are expected to be similar, as the Gatesville Reservoir will utilize channel conveyance and a system type operating regime.

TABLE 4-6

SUMMARY OF TREATED WATER UNIT COSTS (1987 DOLLARS)
FOR GATESVILLE RESERVOIR ALTERNATIVE, ASSUMING ALL FACILITIES
CONSTRUCTED INITIALLY

	Total Shared Cost	Bosque Entities	McLennan Entities
Capital Cost for Gatesville Reservoir	$78,809,000 *	$13,913,000	$64,896,000
Capital Cost for Treatment and Transmission Systems		17,196,000	29,608,000
Total Capital Cost		$31,109,000	$94,504,000
Annual Debt Service **		$ 2,914,000	$ 8,853,000
Annual Reservoir O&M	207,000 *	37,000	170,000
Annual Treatment and Transmission System O&M		529,000	1,644,000
Total Annual Cost		$ 3,480,000	$10,667,000
Yield (MGD)		2.98	13.00
Unit Cost for Treating and Delivering Yield ($/1000 gallons)		$3.20	$2.25

* Assumes excess yield can be sold to other unidentified entities for 31.0% of project cost

** Assumes 8% interest for 25 years
Excludes financing costs, capitalized interest, management fees, and reserve funds

Pipeline construction and operation associated with Gatesville Reservoir are not expected to contribute substantial additional environmental impacts. Pipeline right-of-way would probably have to be surveyed for cultural resources and unique or critical habitats. For example, mature ash juniper stands occur in this region that are critical habitat for the golden-cheeked warbler (*Dendroica chrysoparia*) and might need to be avoided. Environmental impacts may occur where the South Bosque channel is used to deliver water to Lake Waco. Potential environmental impacts, favorable and adverse, depend on the adequacy of channel capacity and proposed operation.

Although habitat values have not been compared in detail because of the lack of site specific studies. Since the Gatesville and Bosque Reservoir sites have similar vegetation and wildlife characteristics the much larger conservation pool of the Gatesville site should result in larger net impacts than at the Bosque River sites.

4.3 BRAZOS RIVER DIVERSION AND OFF-CHANNEL STORAGE ALTERNATIVE

Since the Brazos River flows through the immediate vicinity of some of the participants, diverting unappropriated water from this major Texas river was studied as an alternative water supply (see Figure 4-4). Use of this source does present unusual treatment requirements due to the salinity of the river. Removal of the natural salt in the Brazos River water is technically feasible using demineralization. The general concept for use of unappropriated flood flows from the Brazos River would be to divert raw water from the river, into an off-channel storage reservoir. The stored water would then be pumped as needed from the reservoir to a water treatment plant immediately downstream of Lake Waco for conventional treatment and demineralization. Treated water would then be delivered to the participating project entities' distribution points.

To determine if sufficient water is available to meet the entities needs, streamflow measurements recorded at USGS gage number 08096500 on the Brazos River at Waco, Texas, were analyzed for the period beginning 1950 and ending in 1957. This period includes the drought of record for this location. It was assumed that diversions from the Brazos River would be restricted to periods in which flows were available as indicated in a recently issued water rights permit which anticipated a similar method of diversion, off channel storage, and treatment of Brazos River water. The authorized diversion point for this permit is immediately downstream of the diversion point proposed for this alternative. Using the above factors, a diversion rate and reservoir size needed to meet the demand of the participants was determined. The results indicated that a total raw water supply of 19.4 mgd can be developed using diversion facilities capable of pumping up to 4,000 acre-feet per month (AF/Mo.) into an off-channel storage reservoir with a capacity of 16,300 AF. A 19.4 MGD raw water supply is needed to deliver 15.98 MGD of treated water to account for the feed water rejection rate in the demineralization process. A suitable location for the proposed diversion point and the off-channel storage reservoir was identified approximately 5.5 river miles upstream from the confluence of the Bosque and Brazos Rivers. The off-channel reservoir would be located above the 400 foot contour elevation about one-quarter mile north of the Brazos River. The wet well at the diversion point would contain five pumps capable of meeting the required diversion rate of 4,000 AF/Mo by pumping at a combined rate of 124 mgd for approximately one-third of the month. In this analysis, the storage reservoir was held at 500 surface acres, and the depth was adjusted to provide the yield required. When needed, the water is pumped through approximately 2.7 miles of pipeline to a treatment plant site immediately downstream of Lake Waco. The facilities for development of this alternative were selected to be near the greater concentration of water demand between the two groups of participants. The treatment plant would include demineralization facilities, assumed to be reverse osmosis (R/O) units. After conventional treatment in the plant, part of the water would be demineralized so that the treated water quantity delivered to participants would be a blend of 50% demineralized water and 50% conventionally treated water. The demineralization process rejects about 30% of the raw water to be treated. Using these factors, a 38.8 MGD peak capacity treatment plant is required to meet the 32 MGD peak demand. For this analysis, RO was the demineralization process evaluated since its capital cost is lower than the other commonly used demineralization processes.

4.3.1 Costs

Capital and operating costs for the Brazos River Alternative's river diversion, off-channel storage, treatment facilities, and transmission system are presented in Table 4-7. The facilities are capable of delivering an average of 2.98 mgd to the Bosque County entities and 13.00 mgd to the McLennan County entities as in other alternatives. Capacity was provided to allow the system to meet a maximum daily need which is estimated to be two times the average daily demand. These costs were calculated assuming a 50%-50% blend ratio and a 30% reject water rate because of the demineralization process discussed previously. This alternative assumes that the reject water will be returned to the Brazos River.

Table 4-8 presents a summary of capital cost, O&M cost and annual cost based on the assumption that the project can be financed for 25 years at 8% as discussed previously. The unit costs per 1,000 gallons of treated water was calculated, assuming all of this alternative's yield is used.

4.3.2 Feasibility

Diversion of unappropriated Brazos River flows appears advantageous due to the location of the river. Construction of parts of this alternative can be accomplished with ordinary earthwork, pumping plant, and transmission facilities. However, use of Brazos River water does require expensive demineralization of the water in order to comply with the Federal Safe Drinking Water Act and the requirements of the Texas Department of Health. Demineralization facilities are expensive to construct and, more importantly, they are extremely expensive to operate since they are so energy intensive. As electrical costs rise, demineralization O&M costs

TABLE 4-7

COSTS FOR BRAZOS RIVER ALTERNATIVE
(1987 Dollars)

Diversion, Storage & Treatment System	Capital Costs	Annual Operation and Maintenance Costs
Raw Water Pumps and River Intake	$ 1,747,000	$ 102,000
Raw Water Storage	9,430,000	50,000
Raw Water Pipeline	1,118,000	
Raw Water Pumps and Storage Reservoir Intake	894,000	440,000
32 MGD Water Treatment Plant;		
38.8 MGD Conventional Water Treatment Facilities	23,000,000	1,487,000
22.8 MGD Desalination Facilities	22,200,000	3,537,000
Subtotal	$58,389,000	
Contingencies @ 15%	8,758,000	
Subtotal	$67,147,000	
Professional Services @ 15%	10,072,000	
TOTAL	$77,219,000	$5,616,000
Bosque County Transmission System		
Pump Stations and Pipeline	$16,933,000	$ 152,000
Contingencies @ 15%	2,540,000	
Subtotal	$19,473,000	
Professional Services @ 15%	2,921,000	
TOTAL	$22,394,000	$ 152,000
McLennan County Transmission System		
Pump Station and Pipeline	$ 539,000	$ 165,000
Contingencies @ 15%	81,000	
Subtotal	$ 620,000	
Professional Services @ 15%	93,000	
TOTAL	$ 713,000	$ 165,000

TABLE 4-8

SUMMARY OF TREATED WATER UNIT COSTS (1987 Dollars)
FOR BRAZOS RIVER DIVERSION ALTERNATIVE, ASSUMING
ALL FACILITIES CONSTRUCTED INITIALLY

	Total Shared Cost	Bosque Participants	McLennan Participants
Capital Cost for Diversion, Storage, & Treatment System	$ 77,219,000	$14,400,000	$62,819,000
Capital Cost for Transmission Systems		22,394,000	713,000
Total Capital Cost		$36,794,000	$63,532,000
Annual Debt Service *		$ 3,447,000	$ 5,952,000
Annual O&M for Diversion, Storage, & Treatment System	5,616,000	1,047,000	4,952,000
Annual O&M for Transmission System		152,000	165,000
Total Annual Cost		$ 4,646,000	$11,069,000
Yield (MGD)		2.98	13.00
Unit Cost for Treating and Delivering Yield ($/1000 gallons)		$4.27	$2.33

* Assumed 8% interest for 25 years
Excludes financing costs, capitalized interest, management fees, and reserve funds

increase dramatically. It can generally be stated that any raw water supply alternative that requires demineralization is not the best alternative if there is a nearby water supply source that requires only conventional treatment.

4.3.3 Environmental Assessment

Construction of an off-channel reservoir would have limited impacts to bottomland communities since suitable floodplain areas appear to be available that have long since been cleared and converted to agricultural use, mining, and residential uses.

Demineralizer reject water discharges would be about 5.0 cfs for the average finished water yield of 15.98 mgd, and total dissolved solids (TDS) concentrations of the reject water would be about three times ambient Brazos River levels. Since TDS levels are not critical for survival of aquatic life in this segment of the Brazos River, discharge would have to be managed only to avoid violations of stream standards for the segments. With reject water flows not large compared to the average Brazos River flows at Waco, it is unlikely that any impacts would be significant.

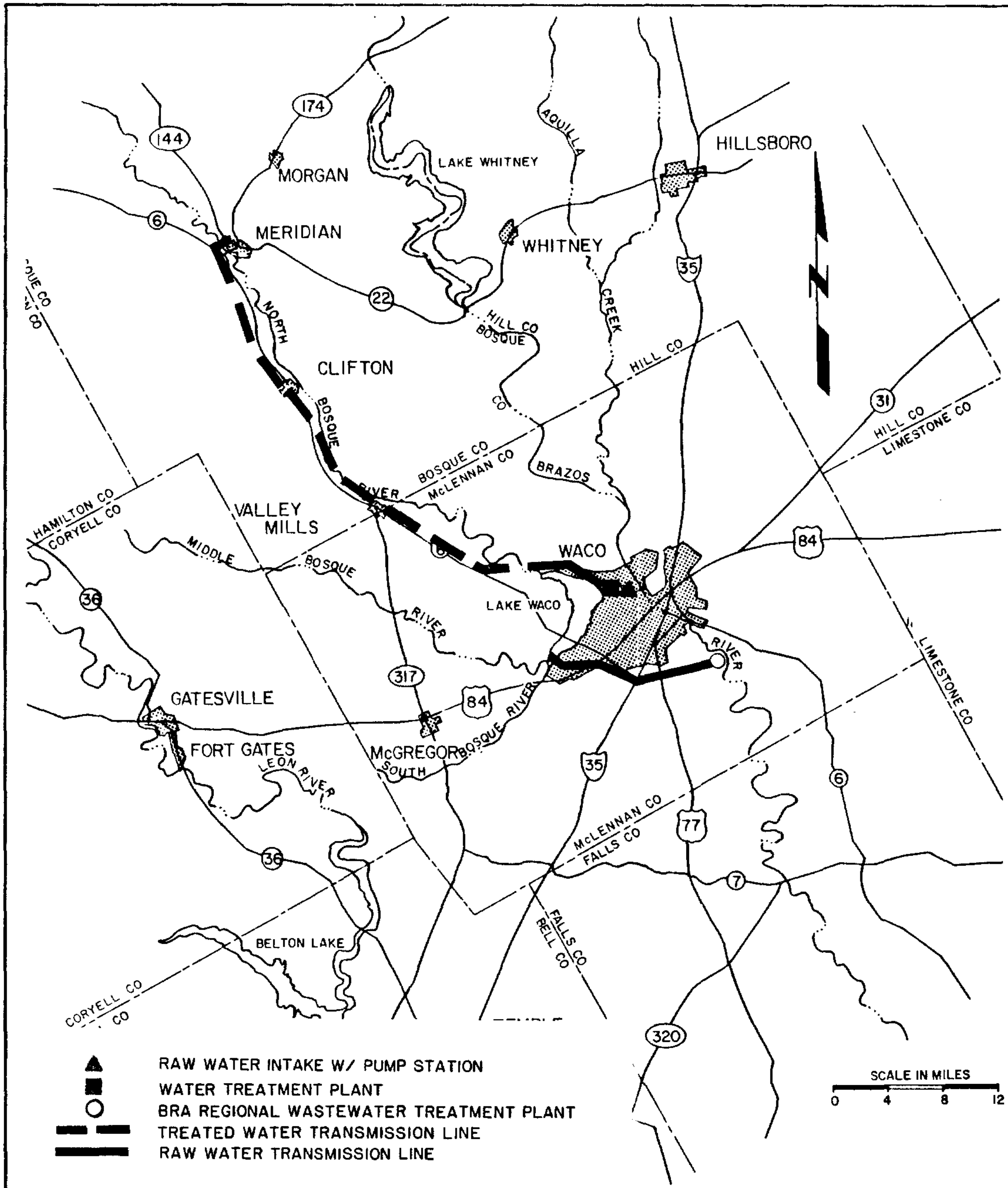
The total land area required for the construction of storage, treatment and distribution facilities would probably total less than 700 acres.

4.4 WASTEWATER REUSE ALTERNATIVE

The BRA Regional Wastewater Treatment Plant at Waco is currently discharging approximately 21 MGD. Therefore, the firm yield of Lake Waco can be increased by using adequately treated wastewater effluent to develop the needed additional water supply. Although wastewater reuse has not yet been widely implemented, it appears technically feasible and could become a more frequently used alternative water supply in the future.

For this alternative, costs associated with upgrading a portion of the 37.8 mgd regional wastewater treatment facility at Waco have been estimated. The estimate is based on upgrading the current secondary treatment process to tertiary treatment levels which include phosphorus removal. These improvements will upgrade effluent quality from 20 milligrams per liter (mg/l) of biochemical oxygen demand (BOD) and 20 mg/l of total dissolved solids (TDS) to 5 mg/l BOD, 5 mg/l ammonia, and 1 mg/l phosphorous. As shown in Figure 4-5, this treated wastewater would then be pumped back into the headwaters of Lake Waco, where it would contribute directly to increasing reservoir yield. Bosque and McLennan County entities would utilize this yield by withdrawing raw water from Lake Waco, processing it through conventional treatment, and pumping treated water to their distribution points. It is assumed the most economical treatment alternative would result if all water treatment occurred in the City of Waco's water treatment plant.

The wastewater treatment plant upgrade would consist of: (1) flow diversion works (2) lime and alum addition for phosphorus removal, (3) separate stage biological nitrification, (4) clarification, (5) filtration, (6) chlorination, and (7) sludge handling facilities. The finished



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WASTEWATER REUSE

FIGURE
4–5

wastewater effluent would then be pumped 14 miles to Lake Waco through a 30-inch diameter force main at 275 feet of total dynamic head (TDH). The raw water would then be withdrawn from Lake Waco through the City of Waco's existing pump station located just below the dam and pumped to a similar treatment system as described in the Bosque Alternative except for upsizing needed in this alternative to include the Bosque County participants. The McLennan County entities would be served through the City of Waco's expanded water system, while service to the Bosque County entities would require that a pump station and transmission pipeline be constructed to the Cities of Clifton and Meridian.

4.4.1 Costs

The preliminary estimated costs associated with the wastewater treatment plant improvements for 15.98 mgd of tertiary treatment capacity added to the existing secondary treatment plant, a transmission main to Lake Waco, a 32 mgd water treatment plant sized for peak demands, and the pumps and pipelines to serve the Cities of Clifton and Meridian are shown in Table 4-9. These values are used to calculate total annual costs and unit water costs (see Table 4-10).

4.4.2 Feasibility

The planned use of wastewater for increasing reservoir yield has few precedents. Therefore in analyzing wastewater reuse by the participants via Lake Waco, effluent limits from a wastewater discharge permit for 24 MGD of effluent returned to Lake Lavon, a municipal water supply reservoir, were used. The referenced permit was granted by the Texas Water Commission to the North Texas Municipal Water District. In this permit, along with

TABLE 4-9

COSTS FOR WASTEWATER REUSE ALTERNATIVE
(1987 Dollars)

Wastewater Treatment Improvements	Capital Costs	Annual Operation & Maintenance Costs
Wastewater Treatment Improvements	$12,750,000	$1,550,000
Effluent Pump Station and Pipeline to Lake Waco	6,812,000	170,000
Subtotal	$19,562,000	
Contingencies @ 15%	2,934,000	
Subtotal	$22,496,000	
Professional Services @ 15%	3,374,000	
TOTAL	$25,870,000	$1,720,000
Water Treatment System		
32 MGD Water Treatment Plant	$19,000,000	$1,256,000
Contingencies @ 15%	2,850,000	
Subtotal	$21,850,000	
Professional Services @ 15%	3,278,000	
TOTAL	$25,128,000	$1,256,000
Bosque County Transmission System		
Pump Stations and Pipeline	$16,933,000	$ 152,000
Contingencies @ 15%	2,540,000	
Subtotal	$19,473,000	
Professional Services @15%	2,921,000	
TOTAL	$22,394,000	$ 152,000

TABLE 4-10

SUMMARY OF TREATED WATER UNIT COSTS (1987 Dollars)
FOR WASTEWATER REUSE ALTERNATIVE, ASSUMING ALL
FACILITIES CONSTRUCTED INITIALLY

	Total Shared Cost	Bosque Participants	McLennan Participants
Capital Cost for Wastewater Treatment Improvements	$25,870,000	$ 4,824,000	$21,046,000
Capital Cost for Water Treatment System	25,128,000	4,686,000	20,442,000
Capital Cost for Transmission System		22,394,000	
Total Capital Cost		$31,904,000	$41,488,000
Annual Debt Service *		$ 2,989,000	$ 3,887,000
Annual O&M for Wastewater Treatment	$ 1,550,000	$ 289,000	$ 1,261,000
Annual O&M for Wastewater Pumping	170,000	32,000	138,000
Annual O&M for Water Treatment System	1,256,000	234,000	1,022,000
Annual O&M for Transmission System		152,000	
Total Annual Cost		$3,696,000	$ 6,308,000
Yield (MGD)		2.98	13.00
Unit Cost for Treating and Delivering Yield ($/1000 gallons)		$3.40	$1.33

* Assumed 8% interest for 25 years
Excludes financing costs, capitalized interest, management fees, and reserve funds

the stated tertiary treatment effluent quality limits, TWC also required an extensive monitoring program to routinely check the plant effluent and the reservoir. They also required intensive monitoring of the reservoir and special studies of reservoir water quality to determine its response to the wastewater discharge.

The permit for discharge into Lake Lavon is considered to be a reasonable model for analyzing the use of wastewater to increase the yield of Lake Waco. From an engineering standpoint, this option is feasible, with the limiting factor being public acceptance and regulatory approval. From an environmental standpoint, constant monitoring of plant effluent as well as continued studies on Lake Waco itself would be advisable to assure sound operations. It should be noted that wastewater reuse under the somewhat similar circumstances at Lake Lavon has been accomplished. However, there could be adverse public reaction in this particular case. Additionally, possible impairment of downstream water rights has not been analyzed.

4.4.3 Environmental Assessment

Additional treatment facilities at the existing wastewater treatment plant site and a transmission pipeline would cause little disruption of existing biological communities or of human uses. Possibly 100 acres might be utilized in treatment facilities and pipeline right-of-way.

Lake Waco is already being impacted by nutrient loading to the extent that the City of Waco now operates two aeration systems in the North Bosque arm of the reservoir for the purpose of eliminating taste and odor problems. If the anticipated wastewater effluent limits were consistently achieved, this plan would add another 50 to 65 kilograms per day (kg/d) of phosphorus and 227 to 257 (kg/d) of inorganic nitrogen to an already enriched system. Other project considerations, including sludge disposal, do not appear to be substantial environmental problems.

4.5 LAKE WHITNEY ALTERNATIVE

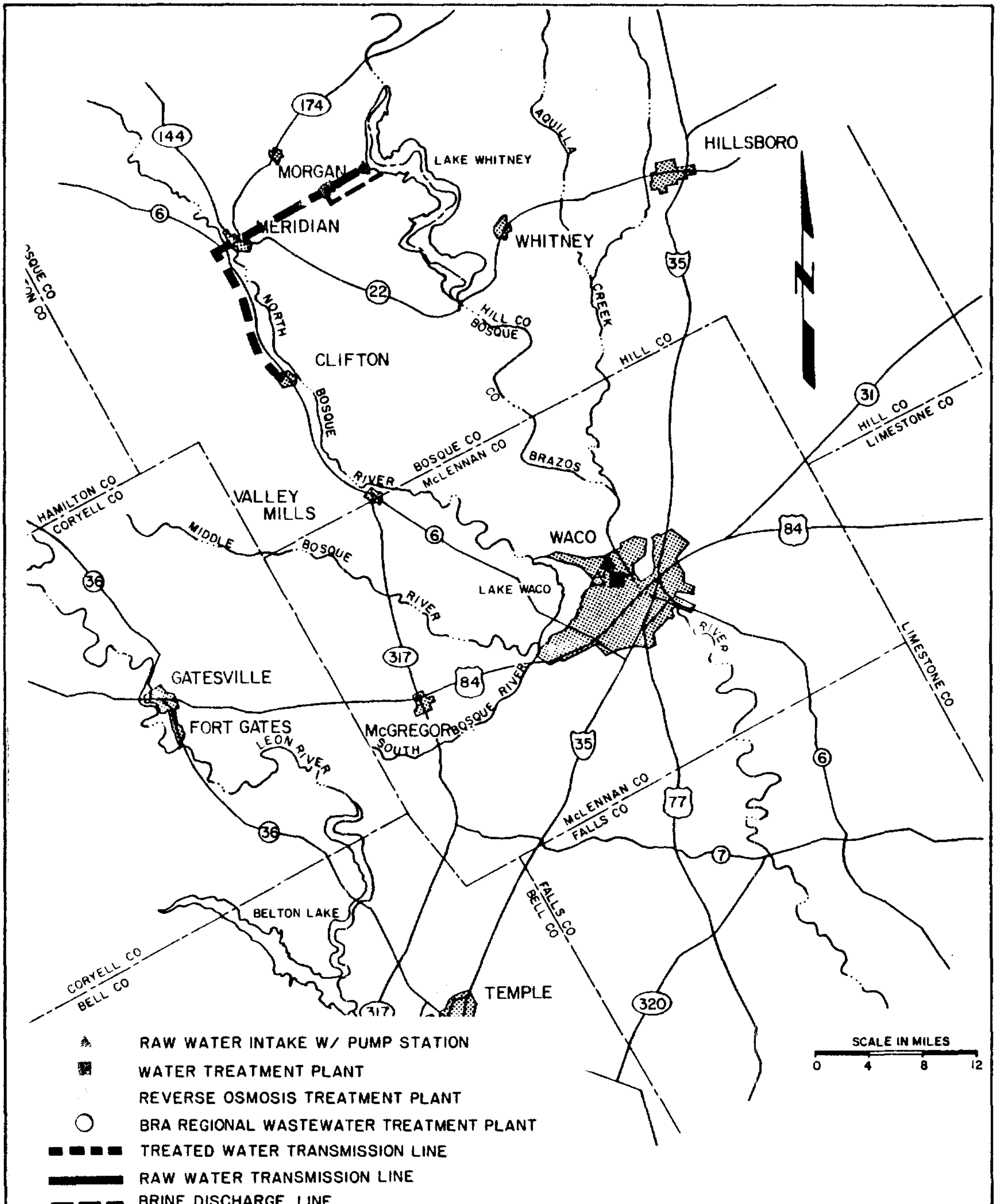
Lake Whitney is an existing Corps of Engineers' multi-purpose project upstream of the City of Waco on the Brazos River and astride the eastern boundary of Bosque County. TWDB in its "Water for Texas" plan has projected that surface water from Lake Whitney will be used to meet water demands in the Bosque and McLennan County area. (See Section 2.4). For the purpose of evaluating this alternative, it is assumed that additional Lake Whitney storage space could be purchased and used to develop a firm yield water supply to meet the needs of the participants.

The required treated water supply for the project entities is 15.98 mgd. Use of Lake Whitney as a raw water source will require both conventional and demineralization treatment because of the natural salt problems associated with Brazos River water. The Bosque County entities, needing 2.98 mgd of treated water, would require a 3.62 mgd raw water supply in order to account for the reject water produced in the demineralization process. Similarly, the McLennan County entities, needing 13.00 mgd, would require a 15.79 mgd raw water supply source to account for demineralization reject water losses plus an additional 0.62 mgd to account for an estimated 4% channel loss expected for releases down the Brazos River from Lake Whitney to the raw water pumping station in the City of Waco. The total McLennan County participants' raw water requirement is 16.41 MGD. Therefore, the combined participants would need to purchase sufficient storage in Lake Whitney to provide a firm yield of 20.03 mgd (22,434 acre-feet per year).

According to current data from the Corps of Engineers (Fort Worth District), Lake Whitney's existing conservation storage capacity of 627,100 acre-feet provides a firm yield of 108,498 acre-feet per year. The resulting yield to storage ratio is 0.173. Applying this ratio to the 22,434 AF/Year firm yield needed by the participants, indicates a storage volume of 129,676 acre-feet would need to be acquired in Lake Whitney. Of this volume, the McLennan County participants would use 105,494 acre-feet, and the Bosque County participants would use 24,182 acre-feet. This simplified method of determining needed storage space should provide a storage requirement that is slightly less than would be derived from detailed firm yield studies and probably leads to a slight understatement of unit water cost for this alternative.

This alternative would include a raw water diversion point for the McLennan County participants immediately downstream of Lake Waco on the Bosque River with the treatment plant sited immediately downstream of the Lakeshore Drive bridge. The required raw water pump station would include a wet well and pump platform sized for pumps to divert a maximum daily rate of 31.6 mgd. Four vertical turbine pumps, each capable of pumping 8 mgd, with one additional 8 mgd pump for standby capacity, would be installed. The raw water would supply a 31.6 mgd water treatment plant, which would include RO demineralization facilities.

The Bosque County entities would construct a raw water intake structure in Lake Whitney, diverting 3.62 mgd through a four mile long pipeline to treatment and demineralization facilities. Treated water would then be transmitted to the Cities of Clifton and Meridian for delivery to their distribution systems. A booster pump station is required at the treatment plant site to pump water 8.5 miles to Meridian and then an additional 11.5 miles to Clifton. A brine discharge pipeline to return reject water from the treatment plant to Lake Whitney would also be required (see Figure 4-7).



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LAKE WHITNEY

FIGURE 4-6

4.5.1 Costs

For the Lake Whitney alternative, costs to purchase storage capacity and construct the facilities to supply the McLennan County demands totalled \$74,296,000 and for Bosque County totalled \$27,056,000. These sums are used to calculate total annual costs and unit water costs (see Table 4-11 and 4-12). Annual costs for debt service assume an 8% interest rate for 25 years. Although not used in the cost analysis of this alternative, it is understood that the purchase of storage in Lake Whitney could be financed through the Corps of Engineers at 8-7/8% interest for 45 years.

The cost of the additional storage in Lake Whitney was calculated by the following formula.

$$\frac{(\text{Total Construction Cost - Specific Cost})\ (\text{Storage Reallocated})}{\text{Total Usable Storage}}$$

The total joint use cost (total construction cost less specific costs) was \$35,402,559, based on the original investment. The needed storage reallocation is 129,676 acre-feet. Since the total usable storage in Lake Whitney is 1,999,500 acre-feet the proposed reallocation involves nearly 6.49% of the total usable storage. Therefore, as calculated below, the cost for needed storage is \$2,296,005.

$$(\$35{,}402{,}559)\ \frac{129{,}676\ \text{AF}}{1{,}999{,}500\ \text{AF}} = \$2{,}296{,}005$$

Adjusting this cost from 1949 price levels at the midpoint of Lake Whitney construction to January 1987 price levels using a ratio of the ENR index for each respective point in time gives an updated cost of storage of \$20,946,679.

$$(\$2{,}296{,}005)\ \frac{4{,}351.90}{277.02} = \$20{,}946{,}679$$

TABLE 4-11

COSTS FOR LAKE WHITNEY ALTERNATIVE
(1987 Dollars)

McLennan County System Costs	Capital Costs	Annual Operation & Maintenance
Water Purchase (81.9% of Capital Cost)	$17,161,000	$ 212,000
Raw Water Pumps and River Intake	878,000	140,000
31.6 MGD Water Treatment Plant	19,000,000	1,240,000
18.6 MGD Desalination Plant	18,600,000	2,919,000
Pump Station and Pipeline	539,000	165,000
Subtotal	$56,178,000	
Contingencies @ 15%	8,427,000	
Subtotal	$64,605,000	
Professional Services @ 15%	9,691,000	
TOTAL	$74,296,000	$4,676,000
Bosque County System		
Water Purchase (18.1% of Capital Cost)*	$ 3,786,000	$ 47,000
Raw Water Pumps and Reservoir Intake	850,000	138,000
7.3 MGD Water Treatment Plant	5,400,000	373,000
4.3 MGD Desalination Plant	4,700,000	683,000
Pump Station & Pipeline	5,722,000	94,000
Subtotal	$20,458,000	
Contingencies @ 15%	3,069,000	
Subtotal	$23,527,000	
Professional Services @ 15%	3,529,000	
TOTAL	$27,056,000	$1,335,000

TABLE 4-12

SUMMARY OF TREATED WATER UNIT COSTS (1987 Dollars)
FOR LAKE WHITNEY ALTERNATIVE, ASSUMING ALL FACILITIES
CONSTRUCTED INITIALLY

	Total Shared Cost	Bosque Participants	McLennan Participants
Capital Cost for Water Purchase	$20,947,000	$ 3,786,000	$17,161,000
Capital Cost for Complete Raw & Treated Water Systems		16,672,000	39,017,000
Professional Services & Contingencies		6,598,000	18,118,000
Total		$27,056,000	$74,296,000
Annual Debt Service *		$ 2,535,000	$ 6,960,000
Annual O&M		1,335,000	4,676,000
Total Annual Cost		$ 3,870,000	$11,636,000
Yield (MGD)		2.98	13.00
Unit Cost for Treating and Delivering Yield ($/1000 gallons)		$3.56	$2.45

* Assumed 8% interest for 25 years
Excludes financing costs, capitalized interest, management fees, and reserve funds

4.5.2 Feasibility

If it is assumed that the U.S. Congress' approval of purchasing reallocated storage can be obtained, the Lake Whitney alternative is a viable water supply option. The purchasing of storage space in Lake Whitney provides a reliable source of water to the participants without requiring construction for new conservation storage capacity. This alternative can be completed using current water treatment technology and standard pumping and transmission facilities. In addition, when compared to the Lake Bosque or Gatesville Reservoir alternatives, large land acquisitions are not needed.

Use of the Brazos River flows, however, requires expensive demineralization in order to comply with the Federal Safe Drinking Water Act and requirements of the Texas Department of Health. Costs of demineralization are high, and similar to the Brazos River Diversion Alternative, such a project should not be undertaken if a reasonable alternative can be found.

Although the cost of purchasing storage in Lake Whitney is reasonable compared to new reservoir construction, the process to acquire reallocated storage space could present overwhelming difficulties. Whether or not the storage space is available for purchase is dependent on the U.S. Congress. Water rights would have to be obtained from the Texas Commission. Environmental considerations discussed in the following section could require the construction of a multi-level release works. The cost and feasibility of this additional facility at Lake Whitney has not been evaluated.

4.5.8 Environmental Assessment

Environmental considerations for this alternative would be similar to those noted for the Brazos River Diversion Alternative with respect to demineralization discharges. Channel conveyance of releases from Lake Whitney

SECTION 5 - RECOMMENDED ALTERNATIVE

Each of the five alternatives has been analyzed from the standpoint of capital cost as well as operation and maintenance costs. These costs, stated on an annual basis, can be compared to the annual yield of the alternative project to provide an average unit cost for delivering treated water to each participant. Table 5-1 provides a comparison summary of costs, yields, and unit water costs.

As shown in this table, the most economical alternative is the construction of Lake Bosque. The Gatesville Reservoir Alternative and the Wastewater Reuse Alternative would be the next two most economical alternatives. The remaining alternatives, Brazos River Diversion and Lake Whitney, require the construction and operation of desalinization facilities which make them more expensive than constructing a new surface water source with associated conventional treatment facilities.

Other than cost, the only other major factor to be considered in selection of the final alternative is the comparison of environmental impacts created by each alternative. Table 5-2 presents a summary of environmental characteristics for the five alternatives. The Gatesville Reservoir, due to size, has the most significant on-site impact to the natural environment, and the Bosque Reservoir has the second most significant impact. None of the alternative projects involve irretrievable committment of resources or affect unique or critical species or habitats.

The selected project will add sufficient water supply in Bosque and McLennan Counties to meet approximately 94% of the counties' demands in the year 2040, assuming that the planned enlargement of Lake Waco occurs. The practical aspect of adjusting contracted water supply with demands in the future is addressed in the participants' contracts for the selected

TABLE 5-1

COST SUMMARY
WATER SUPPLY ALTERNATIVES
BOSQUE AND McLENNAN COUNTIES

		BOSQUE RESERVOIR	GATESVILLE RESERVOIR	BRAZOS RIVER DIVERSION	WASTEWATER RE-USE	LAKE WHITNEY DEMINERALIZATION
RAW WATER SUPPLIED (MGD)		15.98	24.47 *	19.40	15.98	20.03
TOTAL CAPITAL COST	BOSQUE	$18,167,000	$31,109,000	$36,794,000	$31,904,000	$27,056,000
	McLENNAN	$51,687,000	$94,504,000	$63,532,000	$41,488,000	$74,296,000
ANNUAL DEBT SERVICE (25 YR. @ 8%)	BOSQUE	$1,702,000	$2,914,000	$3,447,000	$2,989,000	$2,535,000
	McLENNAN	$4,842,000	$8,853,000	$5,952,000	$3,887,000	$6,960,000
ANNUAL O&M	BOSQUE	$533,000	$566,000	$1,199,000	$707,000	$1,335,000
	McLENNAN	$1,207,000	$1,814,000	$5,117,000	$2,421,000	$4,676,000
TOTAL ANNUAL COST	BOSQUE	$2,235,000	$3,480,000	$4,646,000	$3,696,000	$3,870,000
	McLENNAN	$6,049,000	$10,667,000	$11,069,000	$6,308,000	$11,636,000
ANNUAL YIELD (MGD)	BOSQUE	2.98	2.98	2.98	2.98	2.98
	McLENNAN	13.00	13.00	13.00	13.00	13.00
UNIT COST ($/1000 GALLONS)	BOSQUE	$2.05	$3.20	$4.27	$3.40	$3.56
	McLENNAN	$1.27	$2.25	$2.33	$1.33	$2.45
AVERAGE UNIT COST ($/1000 GALLONS)		$1.42	$2.43	$2.69	$1.72	$2.66

* Project uses 16.88 mgd, costs are calculated based on selling 7.59 mgd.

TABLE 5-2

SUMMARY OF ENVIRONMENTAL CHARACTERISTICS FOR ALTERNATIVE WATER SUPPLY PROJECTS FOR BOSQUE AND MCLENNAN COUNTIES, TEXAS

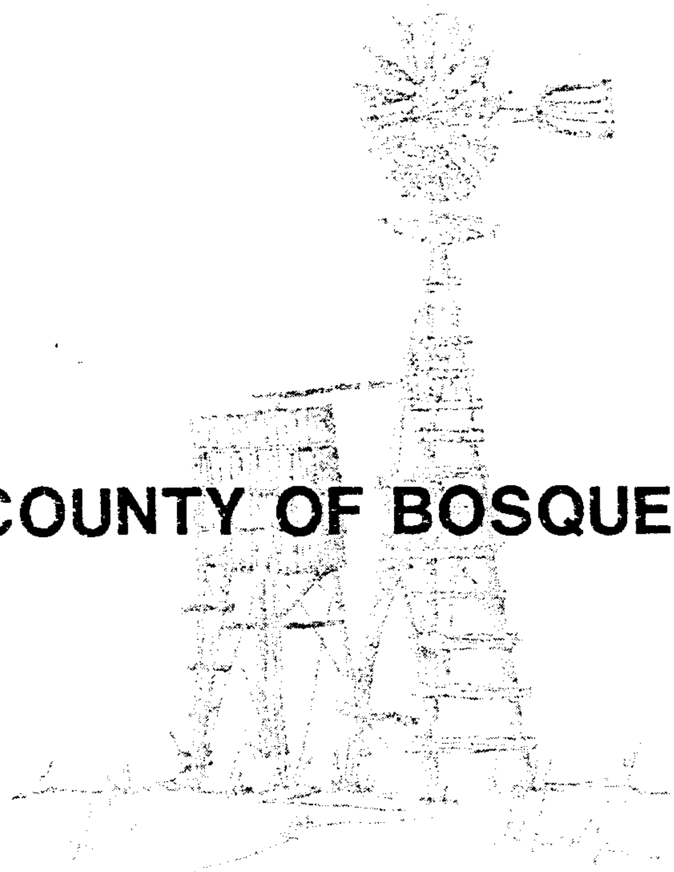
Alternative Projects	Wildlife Impacts (ac)	Pipeline Required (mi)	Water Quality Impacts Reservoir D.O.	Load*	Stream Flow**
Lake Bosque	4564	16	SS	-3	-17.9
Gatesville Reservoir	14400	60	SS	-3	-14.0
Brazos River Division and Off-Channel Storage	500	48	NS	0	<1.0
Wastewater Reuse	NA	60	AS	+1	<1.0
Lake Whitney	NA	25	NA	0	<1.0

D.O. = Dissolved Oxygen
NA = Not Applicable
SS = Potential summer stratification and D.O. depletion in hyppolimnion
NS = Stratification unlikely to be stable enough for D.O. depletion
AS = Already stratifying and experiencing low D.O.
* = Effect on nutrients and dissolved carbon in tailwater reach, projects ranked from greatest increase (+1) to greatest decrease (-3); nutrient removal limited by epilimnitic discharges
** = Streamflow impact: yield/discharge = percent change
<1.0 = Little change because of the location of withdrawal and return flow points, and/or high average Brazos flow.

project. According to their contracts, participants may buy and sell treated water from Lake Bosque among themselves and to new customer entities. This provision assures that this important supply project will provide water service when and where it is needed.

The best available project to meet the participant's needs is Lake Bosque, constructed to have a year 2040 firm yield of 17,900 ac-ft (15.98 mgd). This recommendation is affirmed by the participants previous execution of contracts sufficient to enable the Brazos River Authority to finance construction of the project upon receipt of all necessary regulatory approvals.

WATER SUPPLY ALTERNATIVES FOR BOSQUE COUNTY



THE COUNTY OF BOSQUE

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Henningson, Durham & Richardson

May, 1982

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June 4, 1982

Mr. John B. Stroud
Chairman
Bosque County Water
Study Executive Committee
P.O. Box 351
Clifton, Texas 76634

Dear Mr. Stroud:

In accordance with the terms of our Agreement for Professional Services, dated April 13, 1981, we have enclosed 20 copies of this final report entitled, "Water Supply Atlernatives for Bosque County". This report includes revisions and additions to the previous draft report as a result of additional geotechnical and hydrological studies conducted these past months near the proposed Lake Bosque site.

The results of these additional studies indicate two previous alternatives considered are no longer feasible. These alternatives include:

* Recharge of the Paluxy Aquifer by Spreading Ponds; and

* Pipeline to Lake Aquilla.

The first of these alternatives was determined economically infeasible for the county based on field pressure testing of the Paluxy Aquifer north of Meridian. These tests indicated the recharge characteristics of the aquifer were not conducive for the installation of spreading ponds.

The alternative which considered Lake Aquilla as a water source has also been determined infeasible, as all water from this source is now under contract.

With respect to our on going work on the proposed Lake Bosque site, we are now in the process of evaluating the firm yield of the site in light of water rights considerations both upstream and downstream of the proposed reservoir. We should have some results from this study in the near future.

WATER SUPPLY ALTERNATIVES

FOR BOSQUE COUNTY

Prepared For

THE COUNTY OF BOSQUE

by

HENNINGSON, DURHAM & RICHARDSON, INC.

May, 1982

It has been a pleasure working with you and the other members of the Bosque County Water Study Committee on this critical county wide issue. We look forward to continuing our work with you in assisting Bosque County in obtaining a good quality long-term water supply.

Sincerely,

HENNINGSON, DURHAM & RICHARDSON, INC.

James K. Haney, P.E.
Manager - Austin

R. Anne Smith
Project Engineer

RAS:bb

Enclosure

WATER SUPPLY ALTERNATIVES
FOR BOSQUE COUNTY

Prepared For

THE COUNTY OF BOSQUE

by

HENNINGSON, DURHAM & RICHARDSON, INC.

May, 1982

EXECUTIVE COMMITTEE OF

BOSQUE COUNTY WATER STUDY COMMITTEE

Honorable C. K. Word
County Judge
Meridian, Texas

John B. Stroud
Chairman
Executive Committee
Clifton, Texas

T. F. Crawford
Clifton, Texas

John P. Gilliam
Valley Mills, Texas

Fred Owen
Clifton, Texas

Willard J. Still
Cranfills Gap, Texas

ACKNOWLEDGMENTS

We appreciate the assistance of a large number of individuals of local governmental and state agencies of Texas, without whose help this effort could not have been achieved. Many individuals welcomed requests for information and usually gave more helpful assistance than was requested.

We are unable to name every individual, group or agency that has contributed to this effort but would like to acknowledge those who made major contributions of assistance below:

Judge C. K. Word	Bosque County Water Committee
John B. Stroud	Bosque County Water Committee
T. F. Crawford	Bosque County Water Committee
Carson Hoge	Brazos River Authority (BRA)
Roy Roberts	Brazos River Authority (BRA)
Leland Wilson	Corps of Engineers
Jack Chitwood, PhD	Texas Department of Water Resources (TDWR)
Herbert Grubb, PhD	Texas Department of Water Resources (TDWR)
Bill Crolley	Texas Department of Water Resources (TDWR)
Hugh Davis	Heart of Texas Council of Governments
Beade Northcut	Soil Conservation Service
George Janning	Underwood, Neuhaus & Co., Inc.

A special word of thanks is offered to the Executive Committee Members who provided valuable input and guidance to the consulting team in this effort, especially Mr. John B. "Abe" Stroud and Mr. T. F. Crawford.

EXECUTIVE SUMMARY
AND
RECOMMENDATIONS

The purpose of this project was to evaluate the feasibility of developing and securing a long-term dependable water supply for Bosque County, Texas. During the course of this project numerous water development plans were examined in detail. In addition, population and water use projections for the county were performed for a fifty year planning period.

Bosque County's total fifty year water need is estimated at 9.81 million gallons of water per day (mgd). This is inclusive for municipal, manufacturing, mining, livestock, and irrigation water requirements. Of this total, it is estimated that it would be feasible to supply 4 mgd, the amount required to satisfy the municipal and manufacturing needs and a proportion of the rural and mining needs of the county at the end of the fifty year planning period. This water demand is centered in and around the cities of Meridian, Clifton, and Valley Mills.

The county presently derives most of its water supply from groundwater sources, primarily originating from the Hensell and Hosston aquifer formations. These aquifers are being mined and based on current trends in water level declines, compounded with increasing future water demands, the long term outlook for these aquifers is not favorable. It is estimated that the Hensell and Hosston aquifers will provide a twenty to thirty year supply for the study area. The county could possibly extend the dependable life of their groundwater reserves, through regional management practices. At a minimum, Clifton, Meridian, and Valley Mills should adopt groundwater management practices with respect to well spacing, capacities, and pumping schedules.

Due to the long time frame required to develop major water supply projects, complex surface water rights issues, and spiralling costs, it is recommended that the county take immediate steps towards securing supplemental water supplies. Nine water development plans were evaluated in detail in this project. These involved augmentation of groundwater through artificial recharge, using existing surface water resources, and developing new surface water resources. All of the alternatives evaluated in this study could provide at least the fifty year water needs of the county. However, project costs appear to be outside the financial capacity of individual cities in the county, without formation of a water district and/or without "outside" county participation in a project.

The most attractive water resources development project appears to be the construction of a large dam (Lake Bosque) on the Bosque River upstream from Meridian. Lake Bosque has the potential of providing a long term water supply for the county at the least long term cost, if other communities such as Waco, participate in its development. The effects of the proposed Lake Bosque on Lake Waco and its site suitability must be investigated.

Based on the findings, results and conclusions of this study, Henningson, Durham and Richardson offers the following recommendations to Bosque County:

1. Implement Groundwater Management;

2. Pursue the Lake Bosque Project by:

   A. Seeking Support from other Communities;

   B. Seeking Sponsorship of the Project by the Brazos River Authority; and

   C. Performing a Detailed Hydrologic, Hydraulic, and Geologic Investigation of Site Suitability;

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WATER SUPPLY ALTERNATIVES FOR BOSQUE COUNTY

1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

This study was prepared for and funded by Bosque County, Texas to determine the feasibility of developing supplemental water supplies for the county. The objectives of this study were as follows:

1. Determine Future Water Demands for Bosque County;
2. Evaluate Surface and Ground Water Development Alternatives to Satisfy Future Demands; and
3. Make Recommendations to the County as to the Potential of Developing a Long Term Supplemental Water Supply.

1.2 PROJECT LOCATION AND DESCRIPTION

The study area for this project is inclusive of Bosque County, which is in East Central Texas about 20 miles Northwest of Waco and 75 miles Southwest of Dallas (see Fig. 1.2-1). The county covers an area of 990 square miles and its elevation varies from 500 to 1200 feet above mean sea level. The county-wide population was 13,263 in 1980. Over 40% of that population is centered in the three towns of Meridian, Clifton, and Valley Mills. These three towns are all located on State Highway 6 and are adjacent to the North Bosque River, which is the principal stream in the county. The county is primarily rural and the economy is based on agriculture and retail trade.

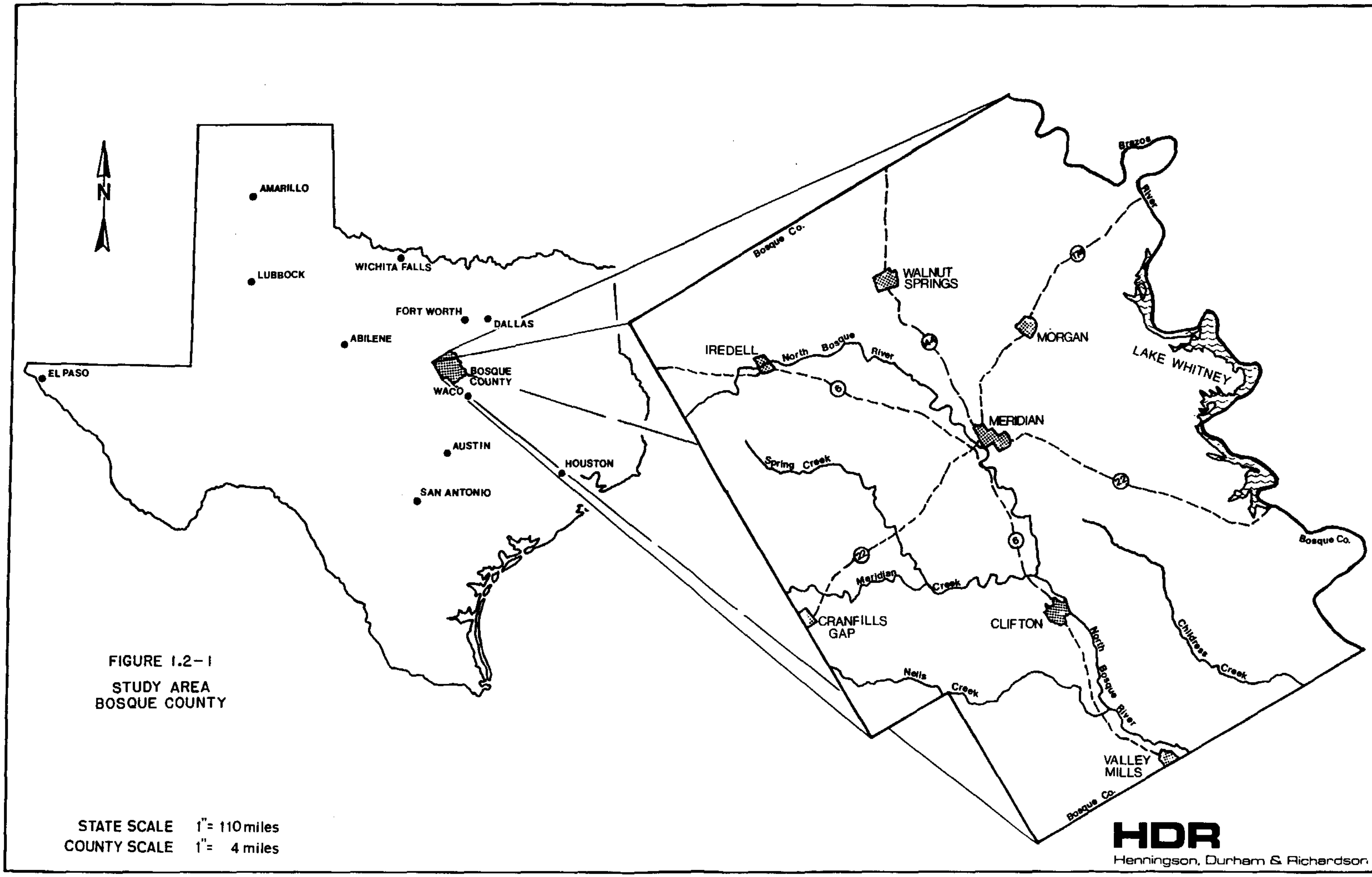


FIGURE 1.2-1

STUDY AREA
BOSQUE COUNTY

2.0 POPULATION AND WATER PROJECTIONS

2.1 INTRODUCTION

The future water requirements for Bosque County are discussed in this section. Water use projections (Section 2.3) are based on population growth. Therefore it is important to prepare sound population projections for the study area (Section 2.2). Manufacturing water requirements (Section 2.4) are directly related to population or labor force. Other water requirements for Bosque County, such as mining, livestock, and irrigation, make up a significant part of the county's total water requirements (Section 2.4).

2.2 POPULATION PROJECTIONS

The determination of the future water needs for Bosque County and its communities was based on past trends of population and water use and consideration of the probable future growth of those communities and their attendant industries (manufacturing sector). The study of population growth was dependent upon records of the U.S. Bureau of the Census of Population and Housing from 1860-1980, the Texas Almanac 1978, and the Texas Department of Water Resources Computer Printout, 1981.

Historically, the major portion of Bosque County's economy has been based on agriculturally related business. This is evident from the trends in the population records. When agribusiness was a fairly large part of the national economy, Bosque County showed a period of growth. In the fifty years from 1860 to 1910 the county population grew from 2,003 to 19,013 due to increased migration to Texas during this period. However, the following 50 years, Bosque County showed a decline as agriculture's dominance of the economy waned.

The limit of this decline appeared to be reached in the sixties and the population remained relatively static for a decade.

In the decade of the 1970's, Bosque County reflected a strong growth pattern, with an average growth of 1.92% per annum. This was primarily due to residential development on the western shores of Lake Whitney, and a steady increase in the municipal population in Clifton, Meridian, and Valley Mills. It is difficult to project a rate at which the county will continue to expand because the county figures include both municipal and rural populations, which have a relatively large disparity in growth patterns. The future population estimate based on the historical rate of increase is indicated in Tables 2.2-1 and 2.2-2 and in Figs. 2.2-1, 2.2-2, and 2.2-3. This projection is based on the average rate of increase in population between the years 1960 and 1980. Another set of population projections for Bosque County were obtained from the Texas Department of Water Resources (TDWR) Computer Printout of Projections, 1981. TDWR projections were based on numerous demographic and migration parameters. As illustrated in Fig. 2.2-1, the TDWR projections and HDR's correlate very closely, although they were obtained through separate analyses.

Clifton, Meridian, and Valley Mills have shown an overall increase in population since 1910, while the smaller communities suffered a decline until 1960. All have exhibited a growth since the sixties and it appears they will continue to do so, if Bosque County follows the economic expansion shown by neighboring counties.

Average trend population projections for the county as a whole are presented in Fig. 2.2-1, and are based on a continuation of the 1960-1980 growth rate. These projections do not reflect the preceeding period of decline. Based on these estimates, Bosque County population is projected to grow from 13,260 people in 1980 to 22,700 people by the year 2030.

Table 2.2-1

HISTORIC AND PROJECTED POPULATION ESTIMATES FOR BOSQUE COUNTY

Year	Historical Figures	HDR Projection	TDWR Projection
1860	2005		
1870	4981		
1880	11217		
1890	14224		
1900	17390		
1910	19013		
1920	18032		
1930	15750		
1940	15761		
1950	11836		
1960	10809		
1970	10966		
1980	13263		13401
1990		15163	14962
2000		17063	15980
2010		18963	19200
2020		20863	21800
2030		22763	25000

Sources: Texas Almanac, 1978
Texas Department of Water Resources, 1981

Table 2.2-2

HISTORICAL AND PROJECTED MUNICIPAL POPULATION

Population Year	Clifton	Meridian	Valley Mills	Cranfills Gap	Iredell	Morgan	Walnut Springs
1910 *	1137	718	708	---	---	831	1340
1920 *	1327	1024	855	---	---	672	1449
1930 *	1367	759	936	---	---	509	765
1940 *	1732	1016	803	---	---	503	723
1950 *	1837	1146	1037	---	---	424	623
1960 *	2335	993	1041	---	366	381	490
1970 *	2578	1162	1002	256	316	415	495
1980 *	3062	1303	1151	337	409	488	621
1990 **	3472	1443	1241	377	469	558	691
2000 **	3882	1583	1331	417	529	628	761
2010 **	4292	1723	1421	457	589	698	831
2020 **	4702	1863	1511	497	649	768	901
2030 **	5112	2003	1601	537	709	838	971

* Source: United States Bureau of the Census, 1910-1980

** HDR's Projections

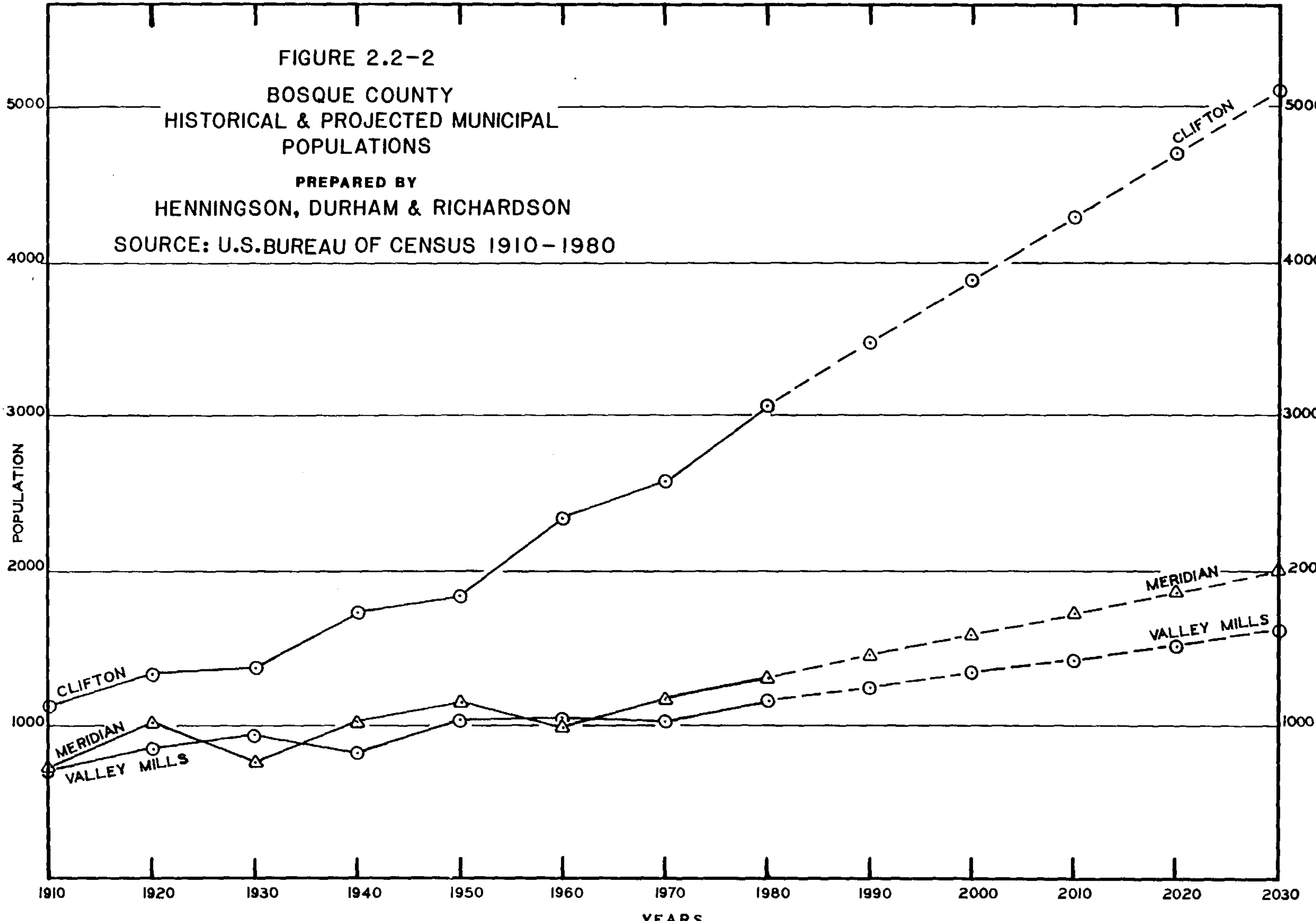


FIGURE 2.2-2
BOSQUE COUNTY
HISTORICAL & PROJECTED MUNICIPAL POPULATIONS
PREPARED BY
HENNINGSON, DURHAM & RICHARDSON
SOURCE: U.S.BUREAU OF CENSUS 1910-1980
POPULATION
YEARS
CLIFTON
MERIDIAN
VALLEY MILLS
1000
2000
3000
4000
5000
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030

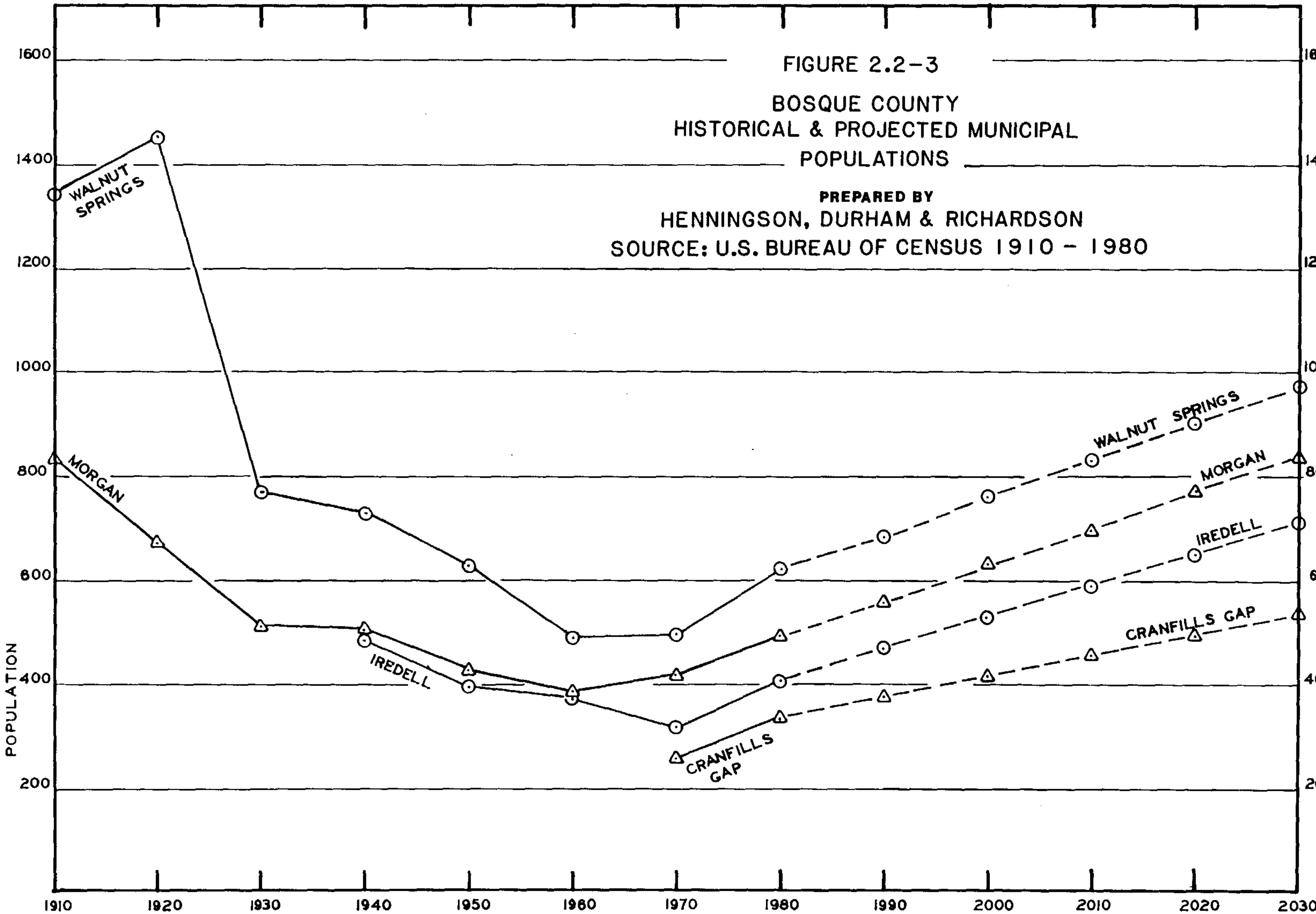


FIGURE 2.2-3

BOSQUE COUNTY
HISTORICAL & PROJECTED MUNICIPAL
POPULATIONS

PREPARED BY
HENNINGSON, DURHAM & RICHARDSON
SOURCE: U.S. BUREAU OF CENSUS 1910 - 1980

2.3 WATER SUPPLY DEMAND CRITERIA

Before realistic water supply development alternatives for Bosque County can be assessed, the future water requirements of the municipal centers, rural areas, and manufacturing demands must be determined. In considering the demands to be placed on the water supply, it is necessary to establish both the total quantity and the rate at which water will be used. The more significant rates and their definitions are as follows:

Average Daily Demand - This rate is generally expressed in million gallons per day (mgd) and represents the average daily use by the entire service area over a period of one year.

Maximum Daily Demand - This is the total amount of water used during the one day of the heaviest consumption in any given year, expressed in mgd. This indicates the total amount of water that must be treated or supplied in one day in order to meet the maximum demand. The maximum daily demand is usually found to be about 1.7 to 2.3 times the average daily demand.

Peak Hourly Demand - This is expressed in mgd and represents the rate at which water was used during the hour of maximum usage in a given year. This rate is usually about 2 times the maximum daily demand.

Per Capita Demand - This rate is generally expressed in gallons per capita per day (gpcd) and represents the average daily amount used per person during an entire year. When this rate is multiplied by the population of the service area, the average daily demand is obtained.

These water usages were established through an assessment of historical water use data for all major municipal, industrial, and agricultural water customers in the study area. Historical water use trends were established and water use projections were made based on population and water use per capita estimates. In this study, water use projections were made by decades i.e., 1980, 1990, 2000, 2010, 2020, and 2030, with 1980 considered as present conditions. The two most important projections were those for the 20 year (year 2000) and 50 year (year 2030) planning base. The 20 year planning base was used for waterworks facility design such as pipelines and, to a certain extent, water treatment plant design capacities. For this study, the water treatment plants were designed for ten year projected water demands with provisions for expansion. The water requirement projections for the 50 year planning base were used to determine the total amount of water which should be reserved or secured.

The average daily demand is generally used to size the supply source. The maximum daily demand is used to determine raw water pumping and treatment capacity. The peak hourly demand is used to determine storage requirements and size distribution pumps and piping.

For estimating purposes, the most useful demand rate is the per capita demand. In its purest sense, this rate is generally considered to be only the water that is used in the households in a city. The major water use in the home is for lawn watering and during dry years, per capita water use is substantially higher than in wet years. But regardless of the influence of a lack or abundance of rainfall, the per capita use rate has consistently increased. Dishwashers, garbage disposals, larger shower nozzles, and other water intensive appliances have all contributed to this increase in per capita use.

In the towns within Bosque County, the commercial and industrial water supply is generally obtained from the municipal system. Therefore, the per capita use rate will be higher in those areas with the most industry. In Clifton, Meridian, and Valley Mills, the 1980 average per capita rate was 153 gallons per day. This compares with a gpcd rate of 81 gallons in Cranfills Gap, Walnut Springs, Morgan, and Iredell. These rates were determined from water usage data obtained from the Heart of Texas Council of Governments (HOTCOG) Report, 1980. The per capita rate has increased in all of the preceeding towns and is expected to do so for the planning period. Clifton, Meridian, and Valley Mills average per capita rate was 108 gallons per day in 1970 and increased by more than 40 percent by 1980. Based on this trend, the average per capita use is expected to reach 215 gallons per day by the year 2030, in the larger communities of Bosque County. In the other more rural towns of Cranfills Gap, Walnut Springs, Morgan, and Iredell, the 1970 average rate was 69 gallons per day, and the growth rate was less than 20 percent by the year 1980. By 2030, those towns are expected to reach an average per capita use rate of about 120 gallons per day.

2.4 FUTURE WATER DEMANDS

Water demands for the project area were determined by analyzing historical water usage trends, per capita water use, and population growth potential. For this study, future water demands were estimated on an average daily basis in million gallons per day (mgd). The future municipal and rural water requirements for Bosque County are determined by multiplying the population estimates by the projected per capita use rates for each sector. Table 2.4-1 reflects the historic and projected municipal water use for the seven largest towns in Bosque County. The tabulated data is shown graphically in Fig. 2.4-1 for Valley Mills and Clifton. Also, graphic representations of municipal water use for Meridian, Morgan, Iredell, Walnut Springs, and Cranfills Gap are shown in Fig. 2.4-2. The total water use by the seven municipalities was about 1 mgd in 1980, and by the year 2030, the projected water use is expected to be almost 2.3 mgd.

Similarly, historic and projected municipal water use for the balance of Bosque County is shown in Table 2.4-2. From the present usage of approximately 0.4 mgd, it is anticipated that use by the balance of the county will grow to about 1.2 mgd. As noted earlier, the remainder of the county is predominantly rural and is expected to have a lower per capita use rate than the towns listed above. A graphic presentation of the historic and projected rural use is shown in Fig. 2.4-3.

The sum of the water use by all of the populace of Bosque County is the county-wide municipal water use. From the present (1980) average water usage of 1.45 mgd, it is anticipated that growth will require an average usage of 3.50 mgd by the end of the fifty year planning period. The projected average annual increase in municipal water use between 1980 and 2030 is about 5 percent per year.

Records of industrial and manufacturing water use in Bosque County were obtained from the Texas Department of Water Resources. Also, TDWR provided projections of industrial water use by decade for the fifty year planning period. The historic industrial demands presented in Table 2.4-3 reflect the usage of

Table 2.4-1

HISTORICAL AND PROJECTED MUNICIPAL WATER USE

Average Daily Water Use (mgd)

Year	Clifton	Meridian	Valley Mills	Cranfills Gap	Iredell	Morgan	Walnut Springs	Total Projected Water Use
1955	0.24	0.11	0.11	0.03	0.01	0.02	0.07	
1957	0.21	0.11	0.12	0.03	0.01	0.02	0.07	
1959	0.21	0.11	0.12	0.04	0.02	0.02	-	
1961	0.23	0.10	0.06	0.01	0.01	0.02	0.03	
1963	0.30	-	0.12	0.01	0.01	0.03	0.04	
1965	0.28	0.08	0.11	0.01	0.01	0.03	0.05	
1967	0.30	0.23	0.11	0.01	0.02	0.02	0.05	
1969	0.33	0.68	0.10	0.01	0.02	0.03	0.05	
1971	0.37	0.50	0.07	0.02	0.01	0.02	0.05	
1973	0.38	0.16	0.07	0.02	0.02	0.02	0.09	
1975	0.38	0.12	0.14	0.02	0.02	0.03	0.04	
1977	0.54	0.15	0.19	0.02	0.03	0.03	0.05	
1978	0.52	0.14	0.19	0.02	0.03	0.03	0.05	
1980	0.54	0.18	0.16	0.03	0.04	0.04	0.05	1.04
1990	0.66	0.23	0.19	0.03	0.05	0.05	0.06	1.27
2000	0.77	0.27	0.24	0.04	0.07	0.07	0.07	1.53
2010	0.89	0.31	0.28	0.05	0.09	0.09	0.08	1.79
2020	1.01	0.34	0.33	0.06	0.10	0.11	0.09	2.04
2030	1.12	0.38	0.36	0.07	0.12	0.13	0.11	2.29

Source: Heart of Texas Council of Governments, 1980 (Historical data)
TDWR

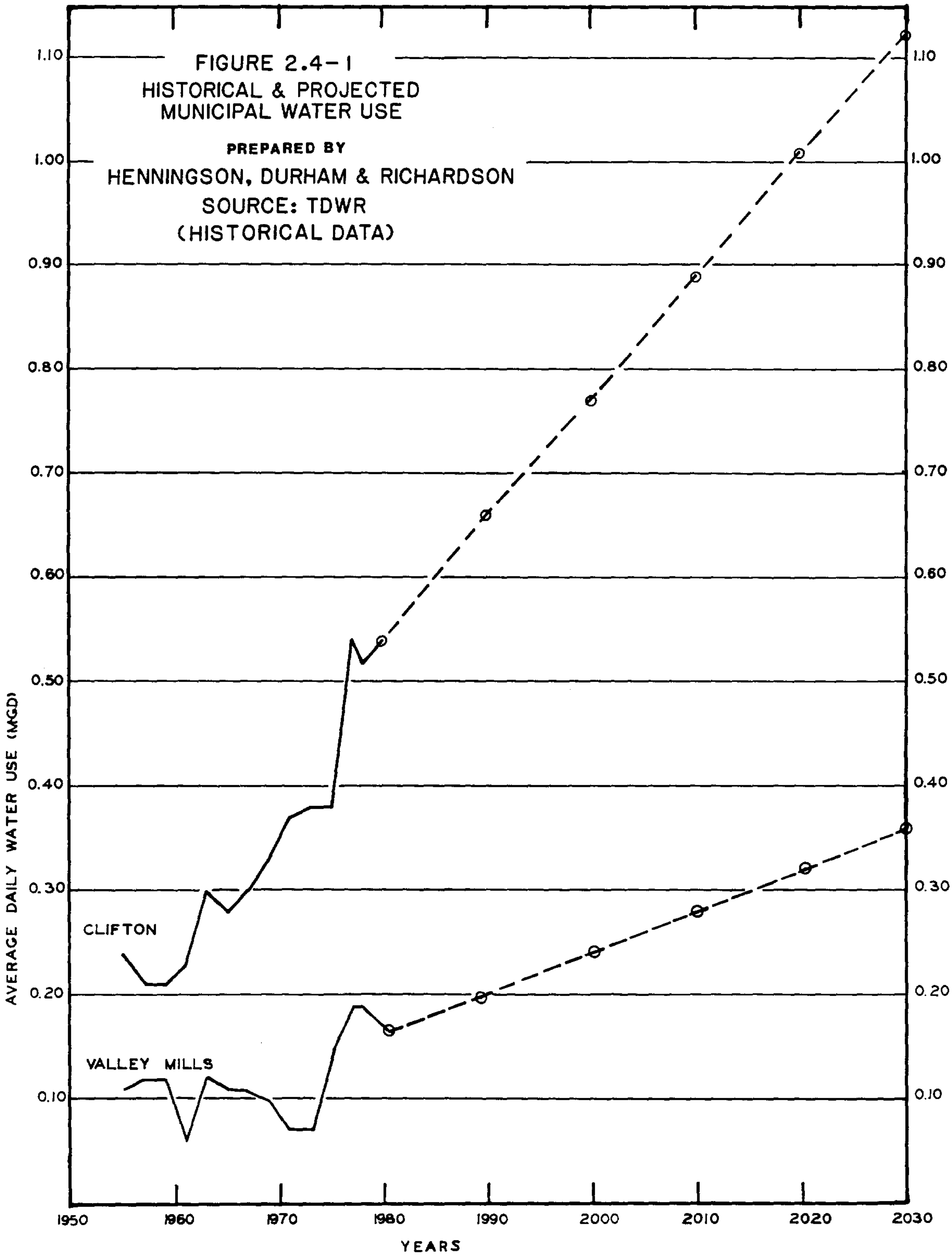


FIGURE 2.4-1
HISTORICAL & PROJECTED
MUNICIPAL WATER USE
PREPARED BY
HENNINGSON, DURHAM & RICHARDSON
SOURCE: TDWR
(HISTORICAL DATA)
AVERAGE DAILY WATER USE (MGD)
CLIFTON
VALLEY MILLS
YEARS
1950
1960
1970
1980
1990
2000
2010
2020
2030
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10

Table 2.4-2

HISTORICAL AND PROJECTED RURAL WATER USE

Year	Historical Water Use (mgd)	Projected Water Use (mgd)
1971	0.21	
1972	0.26	
1973	0.48	
1974	0.31	
1975	0.30	
1976	0.24	
1977	0.36	
1978	0.38	
1980		0.41
1990		0.57
2000		0.73
2010		0.89
2020		1.05
2030		1.21

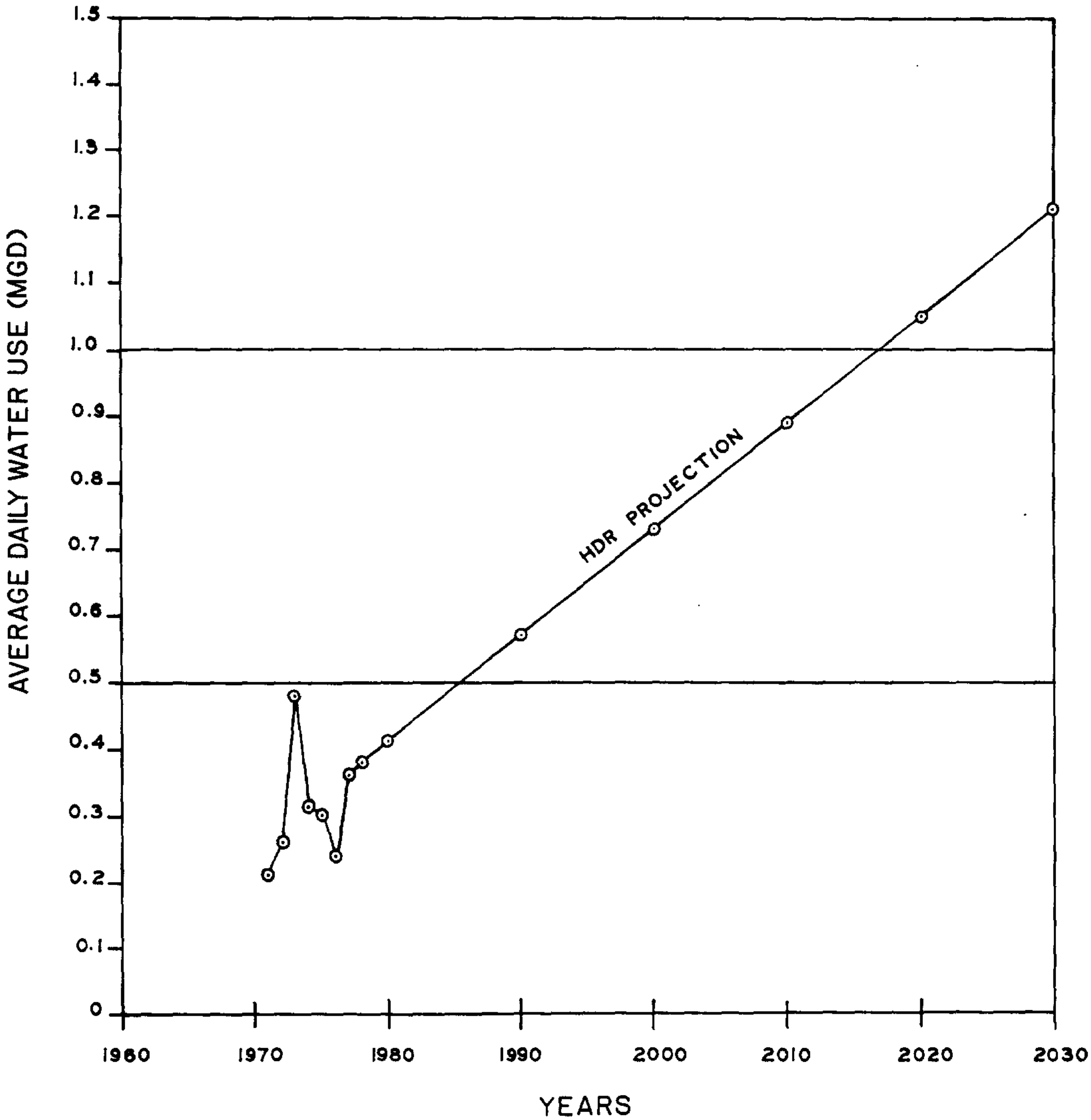
Source: Heart of Texas Council of Governments, 1980 (Historical Data)

FIGURE 2.4-3

HISTORICAL & PROJECTED RURAL WATER USE

PREPARED BY
HENNINGSON, DURHAM & RICHARDSON

SOURCE: TDWR (HISTORICAL)



only one industry, Chemical Lime Company, Clifton, since all other industrial facilities receive their water supplies through municipal service systems. The manufacturing usage shown is fairly consistent until 1977 and then reflects a sudden increase in water use for 1978. Coupled with that increased water usage was a reported employee increase of 70 percent, so it is thought that the growth will continue to be reflected in the future. TDWR projections for 1980 and subsequent decades did not reflect that increase and, therefore, the growth of existing industry has been modified (see Table 2.4-3).

One of the major factors which contributes to the industrial growth of an area is the ability to provide a dependable, quality water supply. This study is evidence that Bosque County is interested in developing such a water supply. When developed, such a supply should attract additional industry into the county. Thus, projections of industrial water use attributable to new industries attracted to a reliable water supply are included in Table 2.4-3 and illustrated graphically in Fig. 2.4-4.

Mining, livestock, and irrigation water demand projection figures are presented in Table 2.4-4 and illustrated in Fig. 2.4-5. These projections were obtained from the Texas Department of Water Resources, 1977. The irrigation usage varies widely depending upon the crops which are irrigated and the rainfall which occurs during the growing season. Also, the distribution of rainfall during the growing season impacts the farmers' decision to irrigate crops. Livestock water needs shown are based on the total numbers of livestock and poultry in the county and the average usage by the various animal classes. Mining water use projections by TDWR are based on the census of mining performed by the U.S. Bureau of Mines. At present, the only reported mining in the county is for limestone.

Table 2.4-3

Historical and Projected Water Demand for Existing and Potential Industry

Projections Year	TDWR Growth Of Existing Industry (mgd)	HDR Growth Of Existing Industry (mgd)	HDR Growth Of Existing And Potential Industry (mgd)
1972	0.18		
1973	0.20		
1974	0.20		
1975	0.20		
1976	0.20		
1977	0.20		
1978	0.33		
1980	0.21	0.34	0.52
1990	0.22	0.38	0.60
2000	0.27	0.42	0.69
2010	0.33	0.46	0.77
2020	0.40	0.49	0.85
2030	0.50	0.53	0.94

Source: Texas Department of Water Resources Computer Printouts, 1980.
Heart of Texas Council of Governments, 1980 (Historical Data).

only one industry, Chemical Lime Company, Clifton, since all other industrial facilities receive their water supplies through municipal service systems. The manufacturing usage shown is fairly consistent until 1977 and then reflects a sudden increase in water use for 1978. Coupled with that increased water usage was a reported employee increase of 70 percent, so it is thought that the growth will continue to be reflected in the future. TDWR projections for 1980 and subsequent decades did not reflect that increase and, therefore, the growth of existing industry has been modified (see Table 2.4-3).

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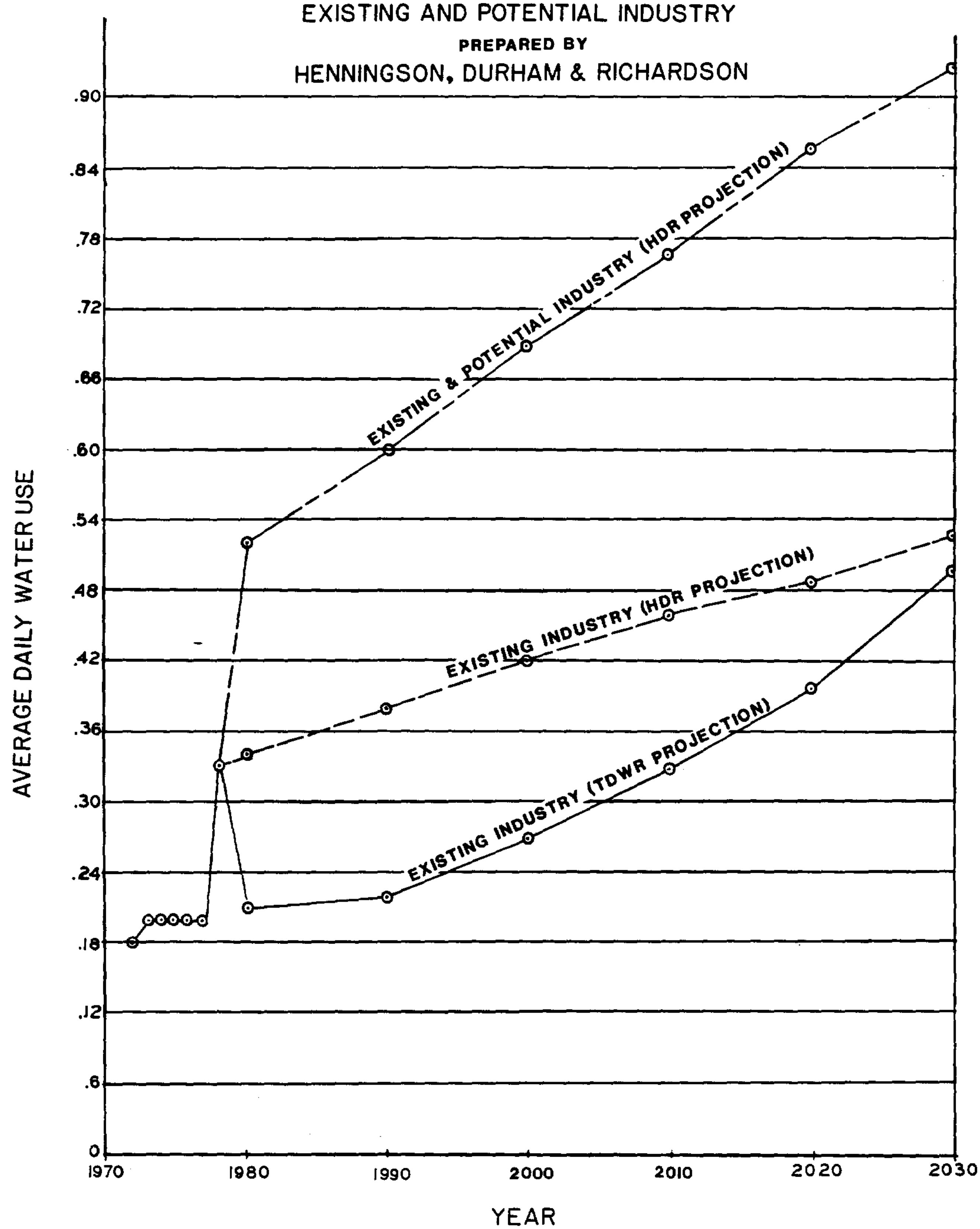
FIGURE 2.4-4

HISTORICAL AND PROJECTED WATER DEMAND FOR EXISTING AND POTENTIAL INDUSTRY

PREPARED BY

HENNINGSON, DURHAM & RICHARDSON



SOURCE: HISTORICAL: H.O.T. C.O.G. 1980

Table 2.4-4

Mining, Livestock and Irrigation Water Use Projections

Year	1980	1990	2000	2010	2020	2030
(mgd)						
Mining	0.09	0.13	0.17	0.22	0.26	0.31
Livestock	1.27	1.82	2.37	2.57	2.78	3.00
Irrigation	1.40	1.53	1.67	1.80	1.93	2.06

Source: Texas Department of Water Resources Computer Printouts, 1977.

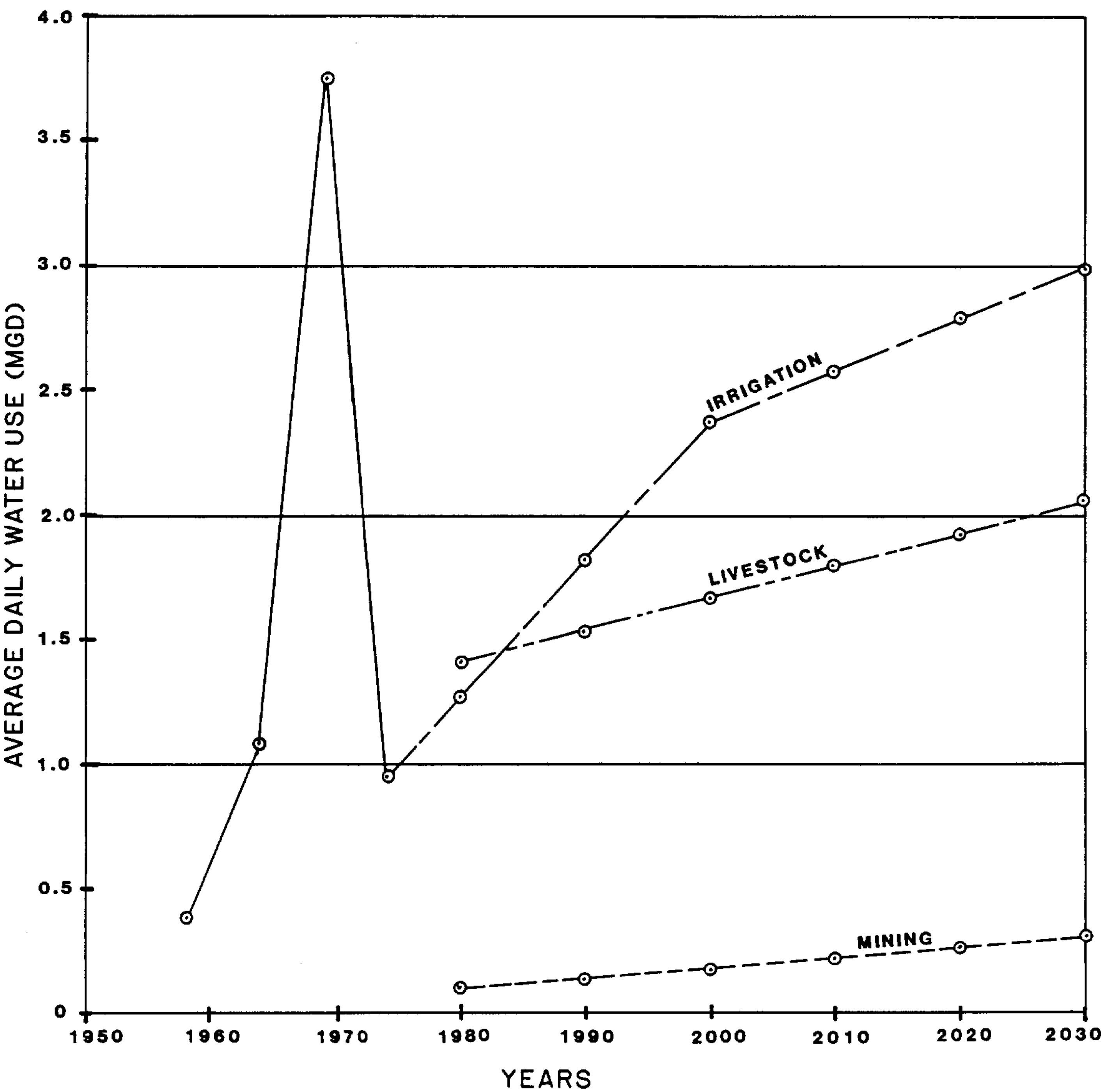
FIGURE 2.4-5

MINING, LIVESTOCK & IRRIGATION

PREPARED BY

HENNINGSON, DURHAM & RICHARDSON

SOURCE: TDWR



The total water use projections (average daily mgd) including municipal, manufacturing, mining, livestock, and irrigation categories, by decade for Bosque County are as follows:

1980	1990	2000	2010	2020	2030
4.73	5.92	7.16	8.04	8.91	9.81

As can be seen, the total average daily water demand projections range from 4.73 mgd in 1980 to 9.81 mgd in the year 2030. If these water requirements are met through groundwater sources, existing aquifers would be greatly overdrafted and depleted within several decades (see Sections 3.1 and 3.1.1). Also, it is impractical to assume all these water demands could be satisfied from surface water sources, due to such factors as distribution and water availability. During the 1970 to 1980 period about 50 percent of the total water needs in Bosque County were satisfied from groundwater sources and 50 percent from surface water sources, according to TDWR water use data. Also, it was considered infeasible to use the total county future municipal water demand projections as a basis for sizing the design alternatives investigated. Many factors influenced this decision including the distribution of population, topography, and type of existing water supply systems and resources. In all cases considered, the cost of supplying the smaller, more remote communities in the county is very prohibitive. It is thus recommended to use only a porportion of the total future demand for design purposes. The recommended volume will supply the total municipal and manufacturing water demands, one-half the rural and mining water demands and all of the projected additional manufacturing demands estimated to occur due to the influx of new industries. These demand requirements are presented in Table 2.4-5. It is estimated that this proportional average daily water use for the county will be 2.67 mgd in 2000 and will reach 4 mgd by the year 2030.

3.0 POTENTIAL WATER RESOURCE DEVELOPMENT

There are three basic alternatives for potential development of water supply sources: groundwater, surface water, and a combined operation using both ground and surface water. In evaluating these alternatives, water rights, project cost, water dependability, and project life are the most important parameters that govern overall feasibility. The following sections describe these parameters for each water resources alternative.

3.1 GROUNDWATER DEVELOPMENT

Bosque County presently derives almost all of its water supply from groundwater sources. The principal water bearing aquifer underlying the study area is the Travis Peak Formation. The Hensell and Hosston members of this formation provide over 95 percent of municipal and industrial water supply to entities in Bosque County. These members have a fresh water sand thickness ranging from 50 feet to 120 feet. The Hensell and Hosston aquifers are the primary source of groundwater throughout this portion of Central Texas. These members have been ideal in the past for the development of wells since they exhibited artesian properties. During the early twentieth century, wells completed in these formations would flow at the surface. However, due to overdevelopment, the artesian pressure surface (piezometric surface) or water level has continued to decline.

In 1980, there were about fifty major productive wells in the Hensell and Hosston formation in Bosque County. The total depth of these wells varies from several hundred feet on the west side of Bosque County to more than 1,000 feet on the east side of the county. Pumping capacity of wells developed in these formations range up to 300 gallons per minute.

Table 2.4-5

Bosque County Water Use Projections Used for Design Purposes

Year	100% Total Municipal Water Use[1] (mgd)	50% Total Rural Water Use[2] (mgd)	100% Total Existing Industry Water Use[3] (mgd)	100% Total Potential Industry Water Use[3] (mgd)	50% Total Mining Water Use[4] (mgd)	Total Projected Water Use For Design Purposes (mgd)
1980	1.04	-	0.34	-	-	1.38
1990	1.27	0.29	0.38	0.22	0.06	2.22
2000	1.53	0.37	0.42	0.27	0.08	2.67
2010	1.79	0.45	0.46	0.31	0.11	3.12
2020	2.04	0.53	0.49	0.36	0.13	3.55
2030	2.29	0.61	0.53	0.41	0.16	4.00

1 - From Table 2.4-1

2 - From Table 2.4-2

3 - From Table 2.4-3

4 - From Table 2.4-4

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Fig. 3.1-1 illustrates historical water levels in the primary water wells for the cities of Meridian, Clifton, and Valley Mills. As illustrated in this figure, water levels have declined since 1940. Also, it is evident that the rates of decline have increased during the last decade. This vividly illustrates that the Hensell and Hosston formations are being "mined" or overdrafted, i.e., water is being withdrawn faster than it is being recharged.

Projections of water level decline for Meridian, Clifton, and Valley Mills are shown also on Fig. 3.1-1. These projections are based on the rate of water level declines since 1965 and on the assumption that future water demands will be met by additional groundwater development. As can be seen in Fig. 3.1-1, the communities of Meridian, Clifton, and Valley Mills have an estimated dependable groundwater supply only for the next 20 to 30 years, based on current development trends.

However, it should be emphasized that water level declines in the Hensell and Hosston formations correlate directly to higher energy costs and poorer quality water. As a whole, Bosque County is not in a present day water crisis situation. But due to severe limitations in surface water rights availability, declining groundwater supplies, and the long time frame required to develop major water resources projects, the county should take immediate steps to better manage its existing resources and/or develop new sources.

3.1.1 GROUNDWATER MANAGEMENT

As pointed out in the previous section, groundwater management may extend the dependable life of the Travis Peak Formation. In the past,

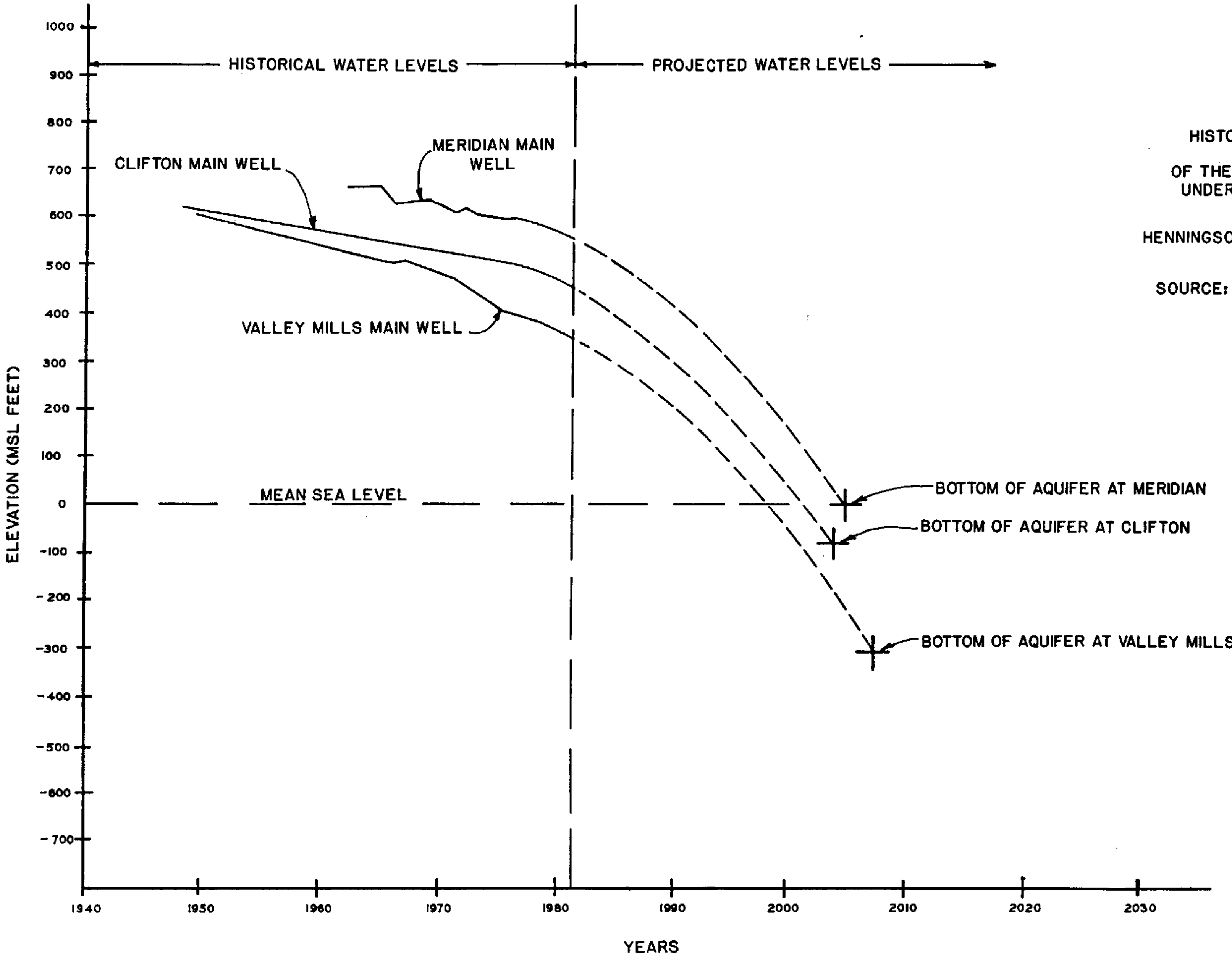

FIGURE 3.1-1

HISTORICAL AND PROJECTED WATER LEVELS OF THE TRAVIS PEAK FORMATION UNDERLYING BOSQUE COUNTY

PREPARED BY
HENNINGSON, DURHAM & RICHARDSON

SOURCE: TDWR REPORT 195. 1978

individual cities, industries, farmers/ranchers have developed a groundwater supplies without regard to the limitations of the resource within Bosque County. Compounding this problem is the fact that the Travis Peak Formation underlies at least 15 counties in Central Texas and is heavily developed. Groundwater management is imperative in order to extend the life of this finite water resource.

Groundwater management includes the consideration of such factors as well spacing, capacity, pumping times, and beneficial water use. Management practices could be implemented on an individual, municipal, county or regional basis. This has been successfully done in Texas through the creation of underground water districts. These districts are generally created through the Texas legislature to provide powers to regulate groundwater practices.

On a municipality basis, local communities such as Meridian, Clifton, and Valley Mills could buy surface land rights to develop underground water resources. This practice is becoming more common throughout Texas. Municipalities essentially buy the rights from the agricultural sector to develop local well fields.

At best, groundwater appears to be a 25 year supply for the County of Bosque, since it is being over developed in a fifteen county area of Central Texas.

3.2 SURFACE WATER RIGHTS

The issue of water rights is the most important factor in all plans which consider the utilization of surface water. The State of Texas requires a permit for all types of diversion of water in streams within the state.

The process of review and permitting is performed to insure that there is "unappropriated" water available, prior to granting additional permits. Thus, the rights of existing permit holders are protected by a "first in time, first in right" philosophy which can be revoked only for failure to utilize the right. If the permit is not put to "beneficial use" for a period of ten years, the Texas Water Commission has the authority to cancel the permit. As long as there is surplus water, however, this cancellation option has generally not been exercised.

The issue of water rights must be addressed in all of the following surface water and combined ground and surface water alternatives. The impact on the existing water rights of each alternative will depend on a number of variables, requiring a detailed analysis of amounts, rates and periods of diversion and releases from impoundments. It is therefore evident that the most feasible alternative, with respect to water rights, is that one which has the least overall impact on, or the highest benefit to existing water rights.

3.3 COMBINED GROUND AND SURFACE WATER ALTERNATIVES BY ARTIFICIAL RECHARGE OF AQUIFERS

Artificial recharge is the process of transferring surface waters into the groundwater system. Recharge occurs naturally when rainfall or runoff contacts the exposed areas of the aquifer at the ground surface. Man can enhance the recharge of the aquifer by using spreading ponds or through injection wells. In either case, a surface water source must provide the supply, and the cheapest supply source in Bosque County would be the "scalping" of water from the North Bosque River. This would make use of surplus water which is available during high flow stages in the river. The level when surplus is available would be dictated by the downstream water rights. When the flow in the Bosque River reached a specified level, water would be diverted to an off-channel recharge area. Then, the recharge of the aquifer would be accomplished using either spreading ponds or injection wells.

3.3.1 SPREADING PONDS

This method of recharge involves infiltration of water from spreading basins into highly permeable aquifers at the position of outcrop, which is the point at which the aquifer is exposed at ground level. The Paluxy is the only aquifer outcropping in Bosque County, and this occurs in the vicinity of the North Bosque River, several miles north of Meridian. This aquifer has an average thickness of 35 feet in the outcrop area and yields small to moderate amounts of fresh water suitable for domestic, livestock and irrigation supply. Texas Department of Water Resources Report No. 195, Ground-water Resources of Part of Central Texas with Emphasis on the Antlers and Travis Peak Formations, Volume I, contains results of studies performed on the Travis Peak Formation including the assessment of properties of the Paluxy aquifer. These results indicate that the sandy permeable soil and vegetative cover of the Paluxy are favorable for recharge with the most promising area of development being in the northern part of Bosque County. A more complete and detailed groundwater investigation is recommended in the TDWR report to fully evaluate the amount and quality of recharge water available.

A preliminary geotechnical investigation (Geotechnical Investigation - PHASE I Proposed Dam Site on North Bosque River Near Meridian, Bosque County, Texas) of the outcrop area was conducted during the course of this study. Borings were drilled through the Paluxy aquifer approximately 4 miles north of Meridian and insitu pressure tests performed at various depths. Water losses recorded within the Paluxy aquifer during the drilling were minor and relatively low permeabilities were obtained from laboratory tests on samples of the Paluxy sands. The results of this study indicate that the Paluxy aquifer does not have the necessary recharge and tranmissivity characteristics to provide an adequate quantity of groundwater for the county economically.

3.3.2 INJECTION WELLS

It is not possible to recharge the Hosston and Hensell members of the Travis Peak formation by means of spreading ponds within the county as they outcrop to the north and west of Bosque County in Erath, Hood, and Somervell Counties. The depth of water in these aquifers presently varies from about 600 feet below ground surface in the north part of the county to about 800 feet in the southern part. Recharge of these members, within the county, would require the use of injection wells.

In order to utilize injection wells, surface water would be scalped from the North Bosque River when the instream flow exceeded a predetermined flow rate, which would be based on the quantity of flow necessary to satisfy downstream water rights. Scalping would be infeasible if the required flow rate was so great that the frequency of diversion would not satisfy the anticipated demand. Assuming the required flow was available, water would be pumped from a diversion structure to an off stream holding pond (see Figure 3.3.2-1). Before the water is injected into the ground, it must be treated so its quality is at least equivalent to the minimum require-

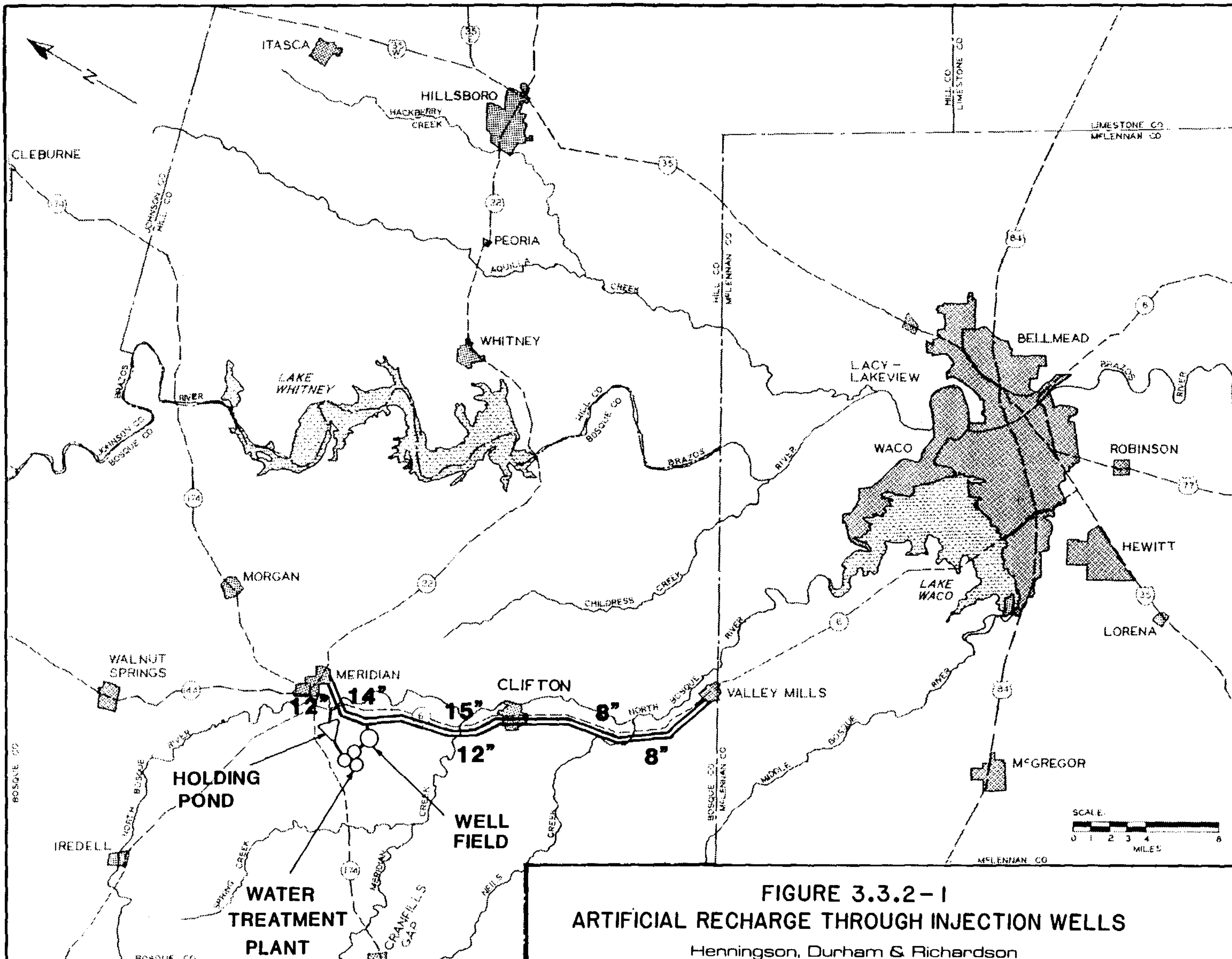

FIGURE 3.3.2-1
ARTIFICIAL RECHARGE THROUGH INJECTION WELLS
Henningson, Durham & Richardson

ments for potable water. Therefore, a conventional treatment plant would be required, and after treatement, the pH and temperature of the water would have to be adjusted to eliminate the possibility of undesirable precipitates forming in the injection well when surface and groundwater are combined.

To make this alternative feasible, due to the treatment required, the injection and recovery process must be at least 90 percent effective and the transmissivity of the aquifer must be such that it will easily take water. Assuming that a portion of the Hosston and Hensell members fit the preceeding requirements, minimum capital costs for this alternative are $7,650,000 for the short term period, with an annual operating cost of $340,000, assuming conventional water treatment is required. To meet the 50 year demand, an additional $10,420,000 capital investment would be required, so the total 1980 capital cost would be $18,070,000 (see Table 3.3.2-1). The major advantages are that parts of the existing system could be incorporated in the recovery and transmission facilities, which would lower the initial capital cost, and the recharge process could be concentrated in one area reducing the transmission costs to the main centers. However, the operation and maintenance costs for the wells would prove prohibitive in the future. A high amount of energy is required to regulate the temperature of the water and create the high injection pressures in the wells. Also, a high degree of control would be required for optimum operation of the wells and to prevent the drilling of unauthorized wells nearby.

Table 3.3.2-1

Cost Estimate (1981 Dollars) For
Artificial Recharge by Injection Wells

Item	Construction Cost Phase I	Construction Cost Phase II	1981 Annual Operating Costs
Diversion Structure	$ 150,000	-	-
Holding Pond	1,110,000	-	-
Injection & Recovery Wells	1,300,000	$ 2,825,000	$ 80,000
Treatment Plant	3,150,000	6,050,000	150,000
Transmission Pipeline	1,940,000	1,545,000	85,000
Labor & Misc.	-	-	25,000
TOTAL	$7,650,000	$10,420,000	$340,000

3.4 SURFACE WATER ALTERNATIVES

A number of surface water alternatives have been identified which could conceivably be used to supply the needs of Bosque County. Within the county, the following alternatives are available:

* Scalping to surface water storage;
* Add conservation storage to Soil Conservation Service dams;
* Construct a small dam sized only for the county's needs; and
* Construct a large conservation storage reservoir.

Surface water may also be available from outside the county from the following sources:

* Lake Whitney; and
* Lake Aquilla.

3.4.1 SURFACE WATER RIGHTS IN THE NORTH BOSQUE WATERSHED

The computation of the water available within the drainage basin is based on the hydrological occurrences during the worst drought recorded. Rainfall (inflows), evaporation, required releases, and projected diversions all impact the quantity of water which an impoundment may be expected to safely yield. The Texas Department of Water Resources has recently performed a very preliminary evaluation of rights within the Bosque River Basin to determine the amount of unappropriated water available. This was available in the form of unappropriated streamflow at the gages on the Bosque River, adjusted for permitted water rights.

This information was available only in the final stages of this study, and was not used in the evaluation of individual surface water supply alternatives. The comparisons of on-channel reservoirs outlined in the following sections are based on total flows obtained from the USGS Water Resources Data Reports, not unappropriated flows. Therefore, the issue of water rights is applicable to all identified plans and further study to determine the possibility of acquirement of those rights would be necessary, regardless of the project selected. While it is not exact, the total flow approach does provide an adequate basis for comparison of projects and is used to evaluate alternatives.

In addition however, a yield analysis was performed on the large dam discussed in alternative 3.4.5, using the TDWR unappropriated flows to obtain the worst case (minimum) yield available from a conservation storage reservoir.

It was determined that unappropriated inflows available for a 62,000 acre-feet conservation reservoir near Meridian would provide about 3.7 mgd for the 1945-57 drought period of record (see Appendix A). This volume will almost meet the projected 50 year demand of Bosque County. By increasing reservoir storage capacity to 97,000 acre-feet, the unappropriated firm yield can be increased to 5.7 mgd (see Appendix B). Thus, it appears that sufficient water rights are available to meet the future needs of Bosque County.

It should be pointed out that the accuracy and validity of the quoted volume of unappropriated water has not been verified. The quoted figures are presented herein as an assumed minimum of unappropriated rights which are available within the basin.

3.4.2 SCALPING TO SURFACE WATER STORAGE

The scalping process required in this alternative is identical to the method outlined in the injection well alternative. Diversion structures would be constructed in the North Bosque River at locations near Meridian, Clifton, and Valley Mills. When the river reaches flood stage, water would be diverted to storage reservoirs having capacities at least twice the design demand plus an allowance which provides for several years evaporation. The evaporation allowance would provide a dependable supply during periods of drought, since it is anticipated the cities would not maintain their well fields (see Fig. 3.4.2-1).

As demand required, water would be pumped to the treatment plants which would be sized for the present demands. The transmission facilities would be sized for the 20 year design demand with expansions based on the long term (50 year) demand. The diversion facilities and storage reservoir would be sized for the long term (50 year) demand. Individual storage reservoirs and treatment plants contribute to the high costs involved in this alternative. (See Table 3.4.2-1). Although a cost saving can be achieved by reducing transmission costs, the high initial cost of constructing the storage reservoirs for a 50 year design period must be borne by the existing customers.

A breakdown of these costs and the annual operations and maintenance costs for the City of Clifton are presented in Table 3.4.2-1. The cost to Meridian and Valley Mills would be very similar, except that the cost for the storage reservoir and treatment plant would be approximately one-half

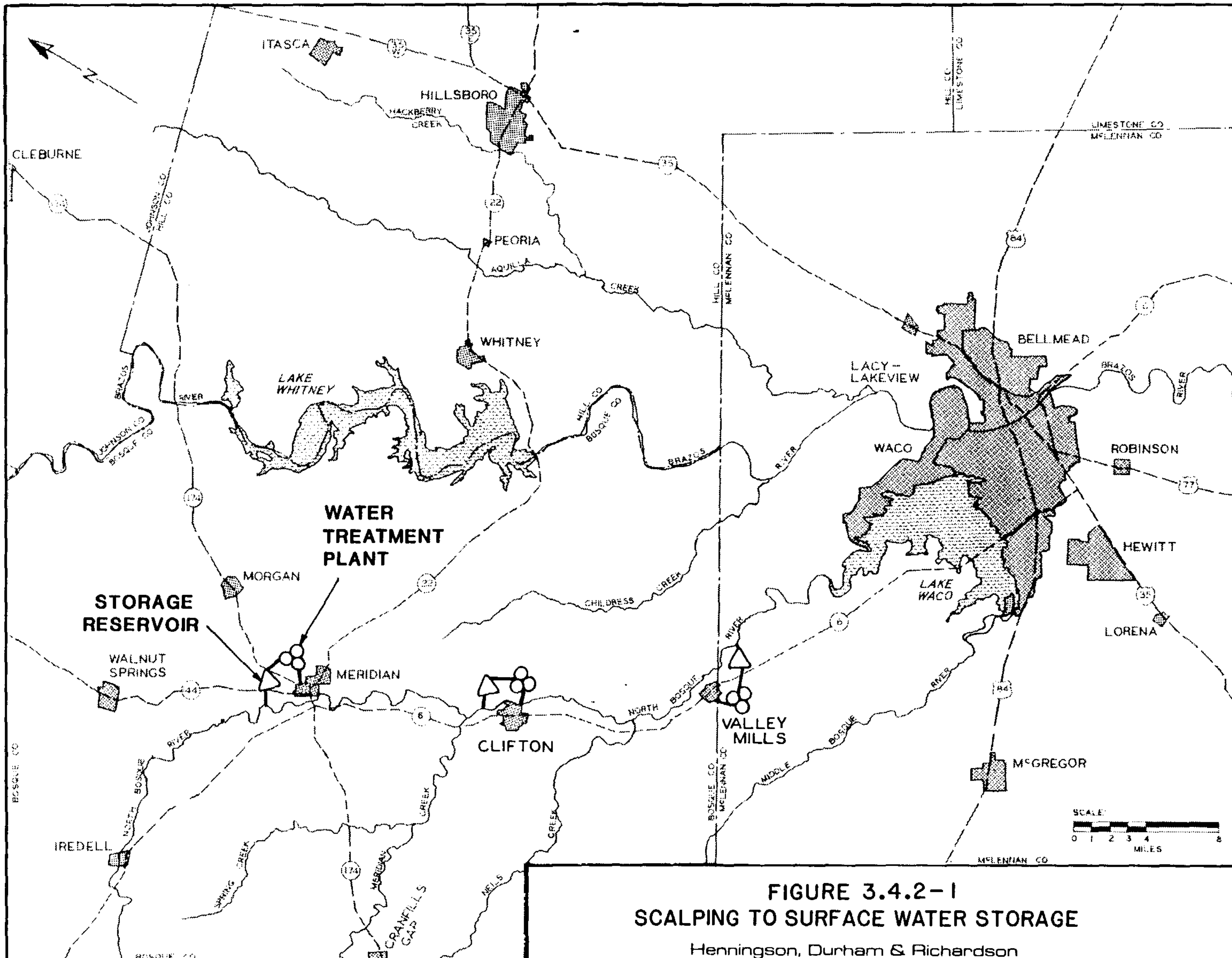

FIGURE 3.4.2-1
SCALPING TO SURFACE WATER STORAGE
Henningson, Durham & Richardson

Table 3.4.2-1

Cost Estimate (1981 Dollars) For
Scalping to Surface Water Storage for Clifton

Item	Construction Cost Phase I	Construction Cost Phase II	1981 Annual Operating Costs
Diversion Structure & Pump Station	$ 200,000	-	$ 20,000
Storage Reservoir	3,850,000	-	-
Transmission Pipeline & Pump Station	650,000	$ 260,000	20,000
Treatment Plant	1,250,000	1,340,000	60,000
Labor & Misc.	-	-	25,000
TOTAL	$5,950,000	$1,600,000	$125,000

that shown, since their water use is about one-half of Clifton's.

The issue of water rights is again the most important factor in this alternative, since diversion of surface water would be required. A greater amount of water would be diverted than with the scalping/recharge alternative due to more water being lost to evaporation with the permanent storage above ground. Notwithstanding the status of water rights, it appears that the cost of implementing scalping to storage schemes for the three main centers is prohibitive and this alternative is not recommended.

3.4.3 SOIL CONSERVATION SERVICE DAMS

The Soil Conservation Service (S.C.S.) of the Department of Agriculture has constructed four flood retarding structures in Bosque County, two on Hog Creek and two on tributaries of the Bosque River near Clifton. The possibility of raising these dams to provide conservation storage for water supply for the county was investigated. Also a preliminary analysis was made of the watersheds which are proposed to receive future SCS structures from data obtained from the HOTCOG report, 1980. (See Fig. 3.4.3-1 for existing and proposed reservoir sites.) None of the analyses revealed potential reservoirs capable of producing a yield of sufficient quantity to meet the needs of Bosque County. Since utilization of multiple reservoir sites would increase costs, further investigation of this alternative was not pursued.

3.4.4 SMALL DAMS

Reservoir sites capable of supplying the long term (50 year) water demand for Bosque County were investigated on tributaries of the north Bosque and Brazos Rivers. The tributaries considered included Meridian, Neils,

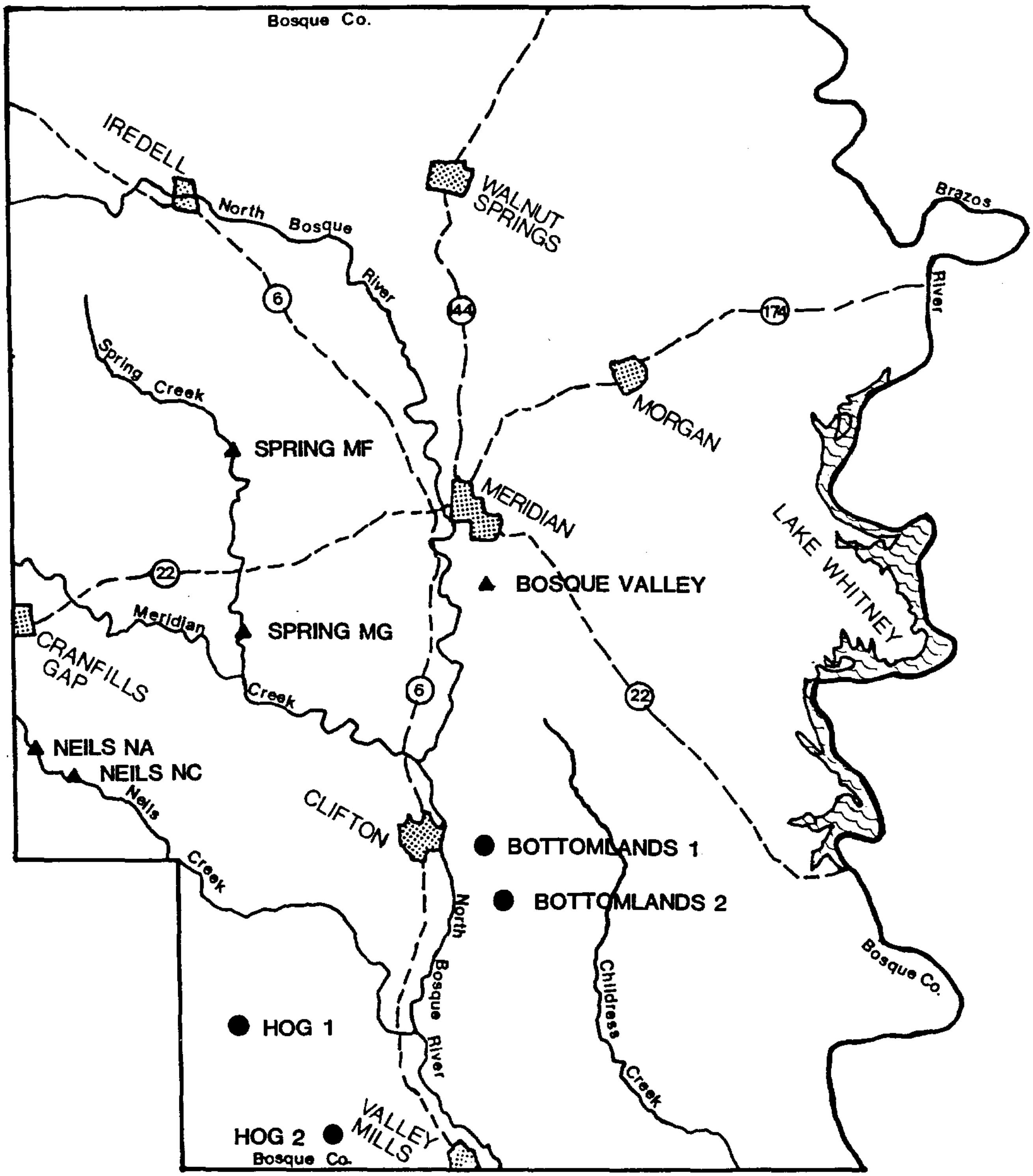

FIGURE 3.4.3-1

● Existing SCS Dams

▲ Proposed SCS Dams

Source : H.O.T.C.O.G. 1980

SOIL CONSERVATION SERVICE DAM SITES

PREPARED BY
HENNINGSON, DURHAM & RICHARDSON

Childress, and Spring Creeks. Preliminary investigation of the drainage areas associated with prospective dam sites indicated that potential sites exist on Meridian and Neils Creeks. The sites on Childress and Spring Creek proved to be too small to provide for the County's long term needs.

A preliminary hydrological study was conducted on the dam site on Meridian Creek. The Meridian and Neils Creek sites are similar in size of drainage area and storage capacity, but only the Meridian site was investigated in great depth as it is closer to the main centers resulting in lower transmission costs. The study performed was a reservoir operations analysis to determine the areal yield of the reservoir based on historical records of evaporation and total streamflow. Unappropriated flow records were not available for Meridian Creek. The TDWR computer program RESOP II was utilized in the analysis.

The results of this analysis show that the potential site would more than adequately provide for the County's long term water demands and allow for some unanticipated expansion. At a storage capacity of 42,700 AF, an areal yield of 12 mgd is available considering total flows in Meridian Creek (see Appendix C for computer printout). This is the areal yield available before any existing water rights downstream are taken into consideration. For the cost estimates, however, the dam has been sized to supply a firm yield of 4 mgd, which is the design demand for Bosque County.

The water would be transmitted from the lake by pipeline to Clifton where the treatment plant would be located. From there, treated water would be transmitted to Meridian and Valley Mills. Fig. 3.4.4-1 illustrates the location of the facilities. The treatment plant was sized for present demands

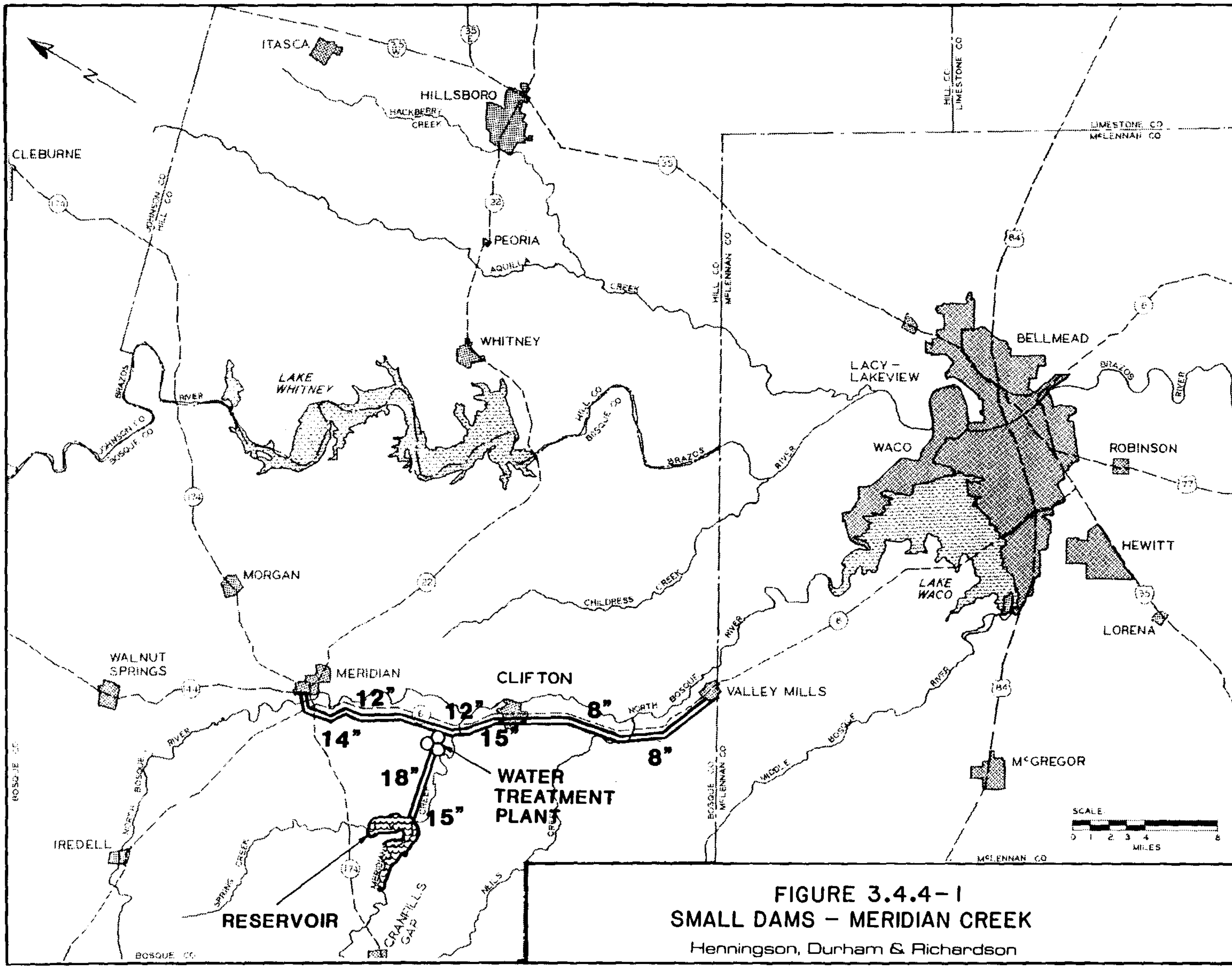

FIGURE 3.4.4-1
SMALL DAMS - MERIDIAN CREEK
Henningson, Durham & Richardson

and the pipeline for the short term (20 year) demand with expansions to meet the long term (50 year) demand. The initial capital costs based on the preceding criteria are presented in Table 3.4.4-1, with annual operations and maintenance costs.

As with other surface water sources, the question of water rights would be the paramount issue which would have to be resolved before project feasibility would be assured. The 12 mgd areal yield would be reduced substantially when the downstream water rights are satisfied. In the case of this specific project, it is evident from the almost $19 million cost estimate that it is infeasible for Bosque County to sponsor a dam project purely for water supply for only the county. The initial cost of the dam construction would have to be borne by the existing customers, even though the alternative is designed to serve the projected long term number of customers. However, the concept of a new surface water reservoir would be advantageous as a long term project and could have a strong bearing in attracting new industry and populace to the County. Therefore, the following investigation was undertaken to evaluate a dam project which would supply an expanded service area outside of the County.

3.4.5 LARGE DAM

The North Bosque River is the only river within the County on which a large dam project would be feasible. It would be infeasible to build a small dam on this river due to the high cost of the spillway structure required to pass flood flows. A potential site with a contributing drainage

Table 3.4.4-1

Cost Estimate (1981 Dollars) For
Small Dam on Meridian Creek

Item	Construction Costs Phase I	Construction Costs Phase II	1981 Annual Operating Costs
Dam and Appurtenant Works	$ 4,415,000	-	-
Pump Station and Transmission Pipeline	2,900,000	$2,350,000	$ 35,000
Treatment Plant and High Service Pump Station	3,150,000	6,050,000	185,000
Labor & Misc.	-	-	50,000
TOTAL	$10,465,000	$8,400,000	$270,000

area of approximately 710 square miles has been identified four miles north of Meridian (see Fig. 3.4.5). A dam controlling this great an area could impact many downstream water rights holders. The primary impact would be to Lake Waco, as 42 percent of its drainage area would be partially controlled upstream. A detailed hydrological study would be required to accurately assess all aspects of the downstream impact.

In order for Bosque County to be able to participate in a large surface water impoundment project, all the costs would have to be shared with one or more major users. There are a number of communities downstream in McLennan County, including Waco, that could be prospective participants. If they should choose to participate, then the inclusion of additional conservation storage in either this reservoir and/or in Lake Waco should be considered.

A number of potential sites were investigated along the North Bosque River. The site offering the optimum ratio of storage to dam size with the least relocation of roads and dwellings was chosen for further investigation as a conservation storage reservoir. A reservoir operations study was conducted for the potential site to determine the areal yield at various conservation capacities. The site had a maximum storage capacity of approximately 97,000 acre feet, dictated by relocation restraints. The area storage curve is presented in Fig. 3.4.5-1 and the areal yield versus capacity curve is presented in Figure 3.4.5-2. It was determined that the optimum, with respect to minimizing capacity, conservation storage was approximately 62,000 acre-feet. This capacity produced an areal yield of 23.5 mgd (see Appendix D for computer printout). A study of sediment load records at the Hico gage on the North Bosque River produced an average annual sediment load

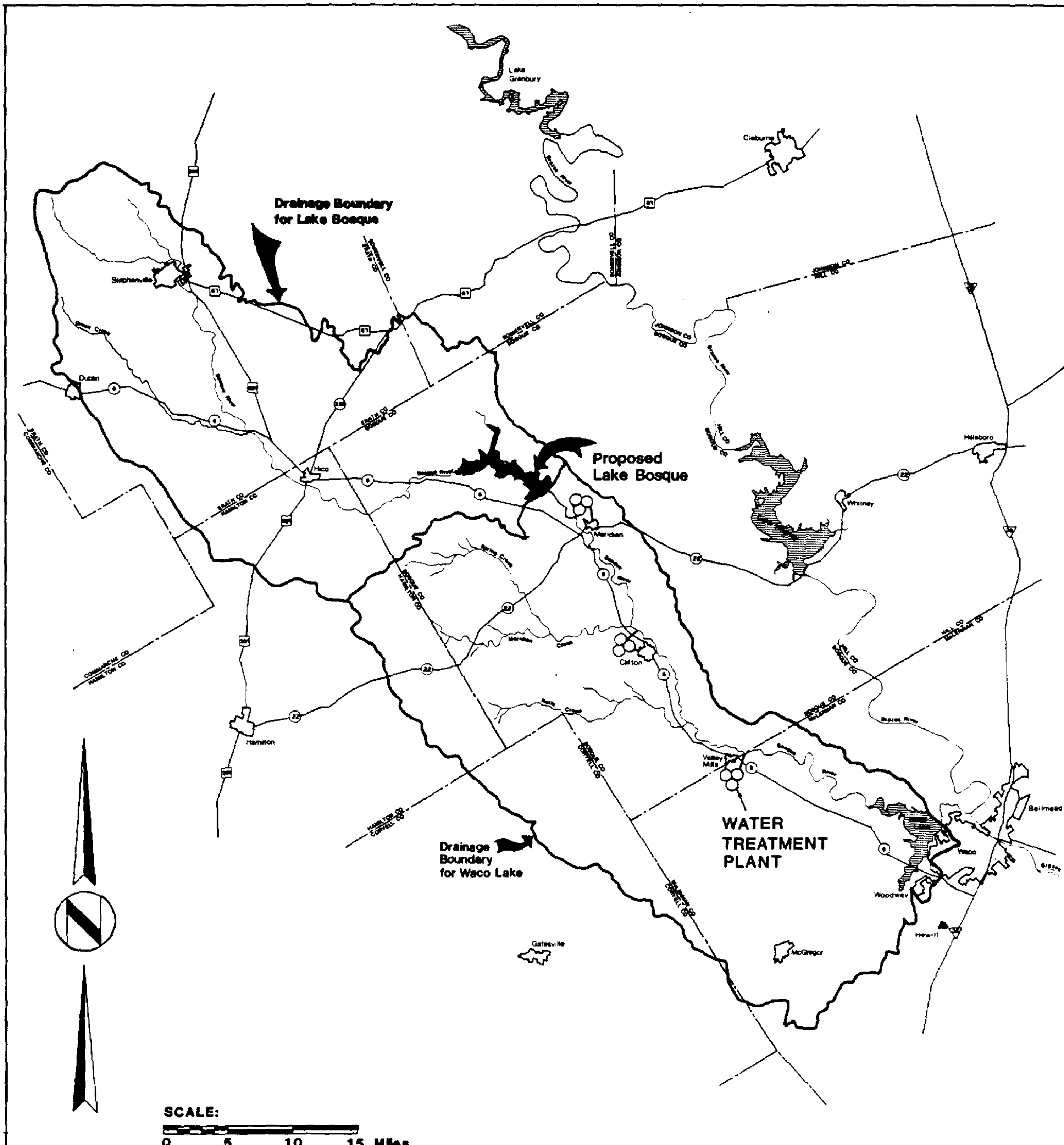

FIGURE 3.4.5

LARGE DAM – NORTH BOSQUE RIVER

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FIGURE 3.4.5-1

LAKE BOSQUE AREA - STORAGE CURVE

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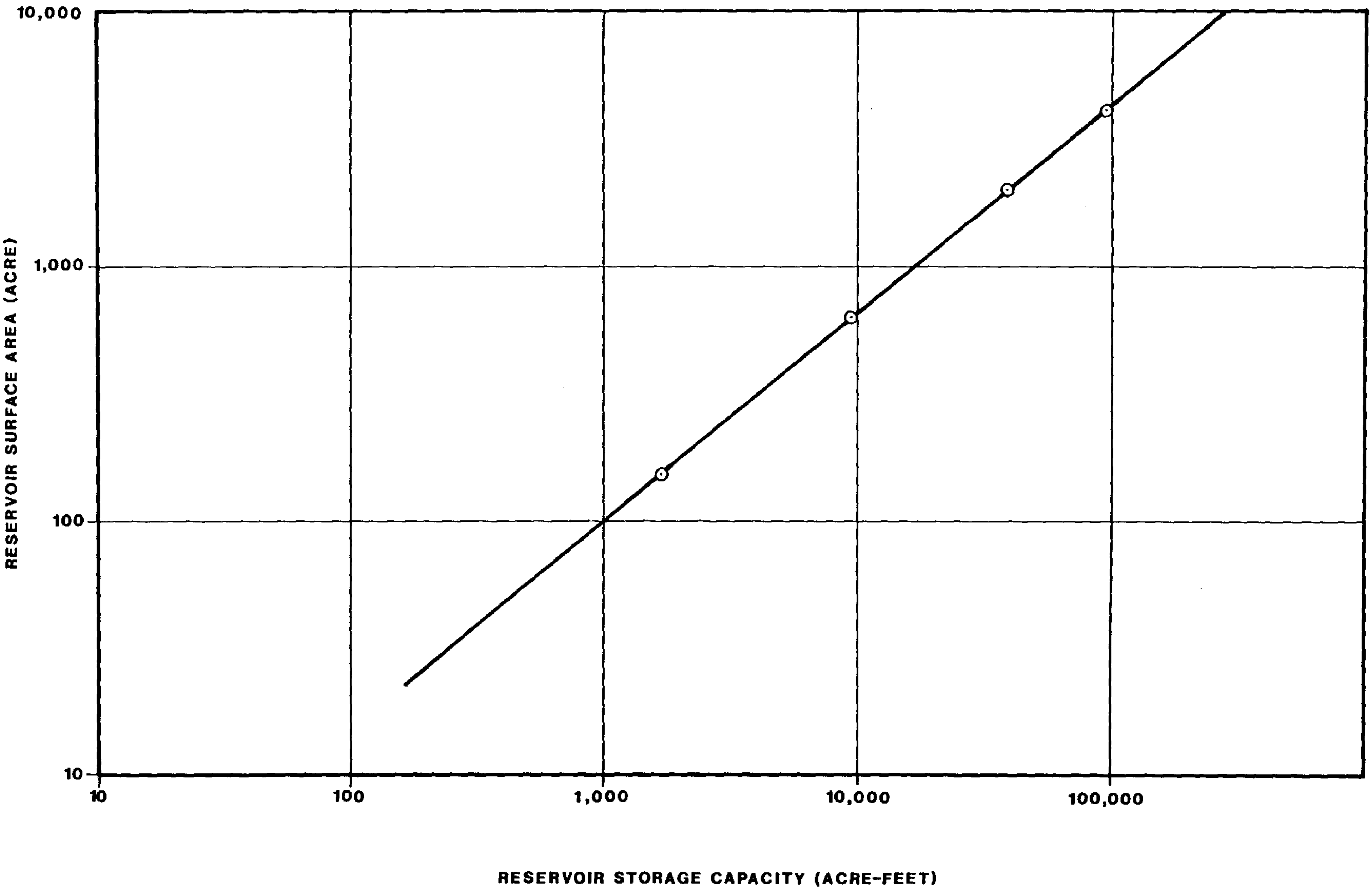
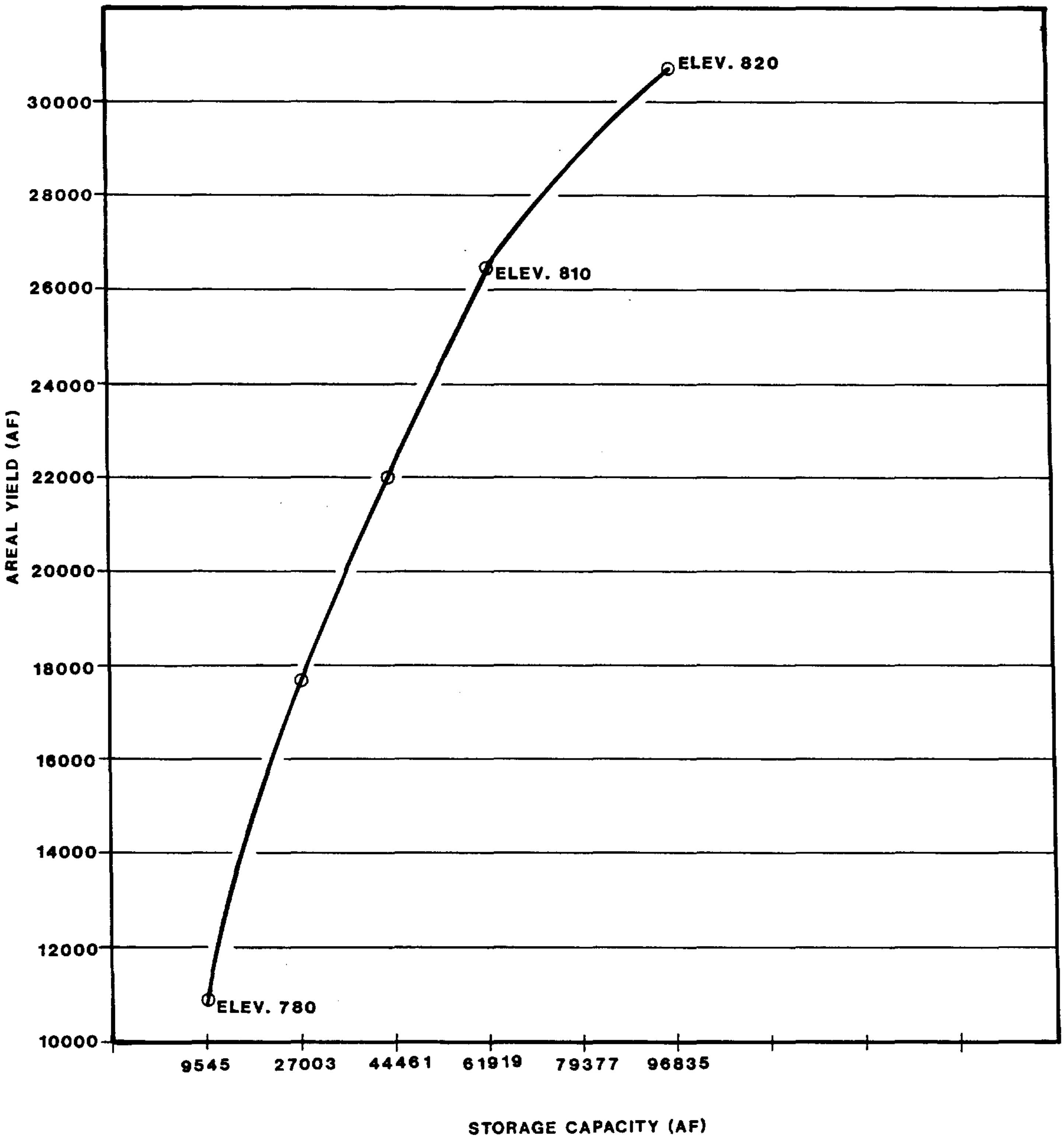


FIGURE 3.4.5-2

LAKE BOSQUE PROPOSED RESERVOIR ON BOSQUE RIVER
NEAR MERIDIAN: REVERSE OPERATION
AREAL YIELD VS. STORAGE CAPACITY

SOURCE: TDWR COMPUTER PROGRAM RESOP 2



at the dam of 0.081 acre feet per mile. This translates to a 50 year load of 2864 acre-feet at the dam which does not cause a significant decrease in areal yield.

The yield is also based on total flows in the Bosque River, not unappropriated flows, and therefore assumes no impact downstream. This would not be the actual case, however, and a proportion of the available areal yield would be required to be released downstream to Lake Waco to compensate for the impact of the new reservoir on normal flow into Lake Waco. A detailed hydrological study of historical flows and channel losses in the river would be necessary to determine the direct impact, and also the trade off which might occur if flood storage in Lake Waco can be converted to conservation storage.

In order to allow cost comparisons to be made, however, an estimate of possible compensations and benefits to the downstream water rights was determined. For this purpose, it was assumed that the net impact on Lake Waco and other water right holders would be 7,250 acre-feet and a 6.48 mgd release would be required. These figures were based on a preliminary estimate of average channel loss of 40% between Lake Bosque and Lake Waco and the ratios of areal yield to conservation storage for the lakes for straight conversion of storage from one lake to the other. The ratio of conservation storage to areal yield used for Lake Bosque and Lake Waco was 3 to 1. The 6.48 mgd release to Lake Waco is estimated to be the difference between the impact due to a decrease in normal flow available for conservation storage and the benefit of withholding flood waters, enabling a conversion of flood to conservation storage to be effected. Thus, the 23.5 mgd yield in the proposed project would be reduced to 17.02 mgd due to this assumed requirement. Then, the cost to Bosque County for a 4 mgd share of the project would be:

$$\frac{4}{23.5-6.48} \quad X \quad \$24,000,000 \quad = \quad \$5,640,000$$

assuming customers can be found to purchase the remaining yield. A breakdown of the cost estimate for the project is presented in Table 3.4.5.

Controlled releases would be made downstream to supply Bosque County's demand. River diversion structures would be located at Meridian, Clifton, and Valley Mills, where the water would be removed and pumped to individual treatment plants prior to distribution. Figure 3.4.5 illustrates the location of these facilities.

The water treatment plants would be sized for present demands, the pipeline for the short term (20 year) demands, and the diversion facilities for the long term (50 year) demands. These capital costs are detailed in Table 3.4.5-1 with the annual operations and maintenance costs.

Alternative reservoir operating schemes may prove to be more efficient in maximizing the yield of the project and/or Lake Waco should be further investigated. These include:

* Various combinations of conservation pool capacities at the new reservoir and conservation pool capacities of Lake Waco; and
* Various release rates to minimize channel losses.

Other considerations which may need to be addressed in future studies include:

* Release rate for instream water rights including domestic and livestock use;
* Releases for recreational purposes;
* Timing of releases to minimize conservation pool fluctuations

TABLE 3.4.5
LAKE BOSQUE
PRELIMINARY COST ESTIMATE

Unit	Quantity	Price	Total (Dollars)
Land - Cultivated	1,700 acres	1,000.00	1,700,000
Unimproved	1,700 acres	800.00	1,360,000
Clearing	600 acres	300.00	180,000
Core Trench Excavation	90,000 yd^3	2.00	180,000
Embankment Fill	2,650,000 yd^3	2.00	5,300,000
Riprap	62,000 tons	30.00	1,860,000
Spillway Concrete	27,000 yd^3	300.00	8,100,000
Outlet	Lump Sum	800,000.00	800,000
Spillway Gates	Lump Sum	1,000,000.00	1,000,000
Relocations	Lump Sum	500,000.00	500,000
SUBTOTAL			$20,980,000
Contingencies, Engineering & Technical Services			$ 3,020,000
TOTAL			$24,000,000

Table 3.4.5-1

Cost Estimate (1981 Dollars) For
Bosque County Share of
Conservation Reservoir on North Bosque River

Item	Construction Costs Phase I	Construction Costs Phase II	1981 Annual Operating Costs
Dam & Appurtenances	$5,640,000	-	-
Diversion Structures & Pump Stations at Clifton, Meridian & Valley Mills	600,000	-	$ 25,000
Treatment Plant	3,000,000	$5,900,000	150,000
Pump Station & Transmission Pipeline	200,000	210,000	30,000
Labor & Misc.	-	-	50,000
TOTAL	$9,440,000	$6,110,000	$255,000

in either Lake Waco and/or the proposed reservoir; and

* Consideration of hydro-power generating facilities.

3.4.6 LAKE WHITNEY

Lake Whitney was constructed on the Brazos River by the Corps of Engineers as a flood control and hydroelectric power project. At the present time, there is no conservation storage in the lake appropriated for municipal water supply purposes.

Two alternatives for the potential use of the water in Lake Whitney have been investigated: the controlled periodic diversion of acceptable quality water, and the diversion of saline water for treatment by the reverse osmosis process.

3.4.6.1 CONTROLLED DIVERSION OF LAKE WHITNEY WATER

The water in Lake Whitney exhibits wide variation in quality at different times and locations on the lake. Data from water quality collection sites on the lake obtained from TDWR Water Quality Reports, were analyzed for the period from 1965-1975 to determine the feasibility of diverting water from Lake Whitney when the quality was acceptable and from one diversion point that supplied a dependable water quality (see Fig. 3.4.6-1). An intake could be placed at this point, assuming a suitable site and access is available and that the depth of water and sediment conditions are favorable. The water would be pumped from the lake to an off-channel storage reservoir when the quality is acceptable, which would usually be less saline after run-off from large storms had entered the lake. Then, as needed, the water would be pumped from storage to a treatment plant close to Meridian,

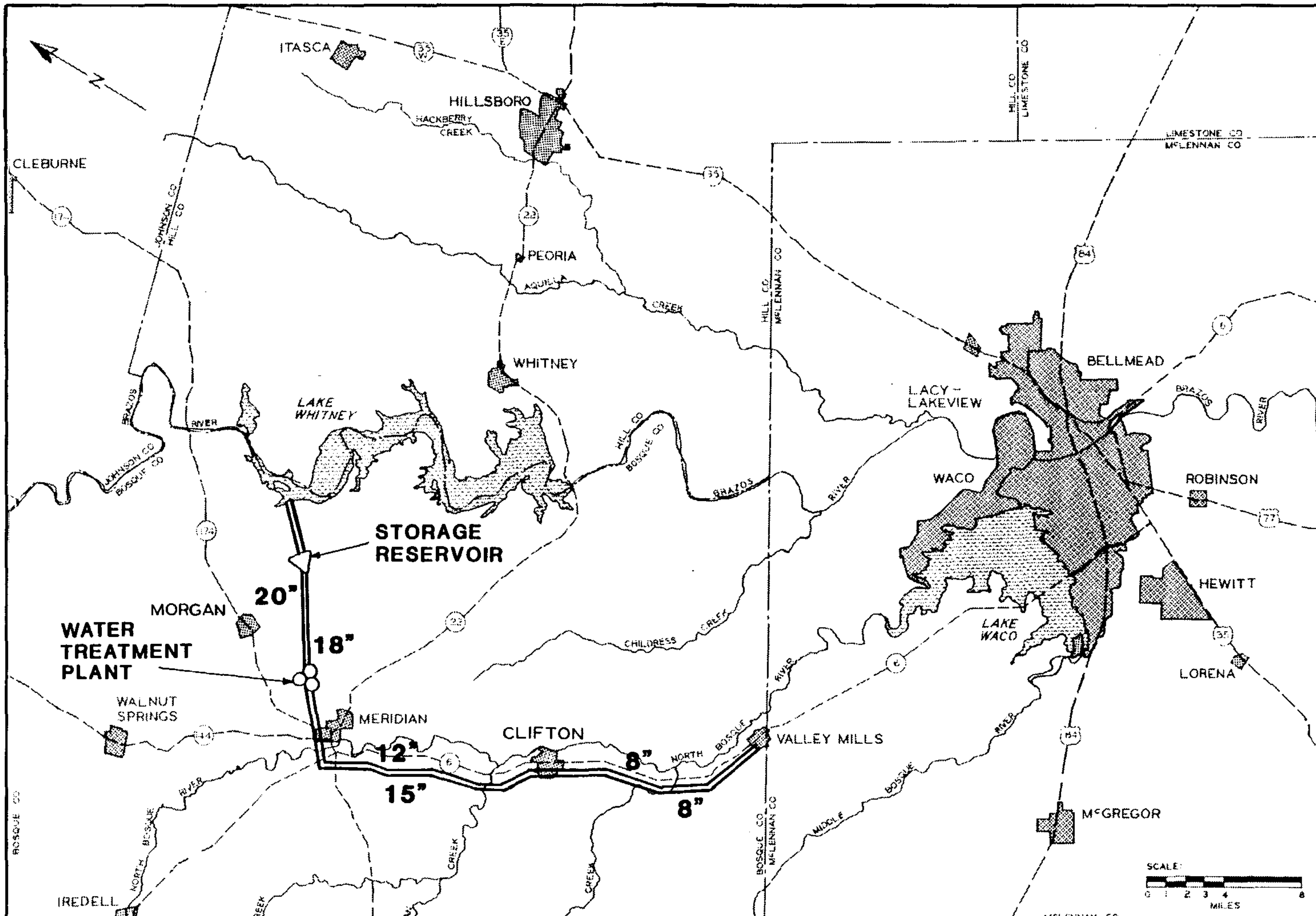


FIGURE 3.4.6-1
LAKE WHITNEY - CONTROLLED DIVERSION
Henningson, Durham & Richardson

from which potable water could be transmitted by gravity pipeline to Clifton and Valley Mills.

The treatment works would be sized for immediate demands, the pipeline for 20 year demands, and the diversion facilities for the long term (50 year) demand. A breakdown of the capital costs is presented in Table 3.4.6-1, as are the annual operations and maintenance costs. This preliminary cost estimate indicates that transmission and treatment plant costs are prohibitive. The water would be transmitted a distance of 40 miles overall and would require a static pumping head of 450 feet to cross a watershed divide. Due to these high costs, a detailed analysis of the water quality in Lake Whitney was not conducted. This preliminary analysis used in selection of a suitable diversion point in Lake Whitney was based on water supply records for only 10 years. These records indicate that it might be difficult to obtain a dependable supply of good quality water, if only one diversion point is used. The prospect of having to use multiple intakes at widely diverse locations would further increase the project costs. Therefore, in view of the high costs, further study of this alternative is not recommended.

3.4.6.2 REVERSE OSMOSIS OF LAKE WHITNEY WATER

Reverse osmosis is a physical process by which dissolved salts are removed from water. This is accomplished by applying a high pressure to the saline water while it is in contact with a semi-permeable membrane. The membrane allows the passage of water but not salts, hence the water is desalinated.

Table 3.4.6-1

Cost Estimate (1981 Dollars) For
Controlled Diversion of Lake Whitney Water

Item	Construction Costs Phase I	Construction Costs Phase II	1981 Annual Operating Costs
Intake Structure & Pump Station	$ 400,000	-	$ 85,000
Storage Reservoir & Pump Station	3,675,000	$ 100,000	85,000
Transmission Pipelines	3,250,000	2,760,000	-
Treatment Plant	3,150,000	6,050,000	150,000
Labor & Misc.	-	-	25,000
Water Purchases	-	-	150,000
TOTAL	$10,475,000	$8,910,000	$495,000

The location of facilities at the supply source depends more on topography, access, and land availability than on the water quality at that point, as a wide range of water quality is acceptable for the reverse osmosis treatment process. The water would be diverted, as demand required, and transmitted by pipeline to the reverse osmosis and water treatment plant. These would be located in the vicinity of Meridian. After treatment the water would be transmitted by pipeline to the three main population centers. Fig. 3.4.6-2 illustrates the location of these facilities. For estimating purposes, the reverse osmosis and water treatment plant were sized for present demands, the transmission facilities for the short term (20 year) demand, and expansions for all facilities were based on the long term (50 year) demand. The capital costs and annual operation and maintenance costs are presented in Table 3.4.6-2.

The treatment and transmission costs are high in this alternative. The operation and maintenance costs would also become progressively higher as a greater amount of energy is required in the reverse osmosis treatment process. In the light of rapid increases of energy costs, it is felt that it would be inadvisable to adopt such an energy intensive scheme.

3.4.7 LAKE AQUILLA

The Corps of Engineers is at present constructing Aquilla Dam and Reservoir on Aquilla Creek with an expected completion in 1983. At the beginning of this study, 9.7 million gallons per day (mgd) were available from this source, but it has now been totally sold. Hillsboro, under the auspices of the Aquilla Water District, has contracted for 9.0 mgd and Itasca Water District has contracted for the remaining 0.7 mgd.

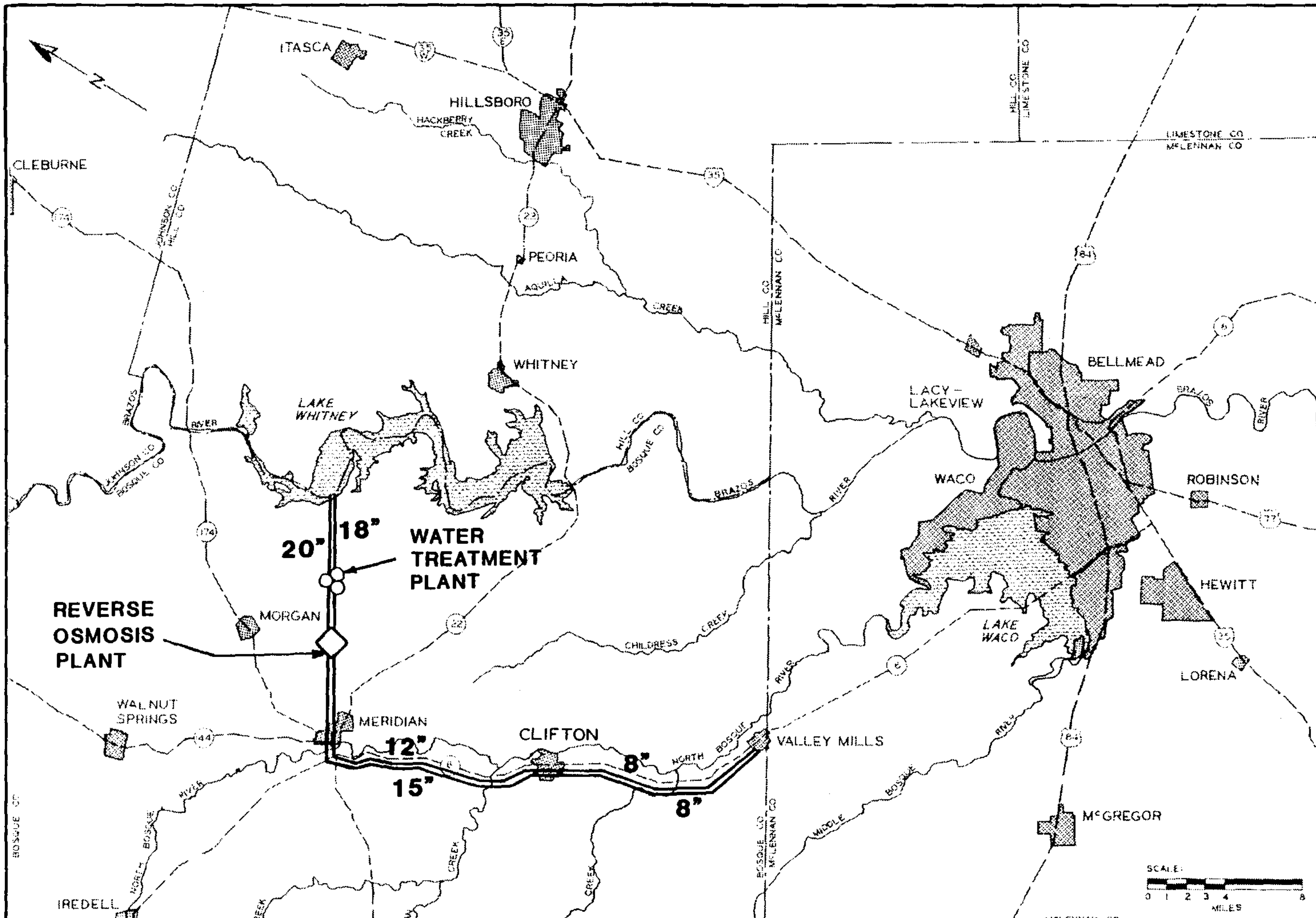


FIGURE 3.4.6-2
LAKE WHITNEY - REVERSE OSMOSIS PROCESS
Henningson, Durham & Richardson

Table 3.4.6-2

Cost Estimate (1981 Dollars) for
Reverse Osmosis of Lake Whitney Water

Item	Construction Costs Phase I	Construction Costs Phase II	1981 Annual Operating Costs
Intake Structure and Pump Station	$ 400,000		$ 85,000
Transmission Pipelines and Pump Stations (Raw and Treated)	3,253,000	$ 2,860,000	85,000
Treatment Plant	3,150,000	6,050,000	150,000
Reverse Osmosis & Evaporation Ponds	2,610,000	5,240,000	750,000
Labor & Misc.	----	----	50,000
Water Purchases	----	----	150,000
TOTAL	$9,413,000	$14,150,000	$ 1,270,000

When water was available, a two phases transmission and treatment alternative (see Figure 3.4.7-1) was investigated. Costs determined for the alternative are presented in Table 3.4.7-1. Extremely high transmission and pumping costs rendered this alternative infeasible even if water were available. A total of nearly 50 miles of pipeline was required to supply the three main centers in Bosque County. The costs would not decrease dramatically with increased usage as the pipelines would need to be duplicated to supply the increased demand.

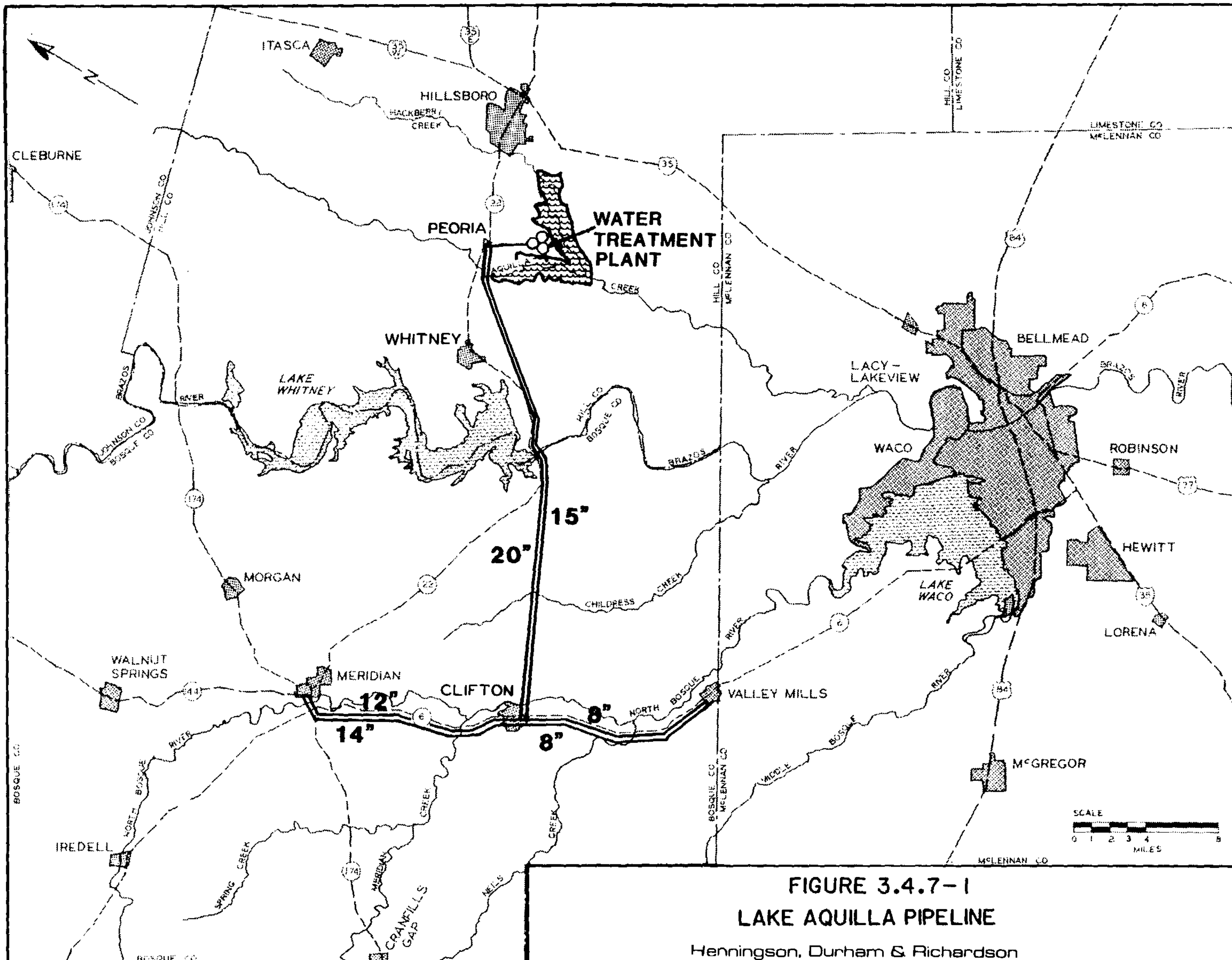


FIGURE 3.4.7-1
LAKE AQUILLA PIPELINE
Henningson, Durham & Richardson

Table 3.4.7-1

Cost Estimate (1981 Dollars) for
Pipeline from Lake Aquilla

Item	Construction Costs Phase I	Construction Costs Phase II	1981 Annual Operating Costs
Transmission Pipeline and Pump Stations	$7,095,000	$ 4,665,000	$120,000
Treatment Plant	2,460,000*	6,050,000	----
Labor & Misc.	----	----	50,000
Water Purchases	----	----	350,000
TOTAL	$9,555,000	$10,715,000	$520,000

*75% of total plant required. See Text.

4.0 FINANCIAL FEASIBILITY/WATER DISTRICT CONCEPT

4.1 BOND FINANCING: THE SELF-LIQUIDATING PROJECT

Financing of regional water supply projects, such as those described in previous sections of this report, involves the issuance of bonds. These bonds are supported by revenues generated from the sale of water or by taxes or a combination thereof. When more than one municipality is involved in a water system, it is generally advantageous under the Texas Water Code to create a water district. Usually the district serves no actual customers and service is provided only to wholesale purchasers, i.e. incorporated cities, large industrial plants, and water supply cooperatives. Wholesale purchasers enter into water purchase contracts with a district in which they guarantee to pay a stated monthly amount for which they are entitled to receive (whether or not they actually accept delivery of) a minimum amount of water. These contracts must run for the life of any revenue bonds for which income from the contracts is pledged as security. Additionally, such water purchase contracts provide for the allocation of operation and maintenance expenses of the system, including the cost of water purchased at the source, between the several wholesale purchasers.

4.2 PROJECT FEASIBILITY FACTORS

Among the numerous factors in determining feasibility, project cost is the most important after water availability. To the estimates of direct construction cost, fees must be added for engineering design (technical services), right-of-way, contingencies, cost of bond issuance fees of attorneys and financial consultants, allowances for creation of a debt service reserve fund, and cost of interest during construction. From the total amount of the bond issue, the amount of annual payments must be computed for principal and interest (called debt service requirements), which is the largest of items to be taken into account in fixing the price for water.

The principal components in the rate to be charged for water use, in descending order of magnitude, are debt service, cost of supply at the source, and operation and maintenance expenses. Inasmuch as debt service outweighs the other components and also becomes a fixed annual charge, it follows that the greater the volume of water which can be placed under take-or-pay contracts, the lower the price which can be established and the greater the feasibility.

While a majority of the regional water supply systems in Texas have been financed with bonds secured solely by a pledge of the net revenues arising from the operation of the systems, there are a number which have required the support of ad valorem taxes -- at least at the outset -- in order to accomplish the financing. Water districts and authorities created under Article XVI, Section 16 of the Texas Constitution can be clothed with authority to levy and collect taxes, when authorized by a majority vote at an election held within the district, and to pledge the same in support of their bonds. Such bonds are usually issued as "combination tax and revenue bonds", and provision is made for the abatement of the tax to the extent that revenues available for debt service may increase. When revenues from the sale of water reach the point that net revenues are sufficient to pay annual maturities of bond principal and interest, the levy of a tax can be discontinued.

The rate of interest at which project bonds can be issued and sold is a factor in economic feasibility of a project and ranks close to project cost in importance. Each element has a material bearing on debt service requirements and upon the cost of the product. Bond market conditions during the last year have been far from ideal, from the standpoint of the borrower. A conservative estimate of the rate of interest which might be available through sale in the open market of bonds on a project of this character would be in excess of 12%.

An alternate source of capital funds might be a loan from the Texas Water Development Board, an agency of the State which periodically has funds available for purchase of bonds of local water projects where a hardship exists. Current maximum lending rate of the Board, which is prescribed by a statutory formula, is 12%. Bosque County appears to meet the criteria established by law and by regulations of the Board for loans to water supply projects, and this source of capital funds should be explored.

Ability to pay on the part of the borrower is an element in all credit analysis, whether it involves private or public credit. There is a relationship between the price which the service area is obliged to charge for water and the income level of the retail water customers of the county and municipalities to be served. This is a relationship which is weighed by the community of bond analysts, bond rating agencies, municipal bond underwriters, and the investing public when an offering of revenue bonds is made in the public market and is the "acid test" for economic feasibility.

Bosque County has a population of less than 13,000 people. It would be extremely difficult for the County on its own financial, population, and income base to afford a water supply project in excess of several million dollars in cost, without outside customers, and substantial taxing support.

4.3 EXISTING ENTITIES AS POSSIBLE VEHICLES OF FINANCING

The largest local governments within Bosque County are Meridian, Clifton, and Valley Mills. These entities have a combined population of less than 6,000 people. These communities could not on their own sponsor a county-wide regional water supply system for a number of reasons, including:

1. Existing Debt Service
2. Geographical Separation
3. Limited Water Customers
4. High Project Cost

The Tri-County Municipal Water District was created in April, 1957, by the Texas Legislature under Article XVI, Section 59, of the Texas Constitution. The District comprises the territory contained within the Cities of Cleburne, Hillsboro, Whitney, Itasca, Valley Mills, Rio Vista, Clifton, Blum and Meridian as of April, 1957. This district has the power to operate waterworks facilities, including supply, and sewer facilities.

None of the powers granted the district by law have been implemented, except that a board of directors has been maintained. The district does have power to issue revenue bonds, unlimited tax bonds, or bonds secured by a combination pledge of ad valorem taxes and system revenues. The comparatively small area of the district would operate to reduce the tax base to the point that the taxing power would be of limited efficiency; moreover, inequities would result from the levy of taxes in such a limited area for the benefit of the service area of this project.

The Tri-County Municipal Water District was created by the legislature in 1957 and has the right to formulate agreements with the Brazos River Authority for the purchase of 50,000 acre-feet of storage in Lake Whitney. The District successfully negotiated a contract with the Brazos River Authority in 1958. The terms of this contract are as follows:

1. The parties hereto agree that they will jointly work together to secure a reallocation in accordance with H.R. 2580, 85th Congress, 1st Session, as to 50,000 acre-feet of the existing storage space in Whitney Reservoir from "Flood Control and Power" to "Conservation Storage". District desires Brazos River Authority to immediately enter into negotiations with the U.S. Corps of Engineers and to acquire the right to utilize any and all reallocated "conservation storage space" for and on behalf of the State of Texas.
2. The Authority agrees that it will keep Tri-County District informed of the progress of such negotiations and that if such storage space is acquired by Brazos River Authority, as much of the water yield therefrom as may now, or hereafter be needed by District will be set aside and allocated to District under a contract to be mutually agreed upon by the parties before negotiating disposition by Brazos River Authority of the remaining water in the reallocated storage space.

3. District agrees that after allocation of District's present existing and future needs, reasonably anticipated as provided in such contract, Brazos River Authority may sell or otherwise dispose of any or all of the surplus waters in accordance with the laws governing the Authority and the provisions of this contract. The contract will contain reasonable rights in the District to recapture, for use within the Tri-County District area, water which may have been sold on a temporary basis upon payment of a reasonable cost therefor by District.
4. Authority will continue its studies and efforts directed to the improvement of "quality" of water in the Brazos River, especially for reduction of salt content. Authority also agrees to furnish sufficient engineering data to enable the District to present its case for preliminary hearing before the State Board of Water Engineers, provided a reallocation is accomplished as provided above.
5. Each of the parties hereto agrees to inform the other as to any negotiations relating to the disposal of the water yield from the aforesaid mentioned storage space which would adversely affect each other party's rights and privileges.

As a result of the above contract, the parties successfully obtained Federal authorization for 50,000 acre-feet of storage in Lake Whitney and a draft contract with the Corps of Engineers. However, a contract has yet to be negotiated between Brazos River Authority and the Corps of Engineers.

Today the Tri-County District is fragmented and limited to selected municipalities in Johnson, Hill and Bosque Counties. It does not appear that it can be a viable financing vehicle for Bosque County since Lake Whitney water is non-potable for municipal purposes, without extended treatment.

4.4 NEED TO CREATE NEW ENTITY

There is not an existing unit of local government or public entity located within the service area of the proposed project which appears as a suitable prospect for the financing, construction, and operation of a major water supply system. It is recommended, therefore, that steps be taken to create an entity designed especially for the purpose needed.

There are three ways under Texas law in which water districts can be created. Districts can be created by county commissioners court, Texas Water Commission, or the Texas Legislature. The powers and capabilities of water districts or authorities are the greatest when created by the Texas Legislature. Permissable activities for districts include supply of water, sewage treatment, drainage, operation and maintenance of facilities, and fire protection. The Texas Water Commission and the Department of Water Resources have supervisory capacities and must approve engineering design of water projects prior to the sale of bonds.

In order for the Bosque County to be able to finance and manage a major water development system, it is most likely that a district or water authority would need to be created.

4.5 COST OF WATER

This study resulted in the evaluation of nine water development alternatives for Bosque County. These alternatives, described in Section 3.0, have construction costs in the millions of dollars. It is unlikely that Bosque County can afford any one of these alternatives without one or all of the following occurring:

* Receive Substantial Outside Support
* Create a Water District/Authority as a Financial Vehicle
* Provide Water to Outside County Customers

The county is in a difficult position. It cannot afford the high cost of water development in today's market and it cannot afford to ignore the declining supplies, water rights issues, and spiralling inflation. The purpose of the above steps is to reduce Bosque's share of the total project cost, which, in-turn, reduces the cost per thousand gallons of water to the customers in the county.

Table 4.5-1 illustrates the per thousand gallon cost of water for each alternative evaluated in this study. Alternatives 1 though 7 shown on this table provide water just for Bosque County. Alternative 8, which involves a large dam on the Bosque River (Lake Bosque) North of Meridian, has surplus water. The costs shown for this latter alternative are those apportioned to Bosque County.

The initial cost of water to Bosque County ranges from $2.24 to $4.46 per 1,000 gallons. It should be re-emphasized that these costs are for comparison purposes only and will change as additional information

Table 4.5-1

COST ESTIMATE FOR WATER DEVELOPMENT ALTERNATIVES FOR BOSQUE COUNTY

	Alternative	Initial Capital Cost (dollars)	Initial Cost Per 1000 gal (dollars) (1)	Initial Water Sales (mgd)	50 Year Additional Capital Cost (dollars)	50 Year Cost Per 1000 gal (dollars) (2)	Projected 50 Year Water Sales (mgd)
1.	Recharge by Spreading Ponds	NOT FEASIBLE					
2.	Recharge by Injection Wells	7,650,000	2.24	1.37	10,420,000	1.50	4.00
3.	Lake Whitney Controlled Diversion	10,475,000	3.13	1.37	8,910,000	1.70	4.00
4.	Lake Whitney Reverse Osmosis	9,413,000	4.46	1.37	14,150,000	2.52	4.00
5.	Scalping to Surface Storage	5,950,000	3.71	(Clifton) 0.54	1,600,000	2.20	(Clifton) 1.12
6.	Lake Aquilla Pipeline	NO WATER AVAILABLE					
7.	Small Dam Meridian Creek	10,465,000	2.68	1.37	8,400,000	1.50	4.00
8.	Large Dam Bosque River Conservation Reservoir	9,440,000	2.44	1.37	6,110,000	1.26	4.00

(1) Includes debt service (10% for 40 years) and O & M.
(2) Includes debt service for initial and 50 year construction (10% for 40 years) and 1980 O & M

on the project complexities is obtained. Also, this cost can fluctuate greatly, depending on the number of customers to be served by the system. To illustrate this point, the following example is presented, for the Lake Bosque Alternative 8. Under Alternative 8, Lake Bosque could provide an annual areal yield of about 24 mgd before water rights are taken into consideration. Assume the following take or pay sale contracts could be consummated:

	Quantity	% of Lake Bosque Yield
Bosque County	4 mgd	17
City of Waco	11 mgd	46
City of Woodway	5 mgd	21
City of Hewitt	2 mgd	8
City of Bellmead	2 mgd	8
TOTAL	24 mgd	100%

If the cost of Lake Bosque is proportioned on the basis of percent of annual firm yield, then the following would be each sponsor's cost:

Bosque County *	$ 4,080,000
City of Waco	11,040,000
City of Woodway	5,040,000
City of Hewitt	1,920,000
City of Bellmead	1,920,000
Total Estimated Construction	$24,000,000

* Excludes Cost of Diversion Treatment, and Delivery System

This estimated construction cost would convert into bond issue amounts and debt service requirements, at an assumed interest rate of 10% for 40 years, as follows:

Total Est. Construction Cost including Engineering and Technical Fees of 20% and Construction Contingencies	$24,000,000
Interest During Construction *	2,400,000
Amount of Bond Issue **	$26,400,000
Average Annual Debt Service ***	$ 2,700,000

* Interest during construction is computed for only 12 months on the theory that the Construction Fund can be invested in short term U.S. Government obligations to the extent of offsetting at least one-half of such interest.

** The amount of the bond issue does not include an amount which will have to be provided for a Debt Service Reserve Fund equal to one year's average annual debt service. Such Reserve Fund can be invested in U.S. Government paper to yield a return in excess of interest accruing on the bond issue; therefore, the interest expense on the amount of the Reserve Fund is not a charge against total costs in computing costs of water.

*** Assumes 10% interest for 40 years.

The cost per 1,000 gallons of raw water to wholesale customers shown is a function of water sales. The following illustrates the cost of raw water for varying water sales assuming an annual debt service of $2.7 million as illustrated above.

Cost Per Thousand Gallons	10 mgd	15 mgd	20 mgd	24 mgd
Debt Service Requirement	74.0¢	49.3¢	37.0¢	30.8¢

The above estimates do not include any treatment or distribution cost, nor any reservoir operation and maintenance costs to Bosque County or other entities.

A project sponsor would be necessary to act as an agency for the construction of a project such as Lake Bosque. A logical entity for such a project would be the Brazos River Authority. The Authority could fund the reservoir through contractual arrangements with local sponsors. In turn, local sponsors could fund individual treatment and distribution projects, either on their own or via creation of local water districts. In this way, taxes could be levied to supplement revenues and further support local bond sales.

5.0 SUMMARY

As shown in previous sections, a relatively large number of water supply options are available to Bosque County. In summary, the following general conclusions can be drawn from the data presented.

The least expensive alternative available to Bosque County is to continue using the present groundwater systems. The only cost incurred would be the replacement of existing wells or the drilling of additional wells. As shown, the county should have ample groundwater to meet its needs for at least the next 15 years, without modification of central Texas groundwater practices. Should the county elect to continue using groundwater as long as possible, then it should pursue active groundwater management programs, both inside and outside the county. Improved management within the county may extend the life of the aquifers somewhat, but only through management of the entire area being served by the aquifers will any real extension of the service from the aquifers be noticed.

Construction of a small dam in Bosque County, on Meridian Creek, or utilization of water from Lake Whitney, or from floodwaters within the county are feasible from an engineering standpoint. In each case, however, the cost of the alternatives excludes them from further consideration. The Meridian Creek dam within the county would prove to be fairly economical if the Texas Water Development Board becomes involved with its storage acquisition program. In this manner, the cost of the excess storage required to meet future demands would be deferred until it is actually needed.

The most feasible alternative for Bosque County now appears to be the construction of a large dam on the Bosque River. However, the cost of a large water supply reservoir project is far beyond the income of Bosque County without other entities which will be required to bear a large part of the cost of the project. Due to its small participation, Bosque could find itself essentially excluded from the management of such a project, but it would still accrue the benefits of a surface reservoir even without the managing role. Such a project would bring in several million dollars to the county during construction, and would attract growth afterwards around the lake. The water supply needs of the county's communities would be met for the foreseeable future and the life of the groundwater aquifer would be extended for rural county residents. Therefore, it is recommended that a detailed hydrologic, hydraulic and geotechnical investigation of a large dam on the North Bosque River be conducted to determine a number of factors that were beyond the scope of this study. These factors include site availability, a detailed analysis of downstream water rights and the impact a large dam would have on these rights, and the determination of channel losses in the river bed to assess the amount of water to be released to downstream permit holders. Once these factors have been evaluated, the firm yield of the dam can be determined with all existing water rights being satisfied. It will then be evident whether it is economically and practically feasible to obtain water supply from a large dam on the North Bosque River.

GLOSSARY

This section is intended to acquaint the reader with some of the terms used in this report.

Acre-foot. The volume of water required to cover 1 acre to a depth of 1 foot (43,560 cubic feet), or 325,851 gallons.

Acre-feet per year. One acre foot per year equals 892.13 gallons per day.

Aquifer. A formation, group of formations, or part of a formation that is water bearing.

Channel losses. The volume of flow in a stream channel lost to infiltration or seepage into the bed and banks of the stream.

Coefficient of permeability. The rate of flow of water in gallons per day through a cross sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot.

Coefficient of transmissivity. The number of gallons of water that will move in 1 day through a vertical strip of the aquifer 1 foot wide extending the vertical thickness of the aquifer when the hydraulic gradient is 1 foot per foot. It is the product of the field coefficient of permeability and the saturated thickness of the aquifer.

Cone of depression. Depression of the water table or piezometric surface surrounding a discharging well, more or less the shape of an inverted cone.

Conservation storage. The portion of reservoir volume dedicated to impoundment of water for later release to serve some beneficial purpose, such as municipal supply, power, irrigation or public health.

Drawdown. The lowering of the water table or piezometric surface caused by pumping (or artesian flow). In most instances, it is the difference, in feet, between the static level and the pumping level.

Firm yield. The maximum demand at a reservoir that can be met with "acceptable" shortages. It is normally determined on an annual basis.

Flood control storage. The portion of the reservoir volume to be storage utilized for impoundment of flood waters.

Piezometric surface. An imaginary surface that everywhere coincides with the static level of the water in the aquifer. The surface to which the water from a given aquifer will rise under its full head.

Recharge of ground water. The process by which water is absorbed and is added to the zone of saturation. Also used to designate the quantity of water that is added to the zone of saturation, usually given in acre-feet per year or in million gallons per day.

Recovery well. A water well drilled for the purpose of recovering groundwater from a recharged aquifer.

Reverse Osmosis. The application of high pressure to a salt solution in excess of its osmotic pressure, resulting in the passage of the water through a semi-permeable membrane leaving the salts behind in concentrated solution.

Spreading basin. Water spreading storage basins from which water infiltrates to the water table.

Sediment yield. The portion of eroded material that travels the drainage network to a downstream measuring or control point.

Safe yield. The rate at which water can be withdrawn from an aquifer for human use without depleting the supply to such an extent that withdrawal at this rate will become no longer economically feasible. The practical rate of withdrawing water from an underground reservoir perennially for human use.

Specific capacity. The rate of yield of a well per unit of drawdown, usually expressed as gallons per minute per foot of drawdown. If the yield is 250 gallons per minute and the drawdown is 10 feet, the specific capacity is 25 gallons per minute per foot.

Water level. Depth to water, in feet below the land surface, where the water occurs under water-table conditions (or depth to the top of the zone of saturation). Under artesian conditions the water level is a measure of the pressure on the aquifer, and the water level may be at, below, or above the land surface.

Watershed. The whole land and water surface area contributing to the discharge at a particular stream or river cross section.

Yield of a well. The rate of discharge, commonly expressed as gallons per minute, gallons per day, or gallons per hour.

Formation. A body of rock that is sufficiently homogeneous or distinctive to be regarded as a mappable unit, usually named from a locality where the formation is typical (such as Glen Rose, Paluxy, and Georgetown Formations).

Head, or hydrostatic pressure. The pressure exerted by the water at any given point in a body of water at rest reported in pounds per square inch or in feet of water is generally due to the weight of water at higher levels.

Impermeable. Impervious or having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Infiltration. The process by which water reaching the ground, such as rainfall, moves through the soil surface.

Injection well. The means by which water is placed directly into aquifers below ground surface by pumping water under pressure at a high rate and at the temperature of the receiving body.

Irrigation. The controlled application of water to arable lands to supply water not satisfied by rainfall.

Mining. The overdrafting of an aquifer, where water is being withdrawn faster than it is recharged causing a decline in the natural groundwater level in the aquifer.

Million(s) gallons per day. One million gallons per day equals 3.068883 acre-feet per day or 1,120.14 acre-feet per year.

Osmotic Pressure. The pressure exerted by dissolved salts on a semi-permeable membrane separating a salt solution and fresh water.

Outcrop. That part of a rock layer which appears at the land surface.

Permeable. Pervious or having a texture that permits water to move through it perceptibly under the head differences ordinarily found in subsurface water. A permeable rock has communicating interstices of capillary or supercapillary size.

Permeability of an aquifer. The capacity of an aquifer for transmitting water under pressure.

pH. The intensity of acidity or alkalinity of a sample measured on the pH scale which measures the concentration of hydrogen ions present.

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Paul Price Associates, Inc. Job No. 027

SOCIOECONOMIC BASELINE REPORT

for the

LAKE BOSQUE PROJECT

BOSQUE COUNTY, TEXAS

Prepared for
The Brazos River Authority

Prepared by

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September, 1987

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1.0 INTRODUCTION

1.1 GENERAL

This report presents the baseline social and economic characteristics of the area potentially affected by the proposed Lake Bosque project. The social and economic factors addressed in this report include demographic trends; population characteristics and projections; employment trends; income data; community services and facilities; housing supply and availability; water demand (including future demand projections); governmental finances; transportation; recreation and aesthetics; and land use. This information is being used as input to the delineation of the Purpose and Need for the Project (EA Section 1.2), the Socioeconomics and Land Use effects assessment (EA Sections 3.8 and 4.6), and certain aspects of the Fish and Wildlife effects assessments and mitigation plans (EA Sections 4.5.3 and 5.0).

1.2 DELINEATION OF THE ANALYSIS AREA

1.2.1 The Study Area

As shown in Figure 1 - 1 the study area was defined as the two county region (McLennan and Bosque County) which encompasses the proposed reservoir site, the area most likely impacted by the construction and operation of the Lake Bosque project and the communities participating in the Project. Except for the City of Waco, the communities in the area are small, with 1986 populations ranging from 1,330 to 9,900, and are characterized by small scale economies based on agriculture and manufacturing or are bedroom communities linked to the City of Waco. The demographic, economic, recreation and aesthetics, and land use sections of this report generally address the two county region as an integrated study area, rather than attempting to dissect the whole into individual communities. Demographic and economic impacts, primarily through increased economic opportunities and possible in-migration of people into the area resulting from development of the proposed Lake Bosque, will be felt to varying degrees in Bosque and

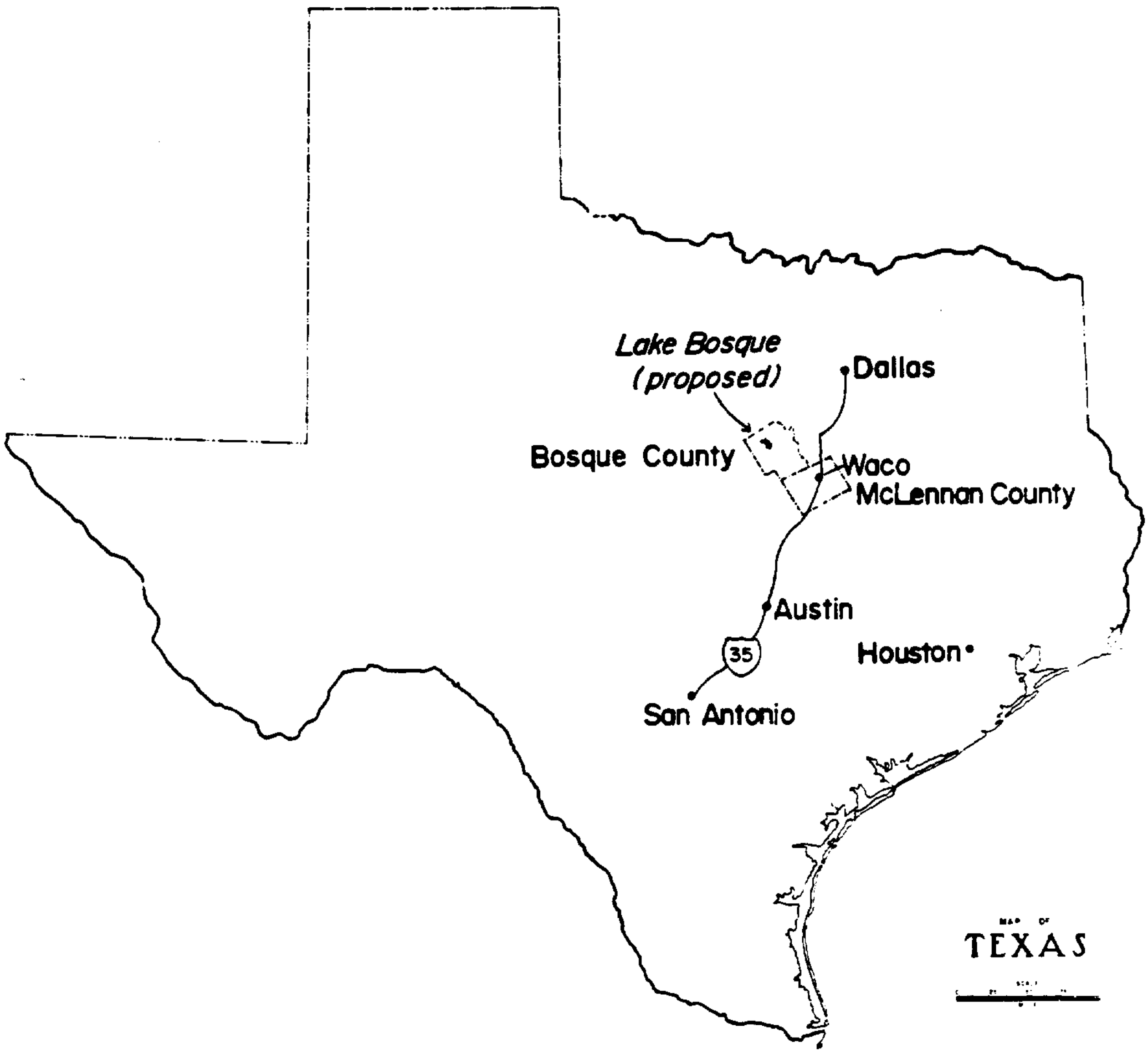

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Figure 1-1
Proposed Lake Bosque
Resevoir Site

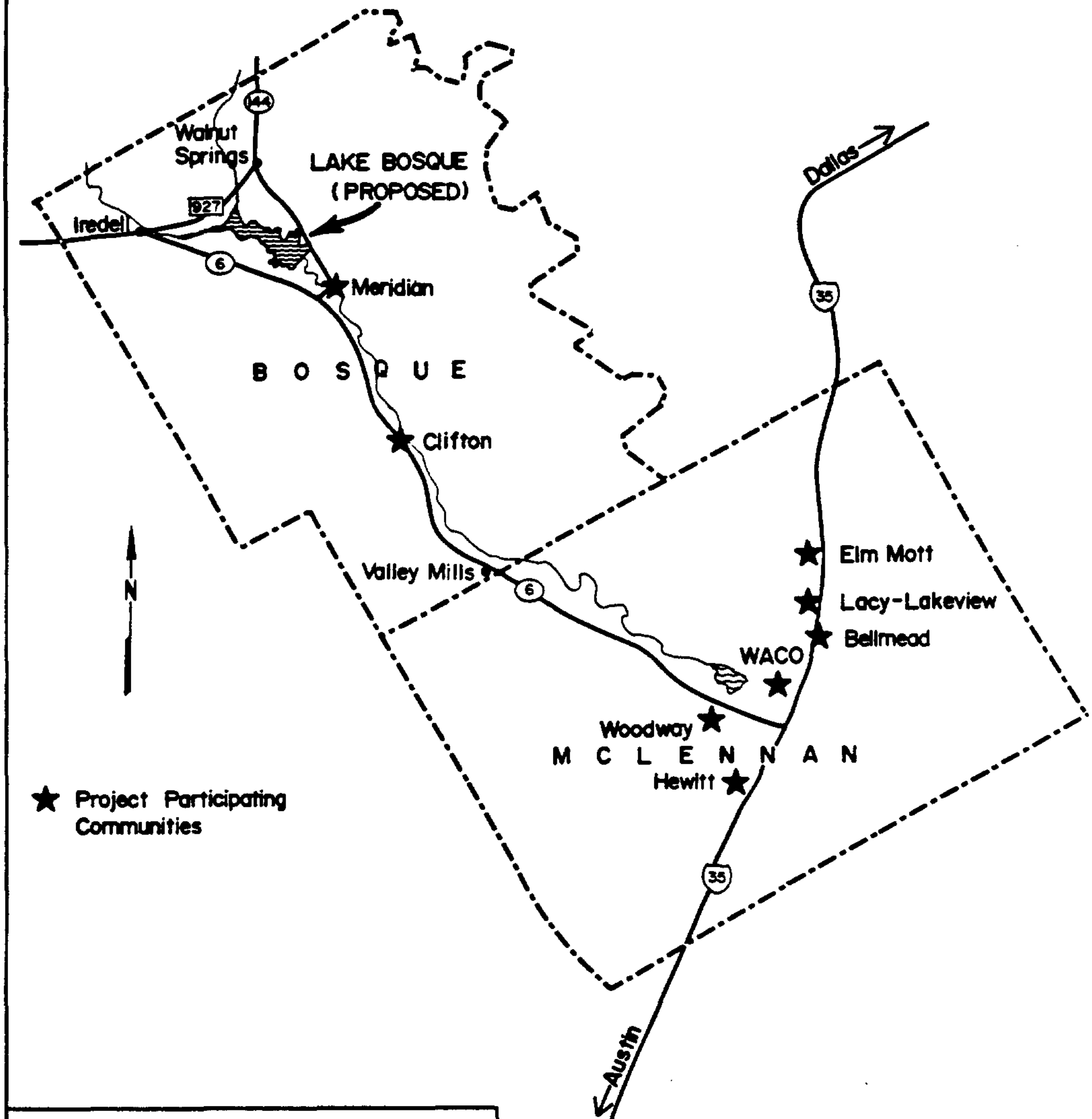

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Figure 1-2

Lake Bosque Project Study Area

(ETJ). McLennan County WCID #2 was created to provide water and sewer facilities for the unincorporated community of Elm Mott.

Waco is the county seat of McLennan County and a major commercial and industrial center of Central Texas. The city is located 90 miles south of Dallas on IH 35. Waco is the approximate geographic center of the Texas population, being within 100 miles of 24% of the States' population of almost 15 million people.

The cities of Hewitt, Bellmead, Lacy-Lakeview, Woodway and the unincorporated community of Elm Mott, located within 1 - 4 miles of Waco along major roadways, are residential suburbs with some light industrial land uses. City 1980 populations range from a high of 7,569 for the City of Bellmead to a low of 1,300 for the community of Elm Mott. Hewitt was the fastest growing city with a population increase from 1970 - 1980 of 822%.

2.0 POPULATION PROFILE

2.1 INTRODUCTION

This section describes present population size, age distribution, population growth trends and projections for the two county study area and project participating municipalities. Texas was used as a benchmark with which to compare county population growth trends and characteristics.

Population data from the U. S. Bureau of the Census, Texas Department of Health, Texas Water Development Board, the University of Texas Bureau of Business Research, the City of Waco and the Heart of Texas Council of Governments were used. Additional data update and supplementation was provided from local chambers of commerce and municipal government publications.

Presented in this document are five different population projections prepared by four separate public agencies. Because each projection contains different population totals and because population projections are the base from which future water needs are projected, a major portion of this section concerns the criteria for choosing the most reasonable and accurate population projection. Discussed are county and municipal population projections prepared by the Texas Department of Health (TDH), Texas Water Development Board (TWDB), the City of Waco Planning Department, and the Heart of Texas Council of Governments (HOTCOG).

2.2 HISTORICAL POPULATION TRENDS

Counties

As shown in Table 2 - 1, during the 1960s the rapid rate of population growth that occurred throughout the State of Texas did not happen in Bosque or McLennan Counties. While Texas' total population increased by almost 17%, Bosque County's population increased by only 1% (157 persons), and McLennan County's population decreased by 2%, a loss of 2,500 persons.

However, during the 1970s and 1980s, population growth in each county increased at rates more comparable to the skyrocketing growth occurring throughout the State. During the 1970s Bosque County's population grew by 22% to a total of 13,401 and McLennan County's population increased by 16% to a total of 170,755. Historically Bosque County's population has always been much smaller than that of McLennan County, however, since 1960 Bosque County's population increased at a faster rate than the population in McLennan County.

Communities

Although the 1960's brought relatively little growth to Bosque and McLennan Counties, the population of each subject community, except the City of Waco, increased at rates comparable to or much higher than Texas' average population growth (see Table 2 - 1).

During the 1960s the City of Waco's population declined by 2%, but the two of the fastest growing communities in McLennan County, Woodway and Bellmead, were located in Waco's extra-territorial jurisdiction (ETJ). In one decade Woodway and Bellmead's populations increased by 287% and 50% respectively. In Bosque County, Meridian and Clifton's populations increased at rates comparable to

Table 2 -1. Study Area Population Growth 1960 -1980

	1960 Population	1970 Population	% Δ	1980 Population	% Δ
Texas	9,579,677	11,198,655	16.9%	14,228,383	27.1%
Bosque County	10,809	10,966	1.5%	13,401	22.2%
Meridian	993	1,162	17.0%	1,330	14.5%
Clifton	2,335	2,578	10.4%	3,063	18.8%
Mclennan County	150,091	147,553	-1.7%	170,755	15.7%
Bellmead	5,127	7,698	50.1%	7,569	-1.7%
Hewitt	NA	569	----	5,247	822.1%
Lacy-Lakeview	2,272	2,558	12.6%	2,752	7.6%
Mclennan Co. WCID #2 (Elm Mott)	NA	NA	----	1,300	----
Waco	97,808	95,326	-2.5%	101,261	6.2%
Woodway	1,244	4,819	287.4%	7,091	47.1%

Source:
U. S. Bureau of the Census. General Population Characteristics, 1960-1980.
Texas Department of Health, Water Hygiene Inventory for 1986.
Note: NA = not available

Texas'17% growth rate.

The 1970s brought unprecedented population growth to Texas as well as significant growth to the municipalities of Bosque and McLennan Counties. Similar to the trend set in the 1960s, the City of Waco's population increased slowly while the population centers in its ETJ grew rapidly. One of the fastest growing municipalities was the community of Hewitt; in one decade its population grew by 882% to a total of 5,247. Despite rapid growth in the 1960s, Bellmead's population declined during the 1970s. Woodway's population grew much slower than in the 1960s but still increased by nearly 50%.

During the 1970s, the population in the communities of Meridian and Clifton increased at rates slower than, but still comparable, to Bosque County's population growth rate. The county population increased by 22% and the populations in Clifton and Meridian grew by 19% and 14% respectively. Clifton's population grew faster in the 1970s than it did during the 1960s, while Meridian's population growth declined.

2.3 1986 POPULATION ESTIMATES

Counties

Table 2 - 2 shows 1986 municipal and county population estimates prepared by the Texas Department of Health. The 1986 population figure for the State is an estimate by the U.S. Bureau of the Census. Also displayed are population growth rates from 1980 - 86.

From 1980 to 1986, the State population increased by 15% however, Bosque and McLennan County populations did not increase as rapidly. Bosque County's 1986 population, estimated at 15,132, increased at a rate comparable to the states average growth rate, while McLennan County's 1986 population, estimated at 182,354, grew only half as fast.

Communities

As shown in Table 2 - 2 population growth in Waco from 1980 to 1986 was slight while growth in the small communities within the city's extra-territorial jurisdiction (ETJ) was rapid. The populations in Clifton and Meridian remained stable experiencing little to no growth.

Table 2 - 2. Study Area Population Growth 1980 -1986

	1980 Population	1986 Population	% Δ
Texas	14,228,383	16,370,000	15.1%
Bosque County	13,401	15,132	12.9%
Meridian	1,330	1,330	0.0%
Clifton	3,063	3,067	0.1%
McLennan County	170,755	182,354	6.8%
Bellmead	7,569	8,500	12.3%
Hewitt	5,247	9,900	88.7%
Lacy-Lakeview	2,752	4,700	70.8%
McLennan Co. WCID #2 (Elm Mott)	1,300	1,600	23.1%
Waco	101,261	104,133	2.8%
Woodway	7,091	8,841	24.7%

Source:
U. S. Bureau of the Census. General Population Characteristics, 1960-1980.
Texas Department of Health, Water Hygiene Inventory for 1986.
Note: NA = not available

2.4 POPULATION DISTRIBUTION BY AGE

Table 2 - 3 displays the distribution of Texas, Bosque and McLennan Counties 1980 populations by five year age groups. Also shown are Texas Department of Health population projections for each age group for years 1990 and 2000. Figures 2 - 1, 2 - 2 and 2 - 3 graphically display the information from Table 2 - 3.

The median age in Texas is projected to increase through the year 2000. In 1980, 29% of the population was 15-29 years of age, by 1990 over a quarter of the population is projected to be 25-39 years old, and by year 2000 it is projected that one-fourth of the state population will be 35-49 years old (see Table 2 - 3 and Figure 2 - 1).

The age distribution of McLennan County's population is very similar to that of the State, however there are some differences (see Table 2 - 3 and Figure 2 - 2). The proportion of people aged 75 and older is slightly higher in McLennan County than the Texas average. That trend is projected to continue through year 2000. In 1980, the median age in the county was 15 - 24 years. This is partially explained by the large number of colleges and trade schools in the county. The high proportion of teenagers and young adults in the county is projected to decline through year 2000. In 1990 the two largest projected age groups are the 25-29 and 30-39 year cohorts. In 2000 the two largest adult age groups are the 35-39 and 40-44 cohorts. From 1980 to 2000 children ages 0-14 are expected to account for 24% of the population. The ageing trend projected for the State is also projected for McLennan County.

Bosque County (see Table 2 - 3 and Figure 2 - 3) is characterized by a much larger proportion of elderly residents than found in McLennan County or the State at large. In 1980 the proportion of people 75 years and older living in Bosque County was almost three times as high as the state average or McLennan County's average; the proportion of those aged 70 - 74 was twice as high as the state average or McLennan County's average. This trend is projected to continue to 2000. Compared to Texas, Bosque County's

Table 2 - 3. Texas, Population Distribution by Age, 1980 - 2000

Age Group	1980	1990	% Change	2000	% Change	% of Total Population 1980	1990	2000
0-4	1,169,061	1,489,062	27%	1,641,473	10%	8%	8%	8%
5-9	1,169,889	1,485,612	27%	1,631,985	10%	8%	8%	8%
10-14	1,179,988	1,339,531	14%	1,603,432	20%	8%	8%	8%
15-19	1,352,355	1,340,203	-1%	1,607,831	20%	10%	8%	8%
20-24	1,420,358	1,377,145	-3%	1,452,429	5%	10%	8%	7%
25-29	1,302,054	1,542,336	18%	1,398,587	-9%	9%	9%	7%
30-34	1,124,483	1,658,215	47%	1,454,691	-12%	8%	9%	7%
35-39	880,229	1,459,029	66%	1,624,675	11%	6%	8%	8%
40-44	723,002	1,218,042	68%	1,713,600	41%	5%	7%	8%
45-49	681,391	929,697	36%	1,477,417	59%	5%	5%	7%
50-54	680,275	736,487	8%	1,195,979	62%	5%	4%	6%
55-59	643,396	680,066	6%	890,958	31%	5%	4%	4%
60-64	531,549	638,097	20%	657,966	3%	4%	4%	3%
65-69	476,110	574,889	21%	573,125	0%	3%	3%	3%
70-74	371,155	427,717	15%	491,784	15%	3%	2%	2%
75+	523,896	745,222	42%	915,919	23%	4%	4%	5%
TOTAL	14,229,191	17,641,350	24%	20,331,851	15%	100%	100%	100%

Source:
Texas Deartment of Health.

Table 2 - 3. (Continued) Mclennan County, Population Distribution by Age, 1980 - 2000

Age Group	1980	1990	% Change	2000	% Change	% of Total Population 1980	1990	2000
0-4	12,654	14,865	17%	15,384	3%	7%	8%	7%
5-9	12,197	14,244	17%	14,652	3%	7%	7%	7%
10-14	12,224	14,102	15%	15,716	11%	7%	7%	8%
15-19	17,881	15,891	-11%	16,469	4%	10%	8%	8%
20-24	19,195	15,869	-17%	16,263	2%	11%	8%	8%
25-29	13,157	15,190	15%	12,313	-19%	8%	8%	6%
30-34	11,031	16,931	53%	13,763	-19%	6%	9%	7%
35-39	8,681	14,688	69%	16,053	9%	5%	8%	8%
40-44	7,879	11,881	51%	17,532	48%	5%	6%	8%
45-49	7,950	8,793	11%	14,584	66%	5%	5%	7%
50-54	8,681	7,732	-11%	11,381	47%	5%	4%	5%
55-59	8,810	7,742	-12%	8,367	8%	5%	4%	4%
60-64	7,881	8,203	4%	7,072	-14%	5%	4%	3%
65-69	7,432	8,095	9%	6,833	-16%	4%	4%	3%
70-74	5,985	6,578	10%	6,638	1%	4%	3%	3%
75+	9,117	12,105	33%	13,916	15%	5%	6%	7%
TOTAL	170,755	192,909	13%	206,936	7%	100%	100%	100%

Table 2 - 3. (Continued) Bosque County, Population Distribution by Age, 1980 - 2000

Age Group	1980	1990	% Change	2000	% Change	% of Total Population 1980	1990	2000
0-4	734	869	18%	913	5%	5%	6%	6%
5-9	777	925	19%	978	6%	6%	6%	6%
10-14	840	1,025	22%	1,037	1%	6%	7%	6%
15-19	925	920	-1%	1,010	10%	7%	6%	7%
20-24	745	689	-8%	739	7%	6%	5%	6%
25-29	714	789	11%	683	-13%	5%	5%	5%
30-34	730	966	32%	847	-12%	5%	6%	5%
35-39	651	853	31%	862	1%	5%	6%	5%
40-44	596	890	49%	1,062	19%	4%	6%	4%
45-49	557	782	40%	939	20%	4%	5%	4%
50-54	700	830	19%	1,046	26%	5%	6%	5%
55-59	857	737	-14%	879	19%	6%	5%	6%
60-64	1,029	892	-13%	886	-1%	8%	6%	8%
65-69	1,125	953	-15%	720	-24%	8%	6%	8%
70-74	989	922	-7%	761	-17%	7%	6%	7%
75+	1,432	1,876	31%	1,961	5%	11%	13%	11%
TOTAL	13,401	14,918	11%	15,323	3%	100%	100%	100%

Source:
Texas Department of Health.

Figure 2 - 1.
Texas, Population Projections by Age, 1980 - 2000

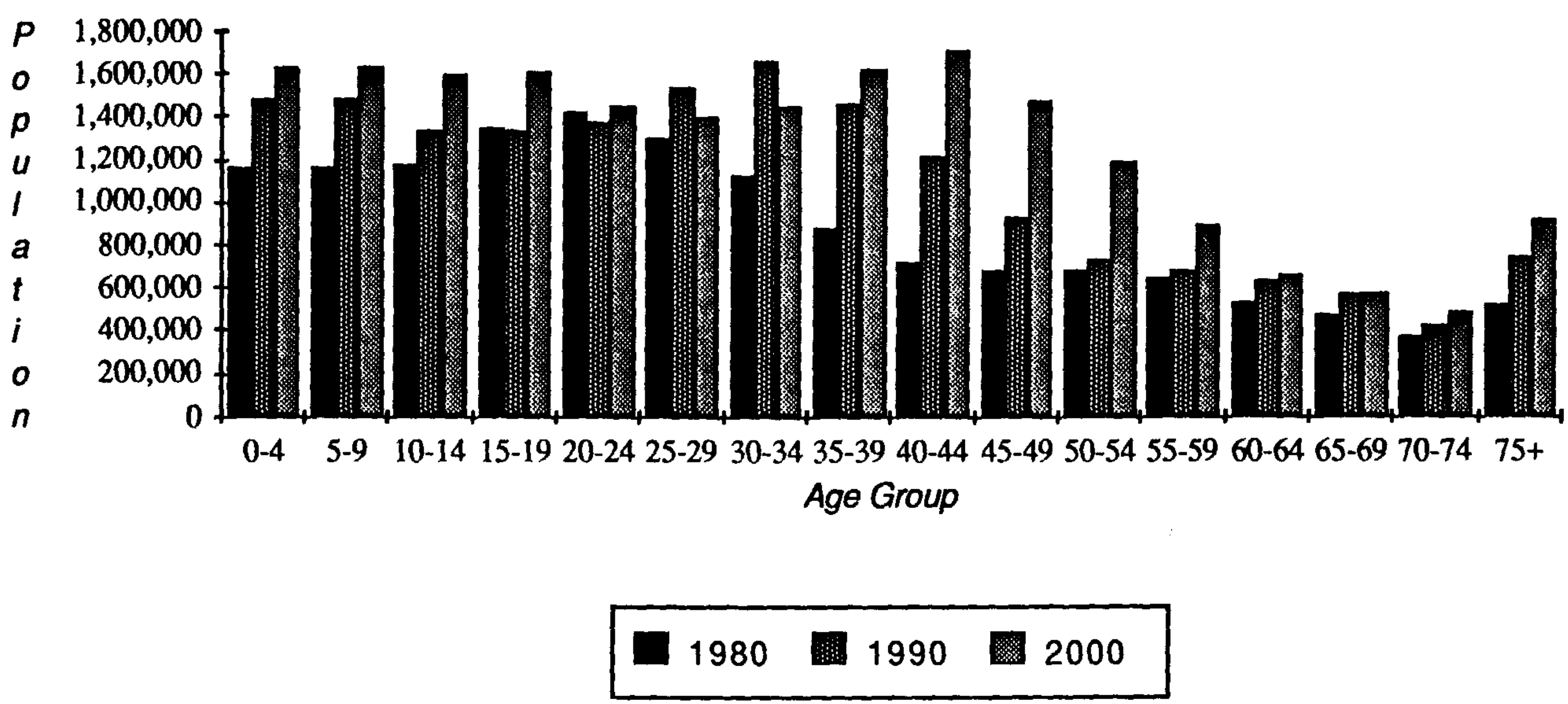


Figure 2 - 2.
Mclennan County, Population Projections by Age, 1980 - 2000

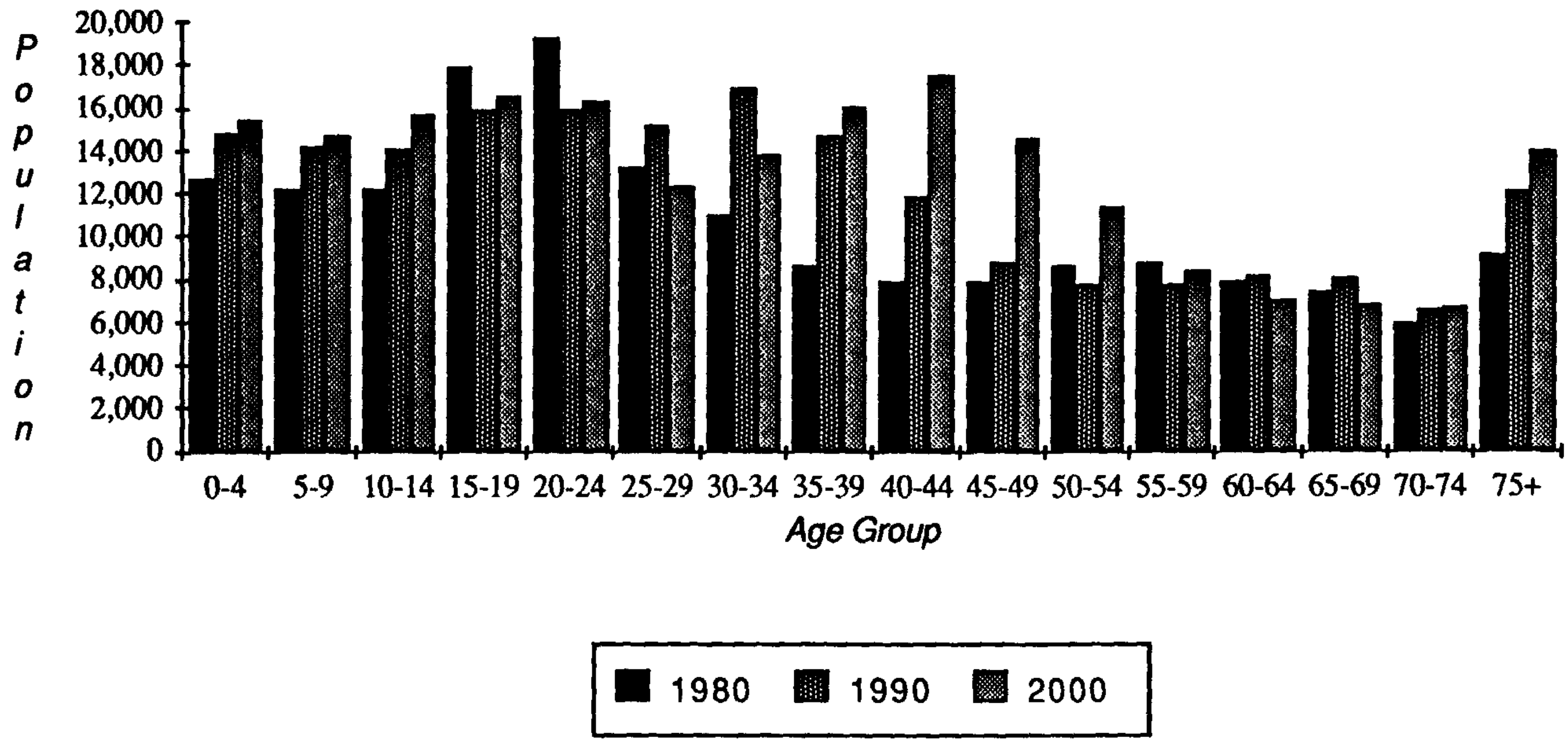
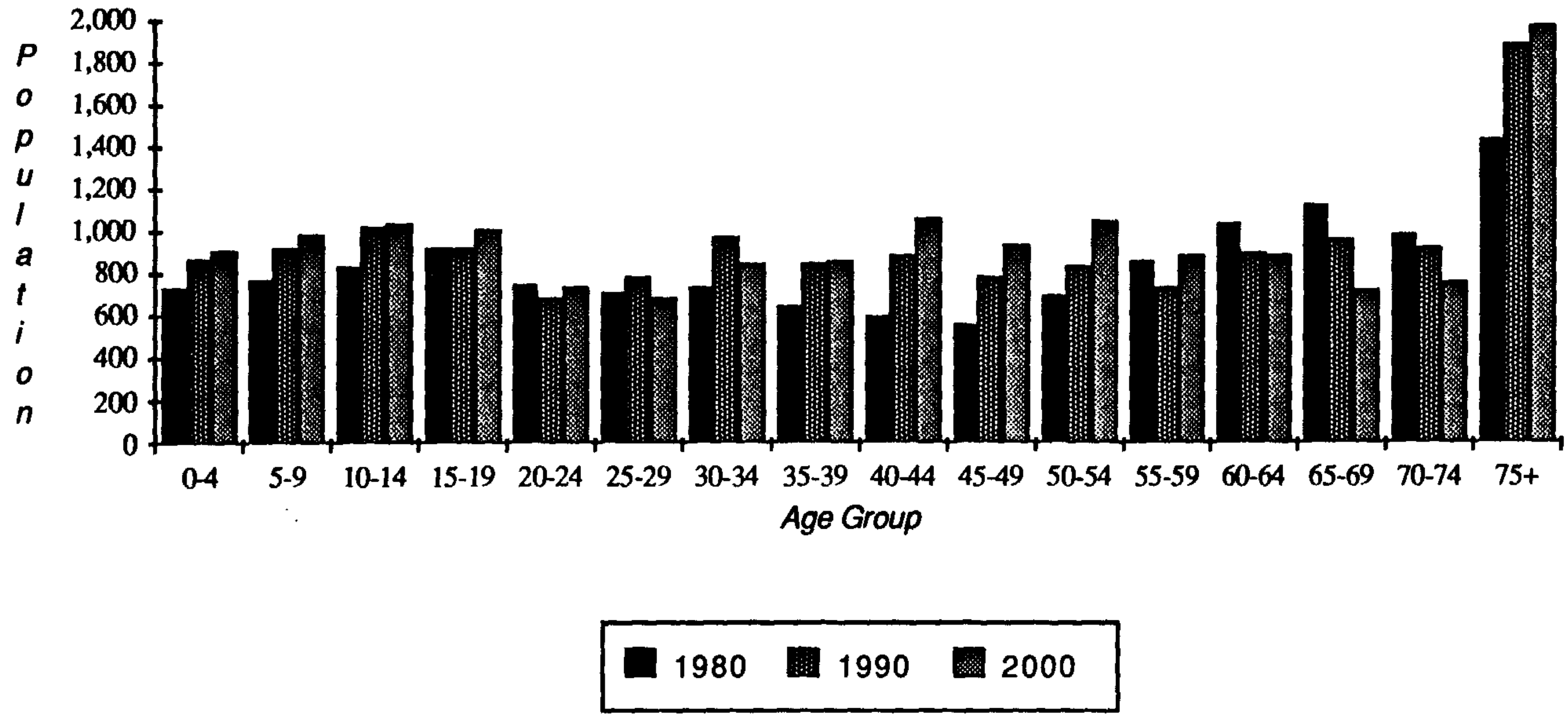


Figure 2 - 3.
Bosque County, Population Projections by Age, 1980 - 2000



population consists of relatively few children, few young adults and few middle-aged adults. The largest age groups are 60 years and older.

2.5 POPULATION PROJECTIONS

2.5.1 Introduction

When screening population projections one must keep in mind that they are the result of starting with a population estimate, a mathematical model of population change, and assumptions for variables such as fertility, mortality, and migration rates; because of this and because the assumptions can be any value, reasonable or unreasonable, likely or unlikely, there are an infinite number of possible population projections (Sierra, 1983). Often models are not always very useful, particularly when formulating projections for small geographical areas or for long time periods. In addition, given any geographical region and past history, a wide range of trends can be justified as reasonable projections, all reflecting satisfactory and professionally acceptable demographic techniques. This is the background against which available projections are judged.

In view of this situation Paul Price Associates has identified a "baseline" or "base-case" projection as the most reasonable or the most likely projection to occur, as well as, provided a range of low, medium and high forecasts. However, when considering a range of forecasts one should not presume that the medium forecast is the most likely to occur or is necessarily the one best used in all circumstances. In the following text analysis five sets of population projections are presented. Each model was scrutinized as to its assumptions, data sources, and methodology. Those population projections are listed below.

> The Texas Water Development Board. Projections of Population and Municipal Water Requirements; High and Low Series. 1980 - 2030.
>
> The Texas Department of Health. Population Data System, State Health Planning and Resource Development, Year 2000 projections.
>
> Heart of Texas Council of Governments. 1980 - 2000 projections for counties and cities.
>
> The City of Waco Department of Planning. 1980 - 2000 population projections for McLennan County, Waco, Waco ETJ, and incorporated cities within the Waco ETJ

The Texas Water Development Board's (TWDB) population projections for counties and municipalities extend to year 2030 while the other projections only cover the period from 1980 to 2000. Paul Price Associates has extended each of the "official" projections to the year 2040 (the approximate lifespan of the proposed Bosque Reservoir). Found in the Appendix of this document is the methodology used to extend each projection.

2.5.2 Population Projection Methodology

2.5.2.1 Texas Water Development Board Population Projection

Texas Water Development Board (TWDB) population projections were prepared in 1982 to project future water needs of the State through 2030. United States Bureau of the Census data for 1970 and 1980 was used for base year data. In February 1987 the TWDB revised their population projections at the county level . These figures were disaggregated by Paul Price Associates at the municipal level and incorporated into this report. The revised projections increased total 2040 population projections for McLennan County by 84 and for Bosque County by 4,000.

The population projections were calculated via a modified "cohort-component"[1] approach. In the TWDB model separate birth, death, and migration rates[2] were applied to each cohort (defined by 5 year age groups, sex, and race) for each county. This was done because rates vary according to sex, race, and age.

---

[1] A cohort is defined as a group of people within an specified age group who share similar characteristics (sex, race, etc...).

[2] When preparing cohort- component population projections, decisions and assumptions about fertility, mortality, and migration rates are crucial. Rates can be applied in many ways, varying at certain points in time, changing linear over time, varing from cohort to cohort, adjusted at the national level, the state level, the county level, the city level, etc..... Therefore when scrutinizing a projection methodology special attention should be given to the application of these rates.

For example: the death rate for men 30 - 35 years is lower than that for men 60 - 75 years.

In the TWDB projection model, national cohort fertility rates[3] for 1975 - 80 by age and ethnicity were adjusted to account for historical differences between Texas and the United States. Those adjusted Texas fertility rates were then readjusted for each county based on the county's birth data for the decade of the 1970s and then applied to each cohort for the next decade's population projection. The age-specific fertility rates, beginning with year 2000, were reduced through time because it was assumed that future societal and technological changes would decrease fertility rates.

Mortality rates[4] were calculated for each age, ethnic and sex cohort. National death rates from the Bureau of the Census 1969-1971 were adjusted for Texas death rates using historical data. Projected rates of change were adjusted over time to account for the historical trend of decreasing death rates. Deaths from each cohort were summed to get the total county deaths for the projection period.

The overall accuracy of population projections depends heavily upon the accuracy of the projected migration component.[5] The importance of this factor becomes apparent when one considers that over one half of the population growth in Texas between 1970 and 1980 was due to in-migration. To estimate the effect of various county characteristics on the migration rate, least-squares estimators (multiple regression), were incorporated in the TWDB model. Each county migration rate was then converted into a specific cohort migration rate.

By using two different migration rates and keeping all other variables (birth, death, etc...) equal the TWDB population projection model provides two series (a High Series and a Low Series) of

[3] Fertility rates were defined as the number of live births per 1000 women aged 15-44 in a given year.

[4] Mortality rates were defined as the number of deaths per 1000 people in a given year.

[5] Migration rates are defined as the number of people who move across a specified boundary for the purpose of establishing a new permanent residence.

population projections. The High Series migration rate was based on 1970 - 1980 Texas migration data, as reported in the 1980 Census. The Low Series projections were based on the same vital statistics regarding birth and death rates as used in the High Series projections. However, the migration rate is a weighted average of reported migration into Texas for the three decadel periods 1950-60, 1960-70 and 1970-80.

2.5.2.2 Texas Department of Health Population Projection

Revised in June 1986, the Texas Department of Health (TDH) population projections were prepared for 16 member agencies under the Community Health and Human Services Coordinating Council for the purpose of providing adequate health planning services and computing rates of disease and mortality in Texas.

The population projections were drawn from a modified 5-year cohort demographic model similar to the TWDB model. United States Bureau of the Census data for 1970 and 1980 was used for base year data. Incorporated into the model were adjusted mortality, migration, and fertility rates.

Fertility rates were based on 1980 child to woman ratios by race for the State and applied to year 1990 and 2000 aggregate population projections of women of childbearing years in each county. Mortality rates were prepared for the State by 5-year cohort, by sex and race and applied without adjustment at the county level. Neither rate was adjusted over time. The migration rate used in TDH's projection model was 75% of the 1970-80 State migration rate. The 1981-1990 rate was adjusted to accommodate gradual increase in migration until 1983, after which the rate was slowly decreased to 75% of the 1970-80 rate. Preliminary estimates of 1984 county and state population projections were compared with Census Bureau estimates and adjusted accordingly.

2.5.2.3 Heart of Texas Council of Governments Population Projection

Heart of Texas Council of Governments (HOTCOG) population projections were prepared in 1984 by Dr. Perryman of the Baylor Forecasting Service for HOTCOG and the Texas Commerce Department. The modified demographic cohort projection model used for these population forecasts is similar to that used by TWDB and TDH, except that this model was combined with an econometric model.

Econometric models of population change are predicted upon a presumed relationship between job availability and migration to or from an area. The difference between a combined model and a pure demographic model (such as the TWDB's and TDH's) is that a demographic model assumes migration is constant or varies by a mathematical function, whereas a combined econometric - demographic model computes migration as a varying function of economic needs.

The primary advantage of an econometric projection model over a demographic model is that it relates migration to and from an area to projected availability of employment. However, if the projections are for an area in which a few employers or sectors of the economy provide most of the employment, the population projections will be so sensitive to assumptions about those industries as to make them only slightly useful. Employment and unemployment variables play key roles in econometric projections of population, yet they are controversial and volatile.

The most significant difference between the HOTCOG model and others discussed in this document is the methodology of forecasting migration rates. While the other models used 1970 - 80 migration rates, 1950 - 80 rates, or other adjusted rates, in the HOTCOG model yearly migration rates were adjusted according to county specific economic growth indicators: post office box rentals, utility hookups, the number of building permits issued in a time period, etc... The resulting migration rates were adjusted to correspond with the State migration rate. National unadjusted mortality and fertility rates were applied by cohort, race, and sex.

2.5.2.4 City of Waco's Planning Department Population Projection

Population projections for year 2000 were made for Mclennen County, the area inside the Waco ETJ, the City of Waco, and other cities utilizing straight line projections plus historic trends. The migration rate for 1980 - 1984 as reported by the U.S. Bureau of the Census was used. Fertility and mortality rates were considered.

2.6 Population Projection Results

Counties

Table 2 - 4 shows 1980 - 2040 TWDB population projections for the State and Bosque and McLennan Counties. Table 2 - 5 displays the four agency population projections for Bosque County and McLennan County. Texas Department of Health (TDH), the City of Waco's Planning Department (WPD) and Heart of Texas Council of Governments (HOTCOG) projections were extended beyond year 2000 to 2040 by Paul Price Associates. TWDB projections were extended from year 2030 to 2040. Excluding HOTCOG population projections for McLennan County, extensions were calculated by applying the average decadel growth rate for the agency reported time period (1970 - 2000) to each successive decade. The average decadel growth rate for HOTCOG projections 1970-2000 was 22% for McLennan County, a growth rate considered too high to continue out to 2040. Therefore, the projected HOTCOG growth rate from 1990-2000 of 17% was chosen. Extensions to 2040 for TWDB projections were prepared by applying the 2020 - 2030 growth rate to the 2030 projected base population. A more detailed description of the extension methodology is provided in the Appendix.

Figure 2 - 4 and Figure 2 - 5 illustrate the discrepancies between the projected population figures found in Table 2 - 5. As shown, HOTCOG's population projections for 2040 of 458,540 and 39,003 for McLennan and Bosque County, respectively, are much higher than the other projections. Texas Water Development Board's Low Series population projections are the lowest for both counties, while TDH, TWDB High Series and the City of Waco's Planning Department projections are all lower than HOTCOG projections but higher than TWDB Low Series projections. TWDB Low Series projections show 2040 population in McLennan County at 239,559 and in Bosque County at 24,045.

Municipalities

Table 2 - 6 lists TWDB High and Low series population projections and the percent change from 1980 to 2040 for subject municipalities. Projections for McLennan County WCID # 2 were prepared by Paul Price Associates. Table 2 - 7 lists the City of Waco's population projections for McLennan County, the City of Waco and incorporated places in Waco's ETJ. Figures 2 - 6 through 2 - 10 graph the City of Waco and TWDB's population projections for Bellmead, Hewitt, Lacy-lakeview, Waco and Woodway.

As shown in Table 2 - 6, the range between projected TWDB High and Low series 1980 - 2040 population growth rates is large. The High series projections show four municipalities (Bellmead, Clifton, Meridian and Woodway) more than doubling their populations and three communities increasing their populations by over one-half. The TWDB Low series projections show only one community (Woodway) doubling its population, three community populations increasing by more than one-half and four communities increasing by less than one-half. In both projection series Woodway is the fastest growing community and Elm Mott the slowest. In both projection series growth rates for Bellmead, Woodway, Clifton and Meridian are among the highest. In accord with area historical trends, communities in the City of Waco's ETJ are projected to grow faster than the City of Waco.

Table 2 - 7 lists City of Waco population projections to year 2000 for Waco and communities in its ETJ. Projections to year 2040 are extrapolations of the planning department's official projections. The historical trend of communities in City of Waco's ETJ growing faster than the City is projected to continue. The fastest growing communities are Hewitt and Woodway.

Figures 2 - 6 through 2 - 10 compare 1980 through 2040 TWDB and City of Waco Planning Department (WPD) population projections for Bellmead, Hewitt, Lacy-Lakeview, Waco and Woodway. Generally, the TWDB High Series projections are the highest, the TWDB Low Series occupy the middle range, and the WPD projections are the lowest. The largest discrepancy between projections occurs with

Table 2-4 Texas Water Development Board State and County Populaton Projections, 1980 - 2040

State & Counties	1980 Population	1990 Projected Population	2000 Projected Population	2010 Projected Population	2020 Projected Population	2030 Projected Population	2040* Projected Population
Texas							
High Series (In millions)	14.2	17.8	21.2	24.8	29.1	34.3	40.4
Low Series (In millions)	14.2	16.8	19.6	22.3	25.1	28.3	31.9
Mclennan County							
Revised High Case	170,755	200,412	208,117	219,587	240,264	262,889	287,645
Revised Low Case	170,755	190,790	194,846	198,243	206,793	222,574	239,559
Bosque County							
Revised High Case	13,401	15,633	19,790	22,015	24,489	27,332	30,505
Revised Low Case	13,401	15,175	16,653	18,275	20,032	21,947	24,045

Source: Texas Water Development Board population projections 2/1987. 2040 projections by Paul Price Associates, Inc.

Table 2-5 Population Projection Comparison

POPULATION ESTIMATES AND PROJECTIONS	1970	1980	% Chng. 1970-80	1990	2000	% Chng. 1990-2000	Avg. Decadel % Chng. 1970-2000
MCLENNAN COUNTY							
Texas Department of Health	147,553	170,755	16%	192,909	206,936	7%	13%
Texas Water Development Board							
high case	147,553	170,755	16%	200,412	208,117	4%	14%
low case	147,553	170,755	16%	190,790	194,846	2%	11%
Heart of Texas Council of Governments	147,553	170,755	16%	208,755	244,700	17%	22%
Waco Planning Department	147,553	170,755	16%	187,745	204,700	9%	13%
BOSQUE COUNTY							
Texas Department of Health	11,072	13,401	21%	14,918	15,323	3%	13%
Texas Water Development Board							
high case	11,072	13,401	21%	15,633	19,790	27%	26%
low case	11,072	13,401	21%	15,175	16,653	10%	17%
Heart of Texas Council of Governments	11,072	13,401	21%	15,900	18,100	14%	21%

Source:
Texas Department of Health, Texas Water Development Board revised 2/87, Heart of Texas Council of Governments and City of Waco Planning Dept.
Note: All 2040 figures and low case TWDB figures are extrapolations by Paul Price Associates of official population projections.

Table 2-5 Population Projection Comparison (concluded)

POPULATION ESTIMATES AND PROJECTIONS	2010	% Chng. 2000-10	2020	% Chng. 2010-2020	2030 Projected	% Chng. 2020-30	2040	% Chng. 2030-40
MCLENNAN COUNTY								
Texas Department of Health	234,697	13%	266,181	13%	301,890	13%	342,388	13%
Texas Water Development Board								
high case	219,587	6%	240,264	9%	262,889	9%	287,645	9%
low case	198,243	2%	206,793	4%	222,574	8%	239,559	8%
Heart of Texas Council of Governments	286,299	17%	334,970	17%	391,915	17%	458,540	17%
Waco Planning Department	225,068	10%	245,393	9%	269,810	10%	296,656	10%
BOSQUE COUNTY								
Texas Department of Health	17,284	13%	19,496	13%	21,991	13%	24,806	13%
Texas Water Development Board								
high case	22,015	11%	24,489	11%	27,332	12%	30,505	12%
low case	18,275	10%	20,032	10%	21,947	10%	24,045	10%
Heart of Texas Council of Governments	21,930	21%	26,570	21%	32,191	21%	39,003	21%

Source:
Texas Department of Health (TDH), Texas Water Development Board (TWDB) revised 2/87, Heart of Texas Council of Governments (HOTCOG) and City of Waco Planning Dept (CWP).
Note: All 2040 figures, TDH, HOTCOG, WPD projections past year 2000 and low case TWDB figures are extrapolations by Paul Price Associates, Inc. of official population projections.

Figure 2-4
McLennan County, Population Projection Comparison, 1970-2040

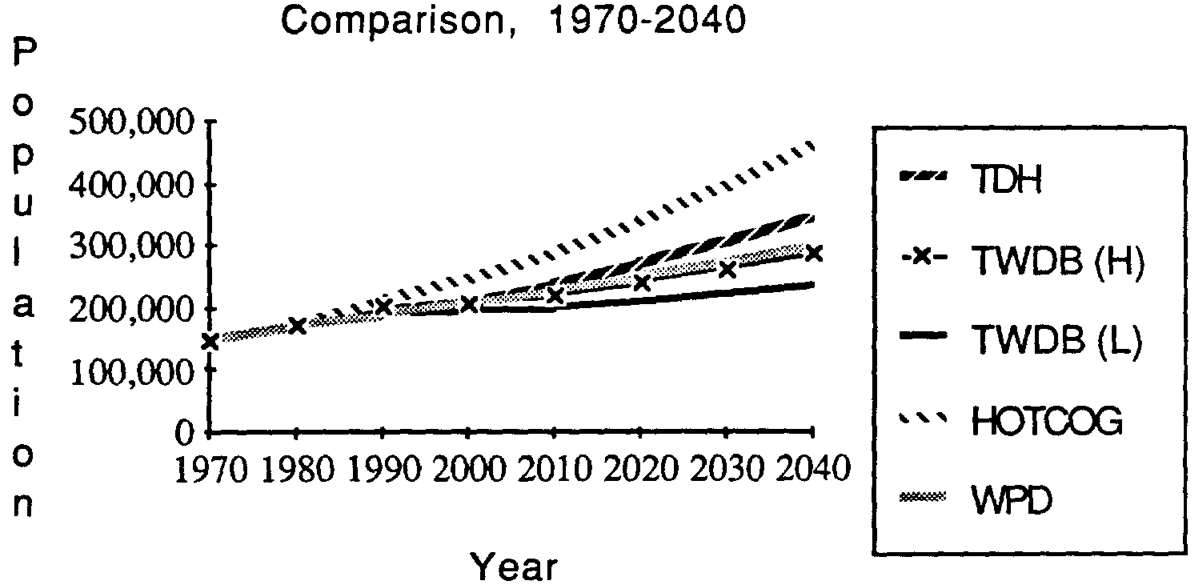
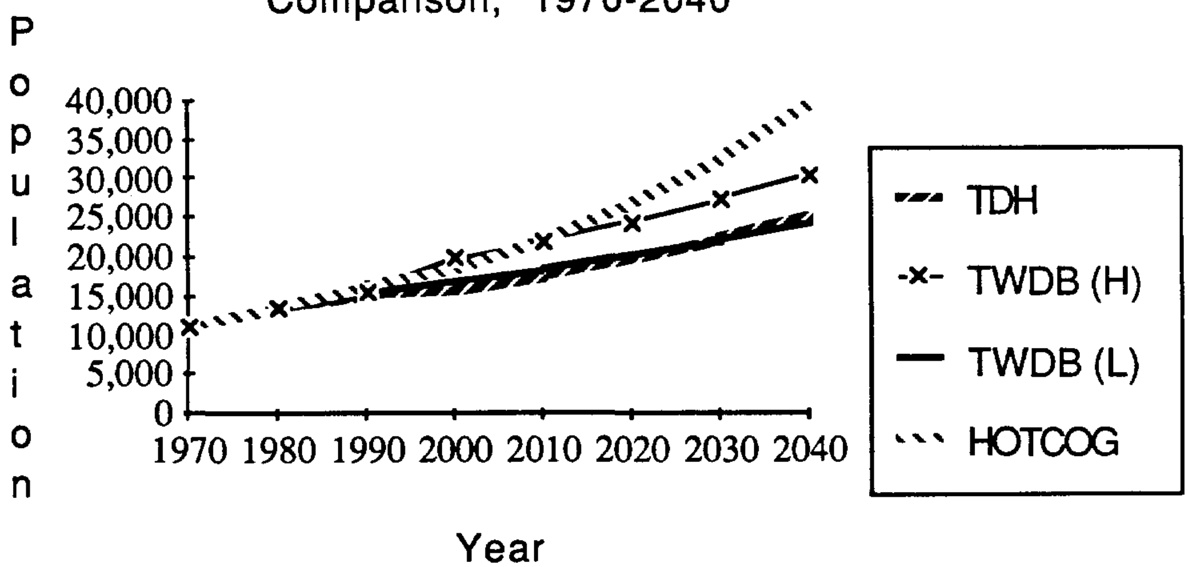


Figure 2-5
Bosque County, Population Projection
Comparison, 1970-2040



Waco and TWDB's population projections for Bellmead, Hewitt, Lacy-lakeview, Waco and Woodway.

As shown in Table 2 - 6, the range between projected TWDB High and Low series 1980 - 2040 population growth rates is large. The High series projections show four municipalities (Bellmead, Clifton, Meridian and Woodway) more than doubling their populations and three communities increasing their populations by over one-half. The TWDB Low series projections show only one community, Woodway, doubling its population, three community populations increasing by more than one-half and four communities increasing by less than one-half. In both projection series Woodway is the fastest growing community and Elm Mott the slowest. In both projection series growth rates for Bellmead, Woodway, Clifton and Meridian are among the highest. In accord with area historical trends, communities in the City of Waco's ETJ are projected to grow faster than the City of Waco.

Table 2 - 7 lists City of Waco population projections to year 2000 for Waco and communities in its ETJ. Projections to year 2040 are extrapolations of the planning department's official projections. The historical trend of communities in City of Waco's ETJ growing faster than the city is projected to continue. The fastest growing communities are Hewitt and Woodway.

Figures 2 - 6 through 2 - 10 compare 1980 through 2040 TWDB and City of Waco Planning Department (WPD) population projections for Bellmead, Hewitt, Lacy-Lakeview, Waco and Woodway. With one exception, TWDB High series projections are the highest, TWDB Low series projections are the lowest, and the Waco Planning Department's projections in the middle range. The largest discrepancies between the projections are for the communities of Hewitt and Bellmead. WPD projections for Hewitt show the community's population increasing at a much greater rate than in either TWDB projection series (see Figure 2 - 7). In contrast both TWDB population projections for Bellmead are considerably higher than WPD's.

Table 2-6 Texas Water Development Board Municipal Population Projections, 1980-2040

Jurisdiction	1980 Population	1990 Projection	2000 Projection	2010 Projection	2020 Projection	2030 Projection	2040 Projection	% Change 1980-2040
Bellmead								
High Case	7,569	10,766	11,708	12,353	13,517	14,790	16,183	114%
Low Case	7,569	10,249	10,961	11,152	11,634	12,522	13,478	78%
Clifton								
High Case	3,063	3,737	4,793	5,332	5,932	6,620	7,388	141%
Low Case	3,063	3,738	4,244	4,750	5,316	5,971	6,707	119%
Hewitt								
High Case	5,247	6,158	6,395	6,747	7,383	8,078	8,838	68%
Low Case	5,247	5,862	5,987	6,091	6,355	6,839	7,359	40%
Lacy-Lakeview								
High Case	2,752	3,443	3,626	3,826	4,187	4,581	5,012	82%
Low Case	2,752	3,277	3,394	3,454	3,604	3,878	4,173	52%
McLennan County WCID #2 (Elm Mott)*								
High Case	1,300	1,275	1,286	1,357	1,484	1,624	1,777	37%
Low Case	1,300	1,213	1,203	1,224	1,277	1,375	1,481	14%
Meridian								
High Case	1,330	1,662	2,142	2,383	2,650	2,958	3,303	148%
Low Case	1,330	1,613	1,802	1,978	2,168	2,376	2,604	96%
Waco								
High Case	101,261	114,555	115,909	122,297	133,813	146,413	160,199	58%
Low Case	101,261	109,056	108,518	110,408	115,171	123,961	133,422	32%
Woodway								
High Case	7,091	12,170	14,368	15,160	16,587	18,149	19,858	180%
Low Case	7,091	11,586	13,452	13,686	14,277	15,366	16,539	133%

Source: High Case Population projections by the Texas Water Development Board as of 2/1987.
2040 projections were extended by Paul Price Associates.
NOTE: *** Elm Mott (McLennan County WCID #2) projections are by Paul Price Associates, Inc.
Municipal population projections were derived by Paul Price Associates by disagregating the TWDB county population projections.

Table 2 - 7. City of Waco Population Projections 1980 - 2040

JURISDICTON	1980	2000	Percent Change	Extended Population Projections 2020	2040
McLennan County	170,755	204,700	19.88%	245,393	294,176
Waco and ETJ	147,014	176,400	19.99%	211,660	253,968
City of Waco	101,261	116,400	14.95%	133,802	153,806

INCORPORATED PLACE	1980	2000	Percent Change	Extended Population Projections 2020	2040
Bellmead	7,569	8,010	5.83%	8,477	8,971
Hewitt	5,247	9,470	80.48%	17,092	30,848
Lacy-Lakeview	2,752	2,960	7.56%	3,184	3,424
Waco	101,261	116,380	14.93%	133,756	153,727
Woodway	7,091	9,410	32.70%	12,487	16,571
Other	10,101	13,550	34.15%	18,177	24,383
Subtotal	134,021	159,780	19.22%	190,490	227,102
Total of outside incorporated places and principally within Waco's ETJ	12,993	16,550	27.38%	21,081	26,852
Total ETJ Population	147,014	176,420	20.00%	211,708	254,054

Source:
United States Census 1970 and 1980, Waco Planning Dept., 1981.
Population projection extensions by Paul Price Associates.

Note:
Other incorporated places include the communites of Beverly Hills, Northcrest and Robinson.

Figure 2-6
Bellmead Population Projections 1980-2040

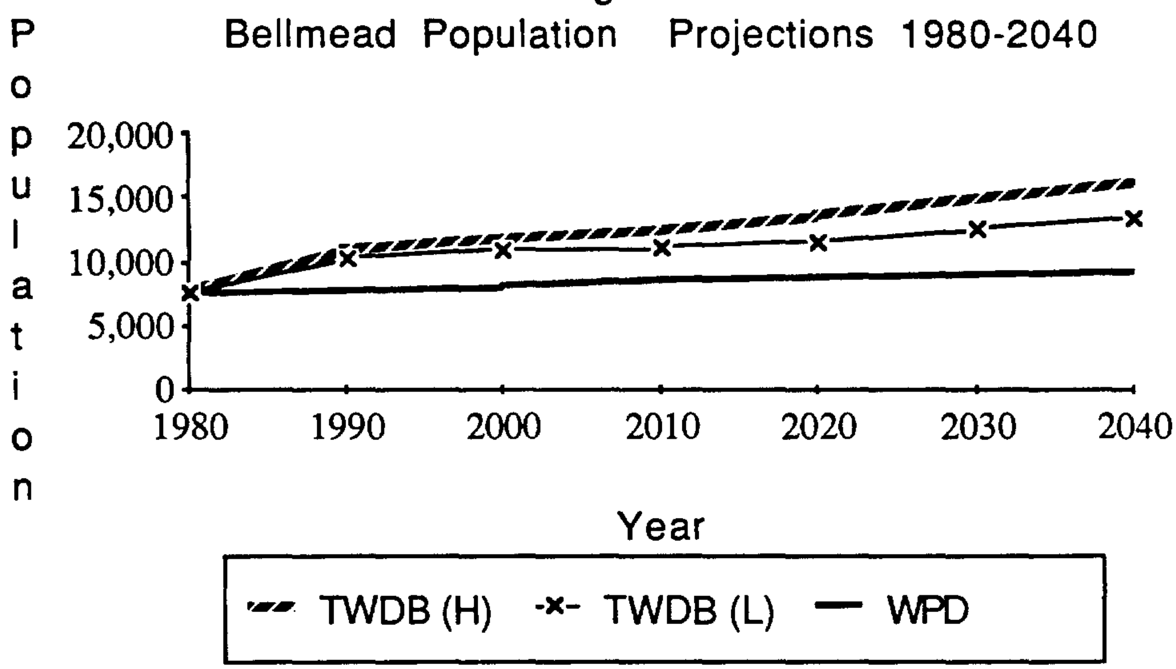


Figure 2-7
Hewitt Population Projections 1980-2040

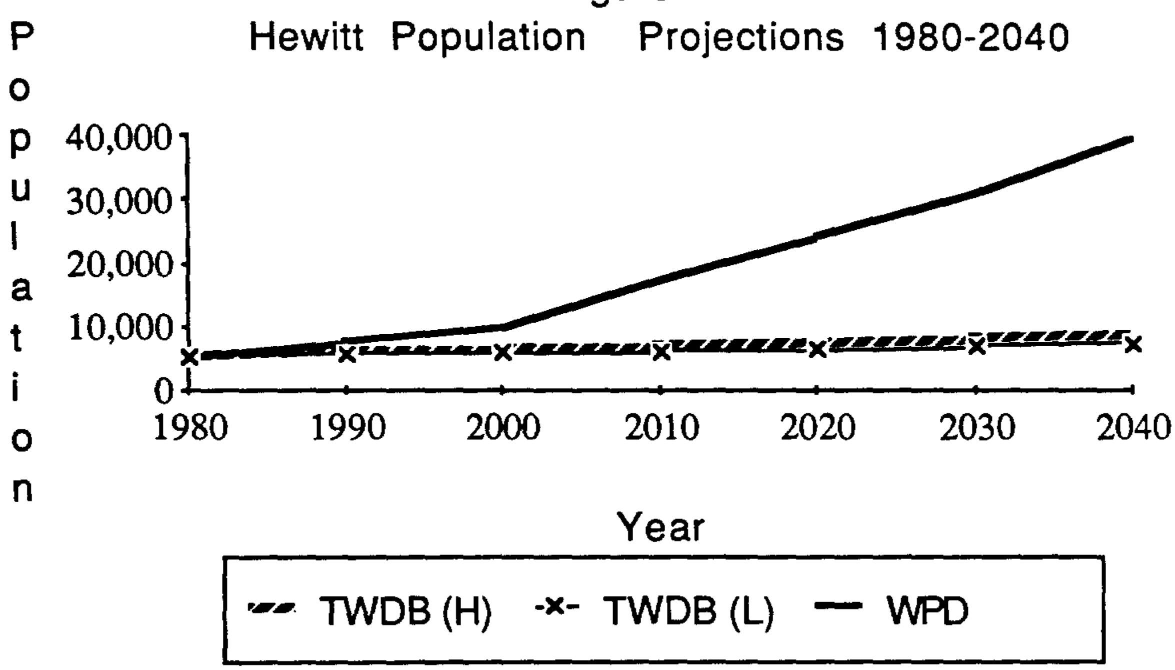


Figure 2-8
Lacy-Lakeview Population Projections 1980-2040

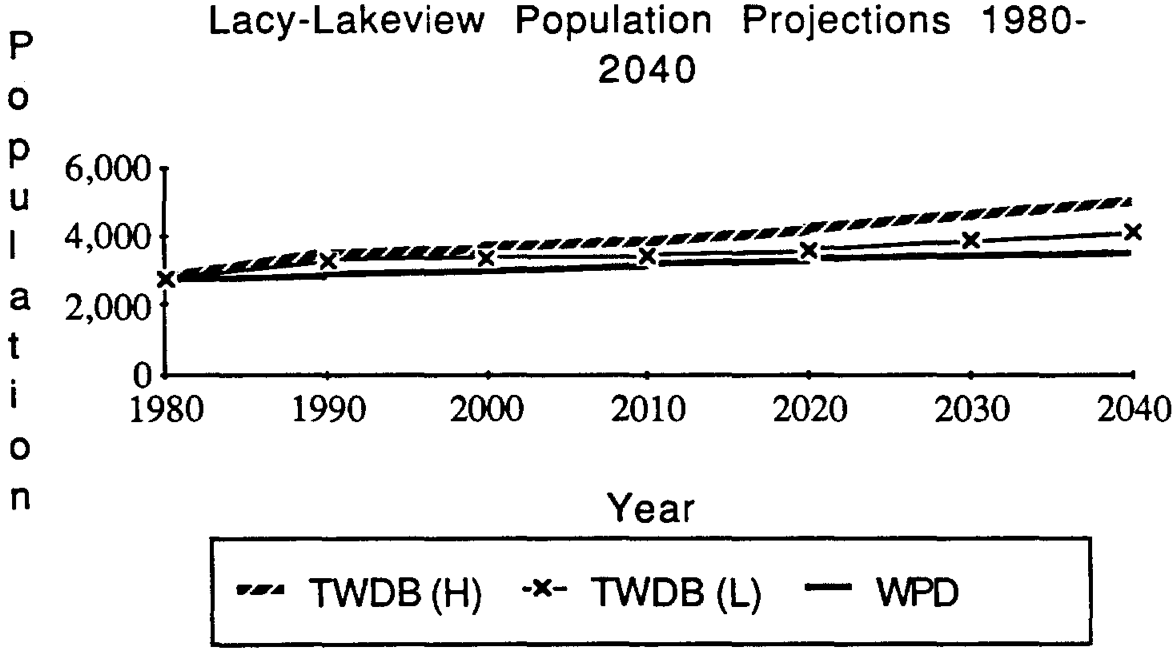


Figure 2-9
The City of Waco Population Projections 1980-2040

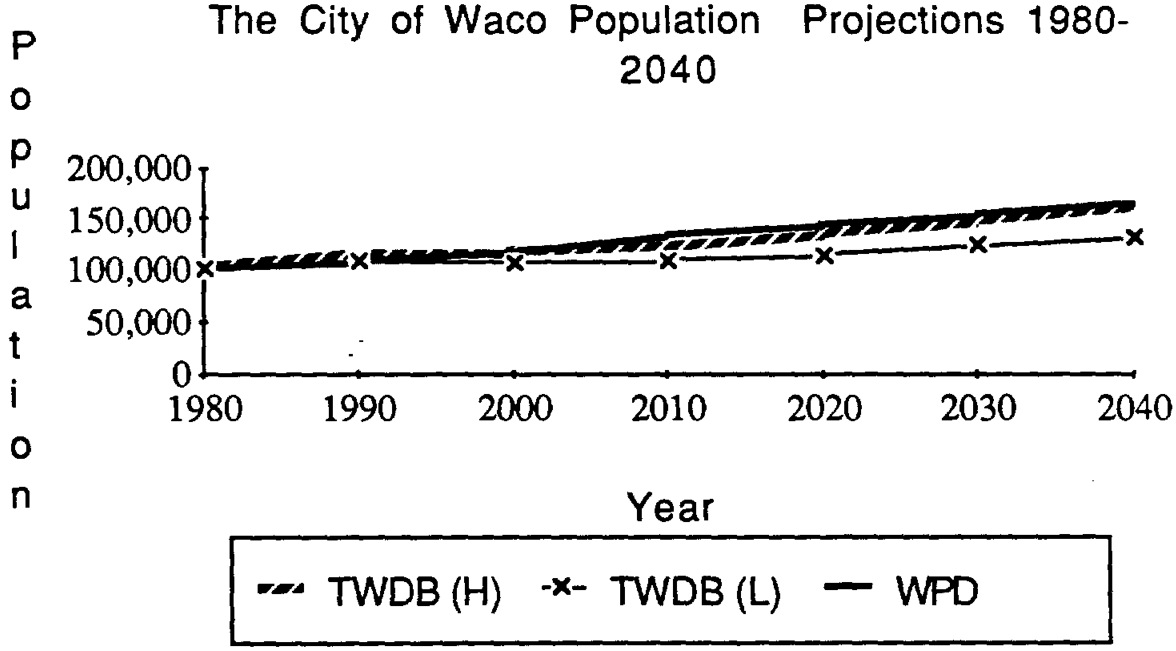
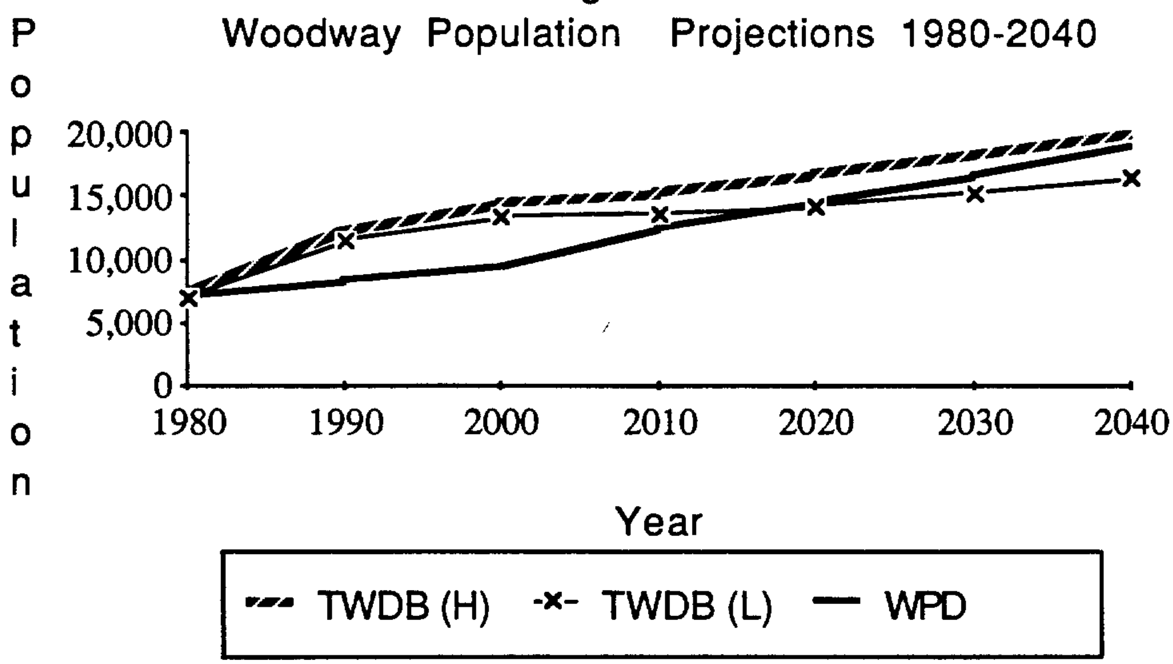


Figure 2-10
Woodway Population Projections 1980-2040



the City of Hewitt. Extended WPD projections place 2040 population at 30,848 (the 1980-2000 WPD projected growth rate of 80.48% was applied to obtain 2040 projections). The TWDB High and Low series project a 2040 Hewitt population of 16,183 and 13,478 respectively (see Figure 2 - 7).

2.7 RECOMMENDED POPULATION PROJECTION

Projections for the near future are generally more reliable than long-term projections. However, the life span of the proposed Lake Bosque Reservoir requires population projections for the far future, 2040. Comparison of different population projections reveals that TWDB projections occupy the bottom and middle range of future county population scenarios. But this does not necessarily mean that TWDB projections are the most accurate. The best method of deciding which projection is most accurate is to scrutinize, as has been done in the preceding text, the methodology and assumptions of each projection model.

The five population methodologies discussed in this document are very similar. Each series of projections is based on a modified demographic projection cohort model, with HOTCOG projections using a combined econometric - demographic model and the City of Waco using straightline projections combined with historic trends.

The most significant difference between the five population projections is the applied migration rate. In each of the methodologies, except for the TWDB Low Series population projection, the migration rate is based on a modified or pure 1970 - 80 migration rate. Texas Department of Health forecasts use a modified 1970 - 80 State migration rate, TWDB High Series projections incorporate the State 1970 - 80 migration rate, the City of Waco uses a 1980 - 84 adjusted migration rate and HOTCOG projections result from a yearly adjusted county based migration rate. The assumption that future migration rates will mirror the 1970's high migration rate results in population projections that are most likely too high.

The TWDB Low Series population projections reflect the result of different assumptions about migration rates. The Low Series projections are based on the same vital statistics regarding birth and death rates as used in the High Series projections; however, the migration rate is a weighted average of reported decadel migration in Texas from 1950 to 1980. The weighted average effectively reduces the impact of the very high rate of migration into Texas in the 1970s, and therefore results in a better long-term population projection.

3.0 ECONOMIC PROFILE

3.1 INTRODUCTION

Described in this section are employment trends in Texas, Bosque and McLennan Counties from 1960 to 1986. Employment was chosen as a growth indicator of the study area's economic activity. Major employment sectors were identified by Standard Industrial Classification codes (SIC) for 1960, 1970, 1980 and 1986. Discussed is the proportional change of employment over time for each industrial sector and the proportion of total employment provided by each sector. Service and export based industrial sectors for 1980 and 1986 were identified as well as the cause and rate of employment growth by sector. In addition, an income distribution analysis of the study area for 1970 and 1980 was conducted.

The Lake Bosque project is within commuting distance from anywhere within the two county study area and could potentially impact any of the area's communities, therefore, analysis of the study area's economy was conducted at the county level and was not targeted at any specific municipality. Other factors influencing the decision to conduct the analysis at the county level were: (1) the participant communities, except for the City of Waco, are small communities with populations ranging from 1,330 to 9,900 and are characterized by small scale economies; (2) the Waco Metropolitan Statistical area includes five of the participant communities in its boundaries and all of McLennan County.

Throughout the analysis Texas was used as a benchmark with which to compare the counties. Employment figures are from the U.S. Bureau of the Census 1960 - 1980 and the Texas Employment Commission Covered Employment and Wages by Industry and County summaries for 1980 - 1986. Income data is from the U.S. Bureau of the Census 1970 - 80. Census SIC codes were aggregated to comply with 1980 - 86 Texas Employment Commission (TEC) classifications. Table 3 - 1 lists those categories; an explanation of those categories follows.

Table 3 - 1

Texas Employment Commission
Standard Industrial Classification Codes

Agriculture, Forestry, Fisheries
Mining
Construction
Manufacturing
Transportation, Communications & Public Utilities (TCP)
Trade(wholesale & retail)
Finance, Insurance & Real Estate (FIRE)
Service Industries
Local and State Government

With the exception of a few categories such as Service Industries and Local and State Government, SIC classifications are fairly straightforward. For example: the category of Agriculture, Forestry and Fisheries includes employment related to crops, livestock, agriculture services, forestry, fishing, hunting and trapping. Service industries include employment in personal services such as dry cleaning, hair salons, restaurant, entertainment, as well as business and professional services (engineering, printing, law, etc..). Local and State Government includes health and education employment as well as traditional government employment.

Due to different collection criteria, Texas Employment Commission (TEC) data for 1980 - 86 does not directly correspond to U. S. Bureau of the Census data for 1980. Census data is drawn from individual survey responses whereas TEC data is collected from employers subject to the Texas Unemployment Compensation Act. TEC data does not account for the self-employed, unpaid family workers and those employed by churches and small nonprofit organizations. Despite those discrepancies it is useful to use both sets of data: Census data provides a historical background which is not readily available through TEC, while TEC data is the most current (as of January 1986, First Quarter).

3.2 HISTORICAL EMPLOYMENT TRENDS

Texas

The 1970s and 1980s was a period of rapid employment and population growth in Texas. From 1960 to 1980 employment in Texas expanded by nearly 60% while the population increased by one-half to 14.2 million. During the 1970s population growth greatly exceeded the national average, 27% for Texas and 11% for the Nation, and employment increased by 52% (see Table 3 - 2). Despite a decline in employment growth during the early 1980s, total state employment from 1980 to January 1986 increased by 17% to a total of 6,543,284 workers (see Table 3 - 3).

As shown in Table 3 - 2 from 1960 - 80 major Texas employment sectors were Manufacturing, Trade, Service and Government. In 1960, according to U.S. Bureau of the Census data, Trade was the single largest employment sector, followed closely by Service and Manufacturing industries. During the 1970s Manufacturing grew faster than Service industries and by 1980 tied with Government as the second largest employment sector. By 1980 nearly 60% of the labor force was employed in Trade, Government and Manufacturing.

As shown in Table 3 - 3 Texas Employment Commission (TEC) estimated 1980 Texas employment at 5,602,405, about 13% or 711,440 fewer jobs than reported by the U.S. Census. TEC data identified Trade as the primary employer (25% of total employment), but differs with Census estimates as to the second, third and fourth largest employment sectors. Manufacturing was listed as the second largest employer followed by Government and then Service.

From 1980 to 1986 total employment in Texas increased by 17%. The three fastest growing employment sectors which also grew faster than the state average for all employment sectors were: Service; Finance, Insurance, & Real Estate (FIRE) and Trade industries. Surprisingly, agricultural

Table 3 - 2. Texas Historic Employment Trends 1960 - 1980

INDUSTRY	TEXAS # Employed 1960	# Employed 1970	%Δ	# Employed 1980	%Δ	% Total Population 1960	% Total Population 1970	% Total Population 1980
Agri., Fisheries, Forestry	291,899	194,635	-33%	187,178	-4%	9%	5%	3%
Mining	100,162	103,075	3%	209,617	103%	3%	2%	3%
Construction	251,938	317,758	26%	545,450	72%	8%	8%	9%
Manufacturing	540,161	765,119	42%	1,129,267	48%	16%	18%	18%
Transp. Comm. & Public Utilities	245,949	286,195	16%	476,436	66%	7%	7%	8%
Trade	703,969	918,693	31%	1,378,408	50%	21%	22%	22%
FIRE	138,230	213,261	54%	377,862	77%	4%	5%	6%
Service & other	627,383	579,537	-8%	809,476	40%	19%	14%	13%
State and Local Gov.	418,812	763,256	82%	1,198,151	57%	13%	18%	19%
Health	73,438	208,892	184%	399,900	91%	2%	5%	6%
Education	182,456	328,564	80%	516,847	57%	5%	8%	8%
Government	162,918	225,800	39%	281,404	25%	5%	5%	4%
Total Employment	3,318,503	4,141,529	25%	6,311,845	52%	100%	100%	100%

Source: U.S. Bureau of the Census, General Social and Economic Caracteristics, 1970, 1980. Tables 123, 178.

Table 3 - 3. Texas Employment Trends 1980 - 86

INDUSTRY	Texas # Employed 1980	Texas # Employed 1986	% Δ	% Total Employment 1980	% Total Employment 1986
Agri., Fisheries, Forestry	56,500	65,201	15%	1%	1%
Mining	219,456	247,799	13%	4%	4%
Construction	416,760	426,312	2%	7%	7%
Manufacturing	1,022,974	974,691	-5%	18%	15%
Transp.Comm. & Pub. Ut.	324,420	354,280	9%	6%	5%
Trade	1,410,800	1,689,822	20%	25%	26%
FIRE	310,881	431,012	39%	6%	7%
Service & Other	881,703	1,238,695	40%	16%	19%
Government	958,911	1,113,109	16%	17%	17%
TOTAL EMPLOYMENT	5,602,405	6,540,921	17%	100%	100%

Source: Texas Employment Commission, Covered Employment and Wages by Industry and County. January, First Quarter 1980, 1986.

employment increased by 15% and Manufacturing was the only sector to lose employment.

TEC reported that for the first quarter of January, 1986, Trade was the largest employment sector in Texas, Service was the second largest, Government was the third largest employer and Manufacturing with 15% of the labor force was ranked fourth.

McLennan County

Similar to Texas, since 1960, major employment sectors in McLennan County have been Manufacturing, Trade and Government. But despite the similarities between McLennan County and the larger Texas economy, population and economic growth in McLennan County never approached the magnitude of Texas' growth.

During the 1960s employment and population growth in McLennan County, as shown in Table 3 - 4, did not reflect the growth that was occurring elsewhere in the State. From 1960 to 1970 total population in Texas increased by almost 17% and the labor force expanded by one-fourth. In McLennan County, population decreased by almost 2% and total employment increased by 8%. However from 1970 to 1980 as the population in Texas nearly tripled and the labor force increased by one-half, McLennan County's slow growth pattern changed; its population increased by 16% and total employment increased by 30%. The early to mid-1980s was a period of moderate growth, as employment in McLennan County increased by 11% while statewide employment increased by 17% (see Table 3 - 5).

As shown in Table 3 - 4, in 1960, 77% of the 52,496 employment force worked in Trade, Manufacturing, Government and Service industries. During the decade of the 1960s total employment grew by 8% as five of the nine industries expanded. The fastest growing sectors were Mining, Government, FIRE and Manufacturing. Four industries lost employment: Agriculture, Construction, Service and

Table 3 - 4 Mclennan County Historic Employment Trends 1960 - 1980

MCLENNAN COUNTY INDUSTRY	# Employed 1960	# Employed 1970	%Δ	# Employed 1980	%Δ	% Total Population 1960	1970	1980
Agri., Fisheries, Forestry	3,025	1,962	-35%	1,471	-25%	6%	3%	2%
Mining	61	156	156%	168	8%	0.1%	0.3%	0.2%
Construction	3,829	3,590	-6%	4,470	25%	7%	6%	6%
Manufacturing	9,759	11,345	16%	15,856	40%	19%	20%	22%
Transp. Comm. & Public Utilities	3,193	3,165	-1%	4,697	48%	6%	6%	6%
Trade	12,100	12,756	5%	16,688	31%	23%	23%	23%
FIRE	2,349	2,806	19%	4,725	68%	4%	5%	6%
Service & other	9,499	8,280	-13%	8,964	8%	18%	15%	12%
State and Local Gov.	8,681	12,499	44%	16,326	31%	17%	22%	22%
Health	2,168	3,673	69%	5,784	57%	4%	6%	8%
Education	3,763	6,120	63%	7,712	26%	7%	11%	11%
Government	2,750	2,706	-2%	2,830	5%	5%	5%	4%
Total Employment	52,496	56,559	8%	73,365	30%	100%	100%	100%

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.

Table 3 - 5 Mclennan County Employment Trends 1980 - 86

INDUSTRY	Texas # Employed 1980	Texas # Employed 1986	% Δ	% Total Employment 1980	% Total Employment 1986	Mclennan County # Employed 1980	Mclennan County # Employed 1986	% Δ	% Total Employment 1980	% Total Employment 1986
Agriculture	56,500	65,201	15%	1%	1%	423	520	23%	1%	0.81%
Mining	219,456	247,799	13%	4%	4%	154	144	-6%	0.24%	0.22%
Construction	416,760	426,312	2%	7%	7%	3,769	3,989	6%	6%	6%
Manufacturing	1,022,974	974,691	-5%	18%	15%	16,005	15,799	-1%	25%	25%
Transp.Comm. & Pub. Ut.	324,420	354,280	9%	6%	5%	3,050	3,157	4%	5%	5%
Trade	1,410,800	1,689,822	20%	25%	26%	16,939	18,977	12%	26%	30%
FIRE	310,881	431,012	39%	6%	7%	3,812	4,592	20%	6%	7%
Service & other	881,703	1,238,695	40%	16%	19%	11,224	15,007	34%	17%	23%
Government	958,911	1,113,109	16%	17%	17%	8,772	9,261	6%	14%	14%
TOTAL EMPLOYMENT	5,602,405	6,540,921	17%	100%	100%	64,148	71,446	11%	100%	111%

Source: Texas Employment Commission, Covered Employment and Wages by Industry and County. January, First Quarter 1980, 1986.

Transportation, Communications & Public Utilities (TCP).

In 1970, 65% of the 56,559 labor force were employed in three industrial sectors: Trade, Government and Manufacturing. During the decade of the 1970s total employment grew by 30%. Eight of the nine sectors expanded, four at a faster rate than the county's employment growth rate. The fastest growing sectors were FIRE, Transportation, Communications and Public Utilities, Manufacturing, Government and Trade. Agricultural and Service employment continued to decline.

By 1980 the distribution of employment had changed little since 1970. The same three major industrial sectors, Trade, Manufacturing and Government employed 67% (slightly more than in 1970) of the 73,365 strong labor force. Although FIRE and Transportation, Communications and Public Utilities sectors had the strongest growth rates during the 1970s each had such a small employment base that the impact on total employment was slight.

TEC estimated 1980 total employment for McLennan County at 64,148, about 13% or 9,217 fewer jobs than the U.S. Bureau of the Census estimate. For 1986, total employment was estimated at 71,446, an increase of 11% from 1980. As seen in Table 3 - 5 during the early to mid-1980s Trade was the single largest employment sector, followed by Manufacturing, Service and Government sectors. The fastest growing industrial sectors were Service, Agriculture and FIRE. This was the first time since 1960 that Agriculture gained employment instead of losing it. For the first time in 26 years employment in Mining and Manufacturing declined.

Bosque County

The boomtime growth occurring throughout Texas during the 1960s and 1970s occurred later and at a slower pace in Bosque County. During the 1960s Bosque County saw only minute employment and population growth, but from 1970 - 80 the situation changed considerably as population increased by 22% and total employment by 24% (see Table 3 - 6). But TEC employment estimates for 1980 - 86 show employment in Bosque County decreasing significantly from the 1970s (see Table 3 - 7).

In 1960, as shown in Table 3 - 6, over 60% of the 4,248 labor force in Bosque County was employed in Agriculture, Trade or Service industries. The largest single employment sector was Agriculture, accounting for over 27% of total employment. From 1960 - 70 total employment increased by 2% to a total of 4,333. The fastest growing employment sector was Mining, followed by FIRE, Government and Manufacturing. Although the growth rate for two Mining and FIRE employment was extremely high, the employment base of those sectors was so small that the impact of rapid growth was slight. Of the four sectors which lost employment: Agriculture; Service; Transportation, Communications and Public Utilities (TCP) and Trade, all but TCP employed a significant proportion of the labor force.

In 1970 major employment sectors in Bosque County were Manufacturing, Trade, Government and Agriculture. In direct response to the rapid population expansion during the 1970s all but two (Mining and Agriculture) of the nine employment sectors experienced growth. The fastest growing industrial sectors (although not the largest employers) were those dealing with the immediate needs of a quickly growing population: Construction; Transportation, Communications & Public Utilities (TCP); and Government. The other expanding sectors were FIRE, Trade and Manufacturing. From 1970 - 80 total county employment increased by 24% to a total of 5,378.

TEC estimates for 1980 place Bosque County's labor force at 3,040, about 2,338 or 43% less than the U.S. Bureau of the Census estimate. As shown in Table 3 - 7 major employers were Manufacturing , Government, Trade and Service. Agriculture accounted for only 4% of total employment. From 1980 - 86 total employment increased by 4% to a total of 3,168. Four of the sectors experienced growth and three lost employment. Construction was the fastest growing sector, with a growth rate of 135% , followed by FIRE and Trade. Both Service and Agriculture employment increased by 6%. Of the three sectors which lost employment, Government with a decrease of 25% was the hardest hit,

Table 3 - 6 Bosque County, Historic Employment Trends, 1960 - 1980

INDUSTRY	# Employed 1960	# Employed 1970	%Δ	# Employed 1980	%Δ	% Total Population 1960	% Total Population 1970	% Total Population 1980
Agri., Fisheries, Forestry	1,166	686	-41%	578	-16%	27%	16%	11%
Mining	22	62	182%	31	-50%	1%	1%	1%
Construction	387	440	14%	700	59%	9%	10%	13%
Manufacturing	519	876	69%	1,071	22%	12%	20%	20%
Transp.Comm. & Pub. Ut.	267	222	-17%	356	60%	6%	5%	7%
Trade	757	748	-1%	927	24%	18%	17%	17%
FIRE	91	182	100%	252	38%	2%	4%	5%
Service & other	644	438	-32%	479	9%	15%	10%	9%
State and Local Gov.	395	679	72%	984	45%	9%	16%	18%
Health	66	320	385%	456	43%	2%	7%	8%
Education	183	181	-1%	369	104%	4%	4%	7%
Government	146	178	22%	159	-11%	3%	4%	3%
Total Employment	4,248	4,333	2%	5,378	24%	100%	100%	100%

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.

Table 3 - 7 Bosque County Employment Trends 1980 - 86

INDUSTRY	Texas # Employed 1980	Texas # Employed 1986	% Δ	% Total Employment 1980	% Total Employment 1986	Bosque County # Employed 1980	Bosque County # Employed 1986	% Δ	% Total Employment 1980	% Total Employment 1986
Agri., Fisheries, Forestry	56,500	65,201	15%	1%	1%	126	133	6%	4%	4%
Mining	219,456	247,799	13%	4%	4%	NA	8	NA	NA	0%
Construction	416,760	426,312	2%	7%	7%	40	94	135%	1%	3%
Manufacturing	1,022,974	974,691	-5%	18%	15%	814	650	-20%	27%	21%
Transp.Comm. & Pub. Ut.	324,420	354,280	9%	6%	5%	130	121	-7%	4%	4%
Trade	1,410,800	1,689,822	20%	25%	26%	628	923	47%	21%	29%
FIRE	310,881	431,012	39%	6%	7%	103	166	61%	3%	5%
Service & Other	881,703	1,238,695	40%	16%	19%	562	595	6%	18%	19%
Government	958,911	1,113,109	16%	17%	17%	637	478	-25%	21%	15%
TOTAL EMPLOYMENT	5,602,405	6,540,921	17%	100%	100%	3040	3168	4%	100%	100%

Source: Texas Employment Commission, Covered Employment and Wages by Industry and County. January, First Quarter 1980, 1986.

Manufacturing following closely losing 20% of its employees, while Transportation, Communications and Public Utilities employment declined by 7% .

3.3 SHIFT SHARE ANALYSIS

3.3.1 Introduction

Shift-share analysis is an economic tool which analyzes the development of individual employment sectors over time. Employment growth is usually due to growth in an industry at large or because of forces that are particular to the region. The benefit of this analysis technique is that the cause and rate of employment growth (relative to some benchmark economy) can be determined. Tables 3 - 8, 3 - 9, 3 - 10 and 3 - 11 display 1970 - 80 and 1980 - 86 shift-share analyses for Bosque and McLennan Counties. Tables 3 - 8, 3 - 10 incorporate U. S. Bureau of the Census employment data by industrial sector for 1970 and 1980. Tables 3 - 9, 3 - 11 incorporate 1980 and 1986 TEC employment data. Texas was used as the benchmark economy.

3.3.2 Methodology

In the following shift-share tables the numbers in the column labeled "Share" represent the hypothetical employment that would have occurred in the industry if the industry had grown at the same rate as the Texas economy at large. The column labeled "Total Shift" is the difference between the hypothetical employment (if the industry had grown at the State average growth rate) and actual employment. Positive values indicate employment growth that is faster than the state's average; a negative value indicates growth which is slower.

The columns labeled "Industrial Shift" and "Regional Shift" are subcategories of the Total Shift column. Positive values in the Industrial Shift column indicate industrial sectors which grew faster than the state average for all industry and therefore gained employment at the expense of other industries. This column indicates the proportion of slow and fast growth industries located in the study area. Positive values in the Regional Shift column indicate a local industry that grew faster than the average for that same industry at the regional level (in this case Texas) and therefore is drawing resources and labor from other regions into the study area. This signifies that the locality in which the industry is located is providing some sort of comparative advantage to that industry that is not found in other areas. That comparative advantage might consist of better access to markets, raw resources or skilled labor, etc...

3.3.3 Shift Share Analysis Results

McLennan County

As shown in Table 3 - 8, from 1970 to 1980 four of the fifteen industrial sectors in McLennan County grew at a faster rate than the average state industrial growth rate. Those industries were FIRE, Business & Repair, Entertainment & Recreation, and Health. The remaining industrial sectors grew slower than the average state industrial growth rate.

The reason those four industries grew faster than the average state industrial growth rate was that the whole industry at the state level was growing and not because McLennan County provided a unique comparative advantage to the industry. In short, growth in FIRE, Business & Repair, Entertainment & Recreation, and Health industries in McLennan County was matched by growth in the same industries throughout the state and not caused by anything unique to McLennan County. In fact, there were no industries for which McLennan County provided a comparative advantage.

As shown in Table 3 - 9, from 1980 - 86 only three of the nine industrial sectors, Agriculture, FIRE and Service grew faster than the state average. Growth in McLennan County's Agriculture industries was not caused by growth in the industry at the state level but because of comparative advantages found in the local region. Growth in FIRE and Service industries was caused by growth at the state industry level and not by any local comparative advantage.

Table 3 - 8 Shift-Share Analysis, Mclennan County 1970-1980

INDUSTRY	Texas # Employed 1970	Texas # Employed 1980	Mclennan County # Employed 1970	Mclennan County # Employed 1980	Absolute change	Share	Total Shift	Industrial Shift	Regional Shift
Agri., Fisheries, Forestry	194,635	187,178	1,962	1,471	-491	1,028	-1,519	-1,103	-416
Mining	103,075	209,617	156	168	12	82	-70	79	-149
Construction	317,758	545,450	3,590	4,470	880	1,881	-1,003	689	-1,692
Manufacturing	765,119	1,129,267	11,345	15,856	4,511	5,945	-1,440	-551	-888
Transp.Comm. & Pub. Ut.	286,195	476,436	3,165	4,697	1,532	1,659	-128	444	-572
Trade	918,693	1,378,408	12,756	16,688	3,932	6,685	-2,759	-308	-2,451
FIRE	213,261	377,862	2,806	4,725	1,919	1,470	447	694	-247
Service & other*	579,537	809,476	8,280	8,964	684	4,339	-3,659	-1,058	-2,601
Business & Repair	135,195	294,238	1,554	2,852	1,298	814	483	1,013	-530
Entertainment & Rec.	29,393	49,117	392	601	209	205	3	57	-54
Professional	658,804	1,172,129	1,265	955	-310	663	-974	322	-1,296
State and Local Gov.	763,256	1,198,151	12,499	16,326	3,827	6,550	-2,729	566	-3,295
health	208,892	399,900	3,673	5,784	2,111	1,925	184	1,432	-1,248
education	328,564	516,847	6,120	7,712	1,592	3,207	-1,618	297	-1,915
government	225,800	281,404	2,706	2,830	124	1,418	-1,295	-753	-542
Total Employment	4,141,529	6,311,845	56,559	73,365	16,806	29,639	-12,860	-27	-12,833

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.

Table 3 - 9 Shift-Share Analysis, Mclennan County, 1980 - 1986

INDUSTRY	Texas # Employed		Mclennan County # Employed		Absolute change	Share	Total Shift	Industrial Shift	Regional Shift
	1980	1986	1980	1986					
Agriculture	56,500	65,201	423	520	97	71	26	-6	32
Mining	219,456	247,799	154	144	-10	26	-36	-6	-30
Construction	416,760	426,312	3,769	3,989	220	631	-411	-545	134
Manufacturing	1,022,974	974,691	16,005	15,799	-206	2,681	-2,887	-3,437	549
Transp. Comm. & Public Utilities	324,420	354,280	3,050	3,157	107	511	-404	-230	-174
Trade	1,410,800	1,689,822	16,939	18,977	2,038	2,838	-800	512	-1,312
FIRE	310,881	431,012	3,812	4,592	780	639	141	834	-693
Service & Other	881,703	1,238,695	11,224	15,007	3,783	1,880	1,903	2,664	-761
Government	958,911	1,113,109	8,772	9,261	489	1,469	-980	-59	-922
TOTAL EMPLOYMENT	5,602,405	6,540,921	64,148	71,446	7,298	10,746	-3,448	0	-3,448

Source: Texas Employment Commission, Covered Employment
and Wages by Industry and County. January, First Quarter 1980, 1986.

Table 3 - 11 Shift-Share Analysis, Bosque County, 1980 -86

INDUSTRY	Texas # Employed		Bosque County # Employed		Absolute change	Share	Total Shift	Industrial Shift	Regional Shift
	1980	1986	1980	1986					
Agri., Fisheries, Forestry	56,500	65,201	126	133	7	21	-14	-2	-12
Mining	219,456	247,799	NA	8	NA	NA	NA	NA	NA
Construction	416,760	426,312	40	94	54	7	47	-6	53
Manufacturing	1,022,974	974,691	814	650	-164	136	-300	-175	-126
Transp. Comm. & Public Utilitie	324,420	354,280	130	121	-9	22	-31	-10	-21
Trade	1,410,800	1,689,822	628	923	295	105	190	19	171
FIRE	310,881	431,012	103	166	63	17	46	23	23
Service & Other	881,703	1,238,695	562	595	33	94	-61	133	-195
Government	958,911	1,113,109	637	478	-159	107	-266	-4	-261
TOTAL EMPLOYMENT	5,602,405	6,540,921	3,040	3,168	128	509	-381	0	-381

Source: Texas Employment Commission, Covered Employment and Wages by Industry and County. January, First Quarter 1980, 1986.

Table 3 -10 Shift-Share Analysis, Bosque County 1970-1980

INDUSTRY	Texas # Employed 1970	Texas # Employed 1980	Bosque County # Employed 1970	Bosque County # Employed 1980	Absolute change	Share	Total Shift	Industrial Shift	Regional Shift
Agri., Fisheries, Forestry	194,635	187,178	686	578	-108	360	-468	-386	-82
Mining	103,075	209,617	62	31	-31	33	-64	32	-95
Construction	317,758	545,450	440	700	260	231	29	84	-55
Manufacturing	765,119	1,129,267	876	1,071	195	459	-264	-43	-222
Transp.Comm. & Pub. Ut.	286,195	476,436	222	356	134	116	18	31	-14
Trade	918,693	1,378,408	748	927	179	392	-213	-18	-195
FIRE	213,261	379,862	182	252	70	95	-25	47	-72
Service & other*	579,537	809,476	438	479	41	230	-189	-56	-133
Business & Repair	135,195	294,238	104	134	30	55	-25	68	-92
Entertainment & Rec.	29,393	49,117	33	16	-17	17	-34	5	-39
Professional	658,804	1,172,129	46	40	-6	24	-30	12	-42
State and Local Gov.	763,256	1,198,151	679	984	305	356	-51	31	-82
health	208,892	399,900	320	456	136	168	-32	125	-157
education	328,564	516,847	181	369	188	95	93	9	84
government	225,800	281,404	178	159	-19	93	-112	-50	-63
Total Employment	4,141,529	6,313,845	4,333	5,378	1,045	2,273	-1,228	0	-1,228

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.

Table 3 - 11 Shift-Share Analysis, Bosque County, 1980 -86

INDUSTRY	Texas # Employed 1980	Texas # Employed 1986	Bosque County # Employed 1980	Bosque County # Employed 1986	Absolute change	Share	Total Shift	Industrial Shift	Regional Shift
Agri., Fisheries, Forestry	56,500	65,201	126	133	7	21	-14	-2	-12
Mining	219,456	247,799	NA	8	NA	NA	NA	NA	NA
Construction	416,760	426,312	40	94	54	7	47	-6	53
Manufacturing	1,022,974	974,691	814	650	-164	136	-300	-175	-126
Transp. Comm. & Public Utilitie	324,420	354,280	130	121	-9	22	-31	-10	-21
Trade	1,410,800	1,689,822	628	923	295	105	190	19	171
FIRE	310,881	431,012	103	166	63	17	46	23	23
Service & Other	881,703	1,238,695	562	595	33	94	-61	133	-195
Government	958,911	1,113,109	637	478	-159	107	-266	-4	-261
TOTAL EMPLOYMENT	5,602,405	6,540,921	3,040	3,168	128	509	-381	0	-381

Source: Texas Employment Commission, Covered Employment and Wages by Industry and County. January, First Quarter 1980, 1986.

Bosque County

In Bosque County, from 1970 - 80, employment in three of the fifteen industrial sectors increased faster than the state average, those industries were Construction, Transportation, Communications and Public Utilities (TCP), and Education (see Table 3 - 10). The remaining sectors grew slower than the state average. Growth in Construction and TCP industries was caused by industrial growth at the state level and was not the result of any regional advantage offered by Bosque County. Growth in the Education sector was caused primarily by local comparative advantages as well as by growth in the industry at the state level.

From 1980 - 86 three industries in Bosque County grew faster than the state average (see Table 3 - 11). They were Construction, Trade and FIRE. The remaining industries did not grow as quickly as the state average. Growth that occurred in Construction was not due to state wide industry expansion but rather to local comparative advantages found in the county. Growth in Trade and FIRE industries was caused by both statewide expansion in the industries and by comparative advantages found in the county.

3.4 ECONOMIC BASE ANALYSIS

3.4.1 Introduction

To analyze the economic base of the subject study area, the economy, in terms of employment, was classified into its basic (export) and nonbasic (service) components for two points in time, 1980 and 1986. U. S. Bureau of the Census 1980 employment data for nine major and six minor industrial sectors was used, as well as, Texas Employment Commission January 1986 employment data for nine industrial sectors. The results are shown in Tables 3 - 12, 3 - 13, 3 - 14 and 3 - 15.

Table 3 - 12 Location Quotients, Mclennan County, 1980

INDUSTRY	Texas Employment 1980	Mclennan Co. Employment 1980	Location Quotient	Employment Breakdown Service (#)	%	Basic (#)	%
Agri., Fisheries, Forestry	187,178	1,471	0.676	Service	100%	*	0%
Mining	209,617	168	0.069	Service	100%	*	0%
Construction	545,450	4,470	0.705	Service	100%	*	0%
Manufacturing	1,129,267	15,856	1.208	13,126	83%	2,730	17%
Transp. Comm. & Public Utilities	476,436	4,697	0.848	Service	100%	*	0%
Trade	1,378,408	16,688	1.042	16,022	96%	666	4%
FIRE	377,862	4,725	1.076	4,392	93%	333	7%
Service & Other	1,726,223	8,964	0.447	Service	100%	*	0%
Business & Repair	294,238	2,852	0.834	Service	100%	*	0%
Entertainment & Recreation	49,117	601	1.053	571	95%	30	5%
Professional	131,342	955	0.626	Service	100%	*	0%
State and Local Government	1,198,151	16,326	1.172	13,927	85%	2,399	15%
Health	399,900	5,784	1.244	4,648	80%	1,136	20%
Education	516,847	7,712	1.284	6,008	78%	1,704	22%
Government	281,404	2,830	0.865	Service	100%	*	0%
TOTAL EMPLOYMENT	6,311,845	73,365					

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.
* Subcategory values are included in main category.

Table 3 - 13 Location Quotients, Mclennan County, 1986

INDUSTRY	Texas Employment 1986	Mclennan Co. Employment 1986	Location Quotient	Employment Breakdown			
				Service	%	Basic	%
Agriculture	65201	520	0.730	Service	100%	*	0%
Mining	247799	144	0.053	Service	100%	*	0%
Construction	426312	3989	0.857	Service	100%	*	0%
Manufacturing	974691	15799	1.484	10,646	67%	5,153	33%
Transp. Comm. & Public Utilites	354280	3157	0.816	Service	100%	*	0%
Trade	1689822	18977	1.028	18,458	97%	519	3%
FIRE	431012	4592	0.975	Service	100%	*	0%
Service & Other	1238695	15007	1.109	13,530	90%	1,477	10%
State and Local Government	1113109	9261	0.762	Service	100%	*	0%
TOTAL EMPLOYMENT	6,540,921	71,446					

Source: Texas Employment Commission, January, First Quarter 1986.

Table 3 - 14 Location Quotients, Bosque County, 1980

INDUSTRY	Texas Employment 1980	Bosque Co. Employment 1980	Location Quotient	Employment Breakdown			
				Service (#)	%	Basic (#)	%
Agri., Fisheries, Forestry	187,178	578	3.624	159	28%	419	72%
Mining	209,617	31	0.174	Service	100%	*	0%
Construction	545,450	700	1.506	465	66%	235	34%
Manufacturing	1,129,267	1,071	1.113	962	90%	109	10%
Transp. Comm. & Public Utilities	476,436	356	0.877	Service	100%	*	0%
Trade	1,378,408	927	0.789	Service	100%	*	0%
FIRE	377,862	252	0.783	Service	100%	*	0%
Service & Other	1,726,223	479	0.326	Service	100%	*	0%
Business & Repair	294,238	134	0.534	Service	100%	*	0%
Entertainment & Recreation	49,117	16	0.382	Service	100%	*	0%
Professional	131,342	40	0.357	Service	100%	*	0%
State and Local Government	1,198,151	984	0.964	Service	100%	*	0%
Health	399,900	456	1.338	341	75%	115	25%
Education	516,847	369	0.838	Service	100%	*	0%
Government	281,404	159	0.663	Service	100%	*	0%
TOTAL EMPLOYMENT	6,311,845	5,378					

Source: U.S Bureau of the Census, General Social and Economic Characteristics, 1970,1980. Tables 123,178.

* Subcategory values are included in main category.

Table 3 - 15 Location Quotients, Bosque County, 1986

INDUSTRY	Texas Employment 1986	Bosque Co. Employment 1986	Location Quotient	Employment Breakdown			
				Service (#)	%	Basic (#)	%
Agri., Fisheries, Forestry	65,201	133	4.212	32	24%	101	76%
Mining	247,799	8	0.067	Service	100%	*	0%
Construction	426,312	94	0.455	Service	100%	*	0%
Manufacturing	974,691	650	1.377	472	73%	178	27%
Transp. Comm. & Public Utilites	354,280	121	0.705	Service	100%	*	0%
Trade	1,689,822	923	1.128	818	89%	105	11%
FIRE	431,012	166	0.795	Service	100%	*	0%
Service & Other	1,238,695	595	0.992	Service	100%	*	0%
State and Local Government	1,113,109	478	0.887	Service	100%	*	0%
TOTAL EMPLOYMENT	6,540,921	3,168					

Source: Texas Employment Commission, January, First Quarter 1986.

Basic sectors are growth inducing industries which, through sales to non-local markets, bring new income into the area. Basic sector industries require support services such as business, advertisement and accounting services and thereby benefit the local economy in many ways. Such benefits include employment growth in service sectors and wages spent in the service sector.

For each basic unit of activity, whether measured in dollars or jobs, spin-off employment is created in the Service sector. A "multiplier effect" is created by the ratio of service employment to basic employment. The resulting ratio provides a rough estimate of induced growth or the number of service jobs created by each additional basic job. The service sector is dependent upon the growth of the export sector for expansion. It does not bring income into the region but redistributes income already in the region. The role of the service sector can be described as "city-maintaining", whereas the export or basic sector's role is that of "city-building".

The local economy must export enough goods and services to the rest of the economy to pay for its imports. While the precise ratio may prove difficult to determine, a certain proportion of an area's economic activity and employment must sell goods and services to outside markets. Non-basic activities by definition serve only the local market and are limited by the existing population size. There are only so many hamburgers and houses that can be sold in Bosque County at any given time. The export sector however, sells to outside markets and may expand independently of local growth conditions. Export industries are therefore critically important in determining the overall level of people and jobs that the local economy can support.

When one considers the factors which determine a locality's ability to attract new basic activity, the argument can be made that long term prosperity and maintenance of a viable export base is dependent on the nonbasic services that the locality can offer to prospective entrepreneurs (Watkins, 1980). If this argument is correct, then growth in Service and especially in FIRE industries is of particular importance to the locality.

Of further importance is the question of "unearned wealth" found in areas impacted by federal spending programs and other interregional transfers of wealth (retirement cities or university towns for example). In such situations "unearned" income, not exports, constitutes the major source of growth. The significance of this point is that the " greater the amount of 'unearned' income flowing into or out of a community, the less applicable is the basic-nonbasic concept" (Blumenfield, 1955).

3.4.2 Methodology

The most direct way of measuring the local export base is to conduct business surveys to determine which sectors sell primarily to outside markets. Because of the expense such information is rarely available; therefore, less direct methods of classifying the basic sectors of the economy must be used. The methodology used in this document consists of a ratio (known as location quotients) between the percent of local industry employment and the percent of state employment in the industry. If the ratio is higher than one, the industry is considered basic, a ratio of one indicates self-sufficiency; if the ratio is less than one the region requires imports.

Location quotients are best used when the study region reflects the benchmark economy. The smaller, more relevant the benchmark is, the better the analysis; for this reason, Texas is used as the benchmark economy rather than the U.S. economy.

The methodology has some faults. One major flaw is the assumption that demand is constant and does not vary by region. For example in a region with an unusually high internal need for product X, location quotients would classify the supposed surplus as basic or export, when actually the difference is the manifestation of higher demand. Another drawback is that the inherent form of the industry is not taken into account. For example: although high-tech industry is inherently a basic industry, only that employment proportion which is higher than the benchmark's proportion would be considered basic. Despite its faults, location quotients are a relatively simple way to understand economic patterns within a region.

3.4.3 Economic Base Analysis Results

McLennan County

Table 3 - 12 shows 1980 location quotients and the proportionate breakdown of service and export employment by industrial employment sector for McLennan County. Of the fifteen employment sectors, nine were service industries whose products were absorbed by the local market. The six export industries were: Manufacturing, Trade, FIRE, Entertainment & Recreation (a subsector of the Service industry), Government and two of its subsectors Health and Education. The export sectors with the highest proportion of export employment were: Manufacturing (17%) and the subcategories Health (20%) and Education (22%). Of interest is the fact that FIRE as well the Service subcategory of Entertainment & Recreation were classified as export industries (7% and 5% respectively). This means that the proportion of total employment in those sectors was higher than the average for Texas. The percentage of employment higher than the state average is the proportion of employment that is considered export. Because McLennan County has a relatively large number of universities and adult education institutions, is located between two major cities (Austin and Dallas) and bisected by major transportation routes, it is not surprising to find that Entertainment & Recreation is to some degree an export industry.

As shown in Table 3 - 13 in 1986 three industrial sectors in McLennan County were export industries. Those industries were Manufacturing (33% of its employment is export), Trade (3%) and Service (10%).

Bosque County

As shown in Table 3 - 14 in 1980 four of the fifteen employment sectors in Bosque County were export industries. Those sectors were Agriculture, Construction, Manufacturing and a subcategory of Government, Health. The export employment proportion for Agriculture is 72% , Construction 34%, Manufacturing 10% and Health 25%.

As shown in Table 3 - 15 in 1986 three of Bosque County's nine industrial sectors were export. Those sectors are Agriculture (76%), Manufacturing (27%) and Trade(11%). The other sectors were oriented solely to the local market.

3.5 INCOME ANALYSIS

3.5.1 Introduction

An analysis of income distribution in Bosque County and McLennan County is presented in this section. Texas was used as the benchmark with which to compare county income distribution. Income data was drawn from the U.S. Bureau of the Census for 1970 and 1980. The method of analysis side-steps the problem of inflation as the results are a relative measure not an absolute measure of the proportional distribution of the population within five designated income brackets or quintiles.

The 1980 census collected income data for households, families and unrelated individuals as separate categories while the 1970 census collected data primarily for the family unit. The result is that for areas with a proportionally large number of unrelated individuals (universities, military bases, state hospitals, etc...) comparisons between 1970 and 1980 data must take those sampling differences into account. Therefore, in this report only income data collected for families was analyzed.

3.5.2 Methodology

To analyze the income distribution within the study area two steps were taken. First, the relationship of each county to the state was assessed with respect to household-income distribution at two specific points in time, 1970 and 1980. Second, the 1970 profile of each county was contrasted with its respective 1980 profile to identify changes and possible trends in the composition of the counties.

To accomplish the first step, all households in Texas were separated into five equal groups, or quintiles, by annual income level for 1970 and 1980. Each quintile contains 20% of families in Texas. The income limits of each quintile were calculated to define income sectors. These sector limits were then applied to the families in each county, following which, the approximate number of families earning incomes within each sector was calculated. The number of families in each sector was then converted to a percentage. The resultant percentage figure indicates the share of each county's population within each income sector defined for the state. For example, a figure of 30% for a county would indicate that 10% more of the families in that county have income in that particular quintile than the average for the state (30%-20%=10%).

The second step of the analysis involved identifying changes and possible trends within each county. To accomplish this, the percentage of households within each sector during 1970 was compared with its counterpart for 1980. Both the size and direction of any changes were noted in order to detect significant growth or decline in any particular sector. Finally, the overall change of all the sectors within each county was assessed to identify any possible trends in the income composition of the county.

3.5.3 Income Analysis Results

Five income brackets (quintiles) each containing 20% of all Texas families for 1980 and 1970 are shown in Table 3 - 16.

Table 3 - 16

Texas Income Quintile Distribution

Quintiles	1980	1970
Q1	0 - $9,391	0 - $4,120
Q2	$9,392 - $16,204	$4,121 - $7,094
Q3	$16,205 - $23,244	$7,095 - $9,996
Q4	$23,245 - $33,114	$9,997 - $14,120
Q5	$33,114 +	$14,121+
	median income $19,618	median income $8,490

Source: Paul Price Associates. U.S. Bureau of the Census, 1970 and 1980.

Income quintiles for McLennan County and Bosque County families for 1980 and 1970 are shown in Table 3 - 17. Listed is the distribution of county families per quintile for 1970 and 1980. For example: Twenty-four percent of McLennan County families were in the lowest quintile income category for Texas, 4% more than the state average (24%-20%= 4%). Figures 3 - 1 and 3 - 2 graphically display the data from Table 3 - 17. Figures 3 - 3 and 3 - 4 display the percentile difference between the proportion of county families and Texas families in each income quintile for 1970 and 1980. As can be seen, in comparison to the state average, both counties have a very high proportion of low income families.

Table 3 - 17

Family Income Distribution by County for 1970 and 1980

	McLennan County			Bosque County	
Quintiles	1980	1970	Quintiles	1980	1970
Q1	24%	23%	Q1	28%	36%
Q2	23%	21%	Q2	26%	24%
Q3	21%	22%	Q3	21%	17%
Q4	18%	19%	Q4	15%	13%
Q5	14%	15%	Q5	9%	10%

Source: Paul Price Associates.

Figure 3 - 1. Study Area Income Distribution 1980

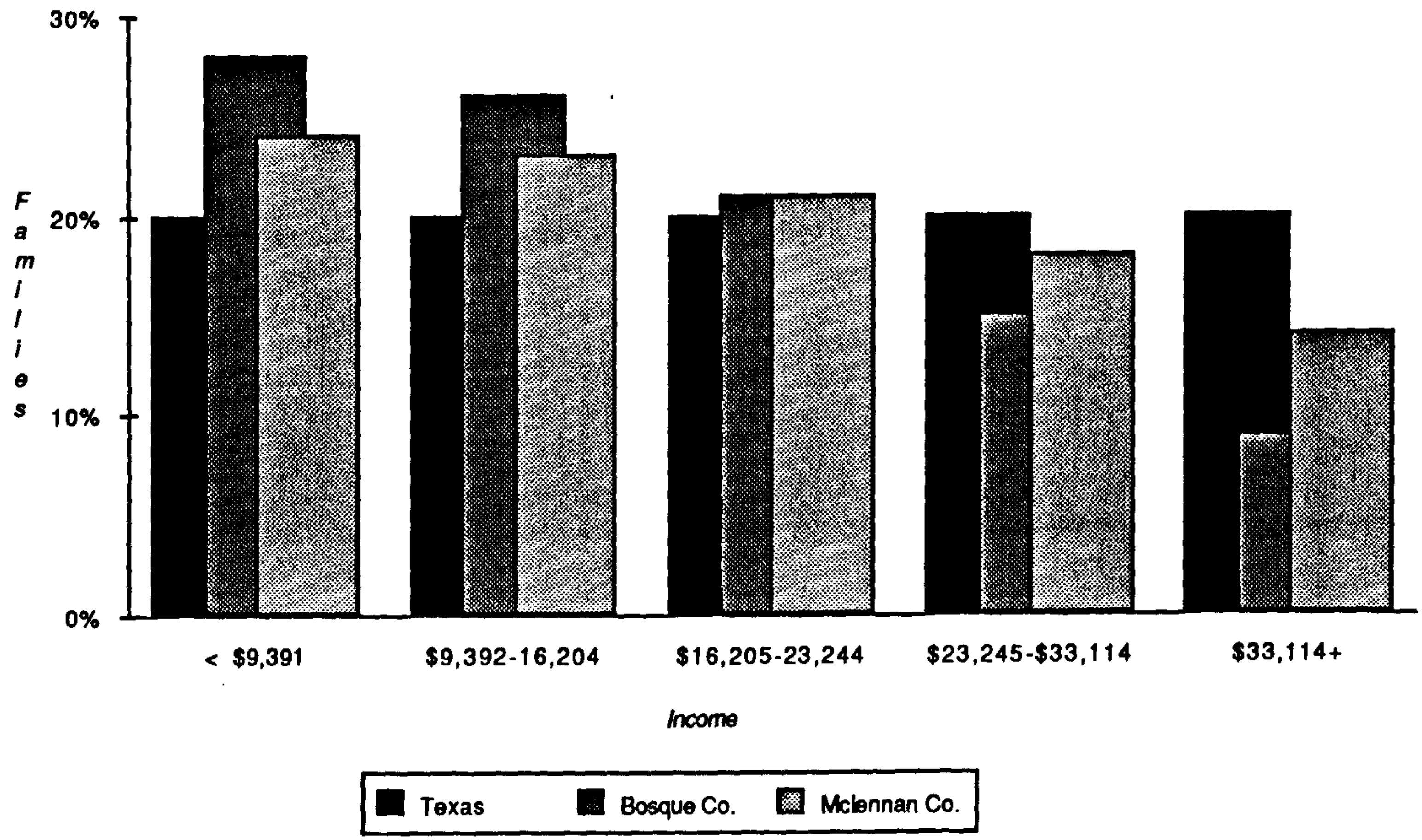
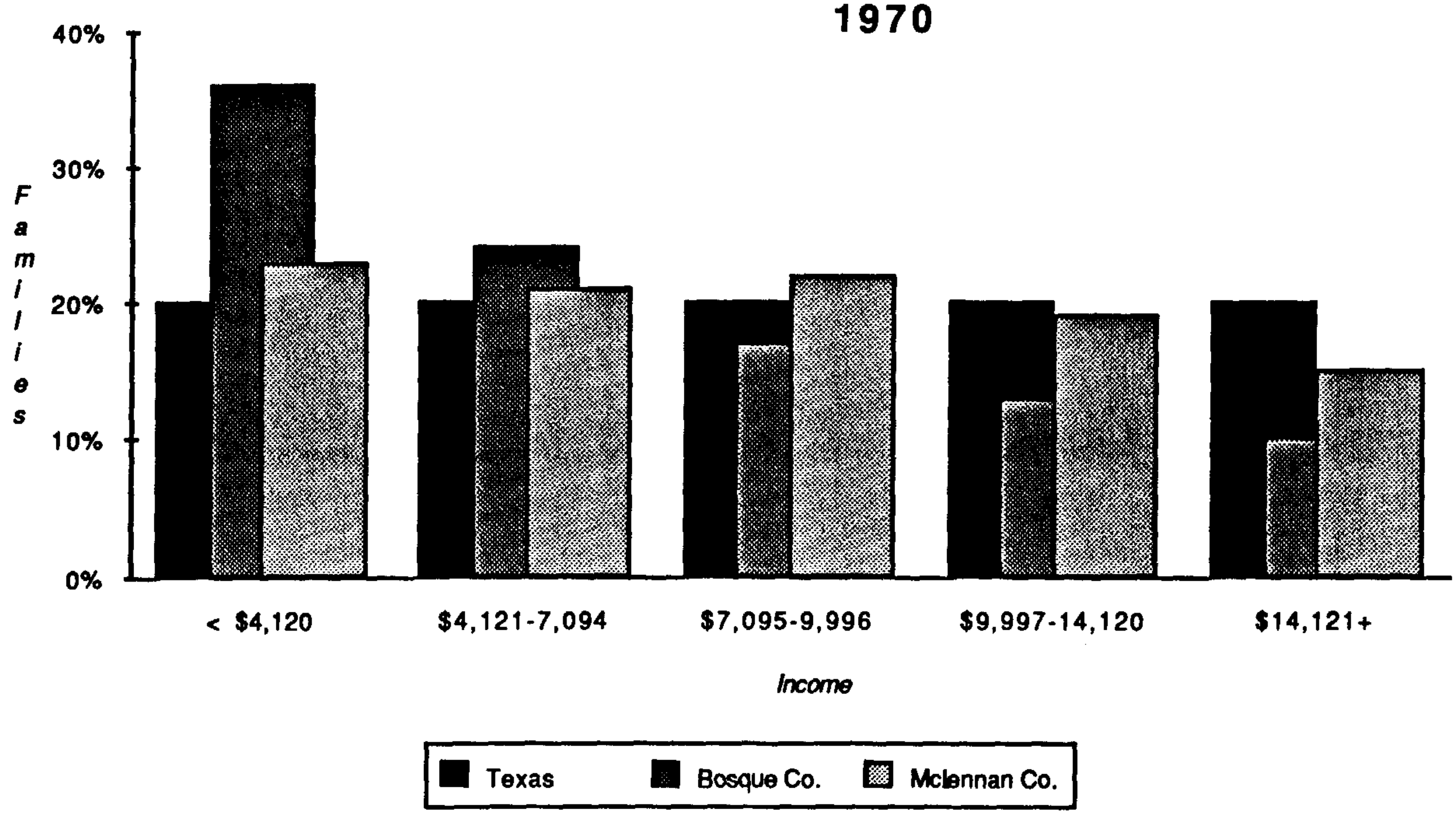


Figure 3 - 2.
Study Area Income Distribution
1970



McLennan County

In 1970 and 1980 the proportion of McLennan County families in the three lower income quintiles (Q1, Q2, Q3) was consistently higher than the Texas average (see Figure 3 - 3). Inversely the proportion of families in the two highest quintiles was for both time periods lower than the Texas average. Of significance is the fact that the income distribution pattern has not improved over time but has deteriorated. From 1970 to 1980 the proportion of families in the two lowest income brackets increased while the proportion in the three highest brackets decreased. In short, from 1970 - 1980, the county gained additional low income families and lost wealthy and middle income families.

Bosque County

As shown in Figure 3 - 4 income distribution in Bosque County in 1970 and 1980 was skewed in the direction of poverty. In 1970, 36% of all families were in the lowest income bracket (Q1), approximately 16% more than the state average (see Figure 3 - 4). Sixty percent of all Bosque County families occupied the two lowest income brackets. The proportion of families in the three highest income brackets (Q5, Q4, Q3) was much lower than the state average.

By 1980 the situation improved. The proportion of families in the lowest income quintile (Q1) decreased by one-half but was still 8% higher than the state average. The proportion of families in the lower-middle (Q2) and middle (Q3) quintiles increased, while families in the upper-middle (Q4) and upper income (Q5) quintiles increased slightly or remained fairly stable. In short, family income in Bosque County improved during the 1970s, but by 1980 the county was still characterized by a higher proportion of lower income families than the state average.

Figure 3 - 3: Income Comparison for Texas and Mclennan County - 1970, 1980

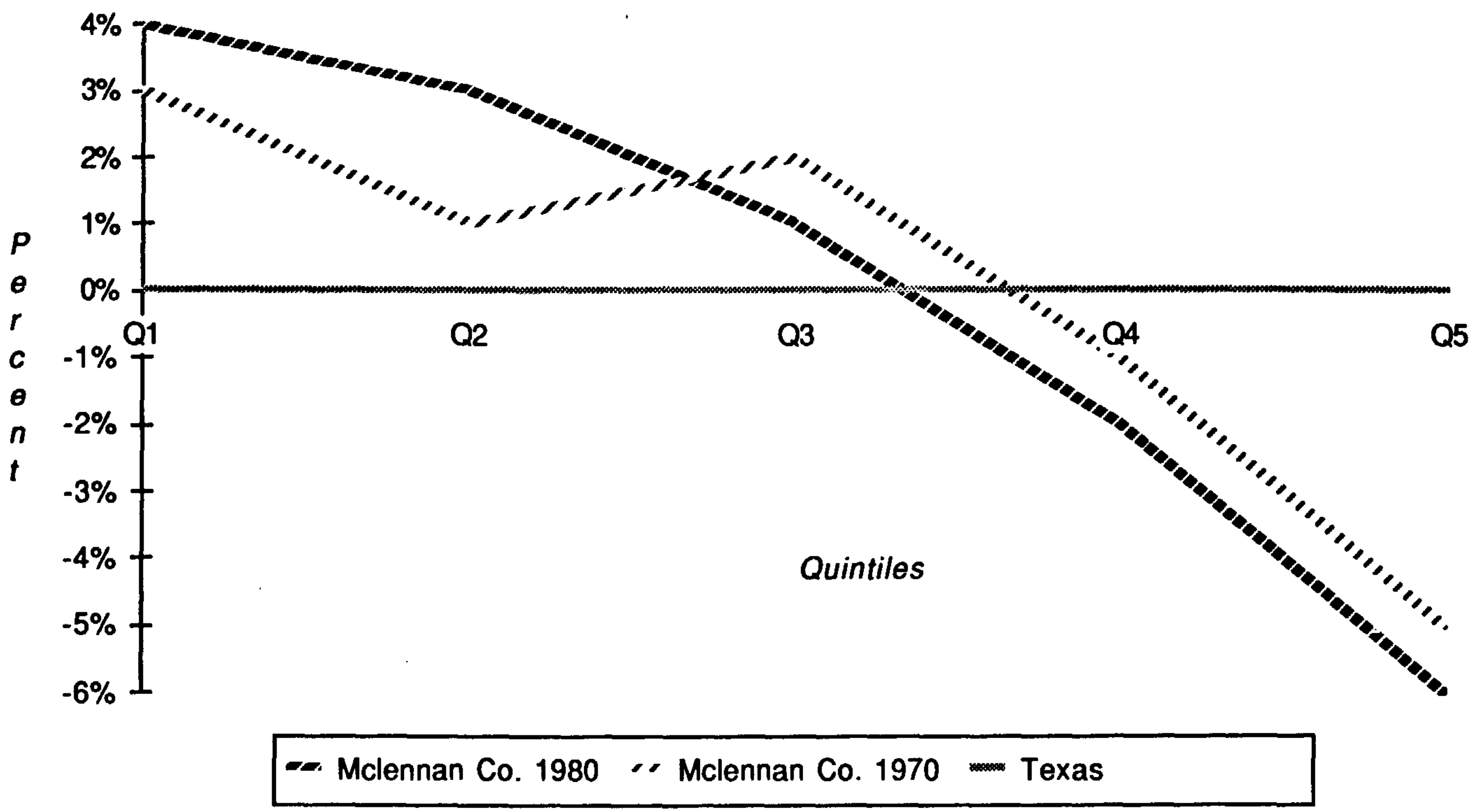
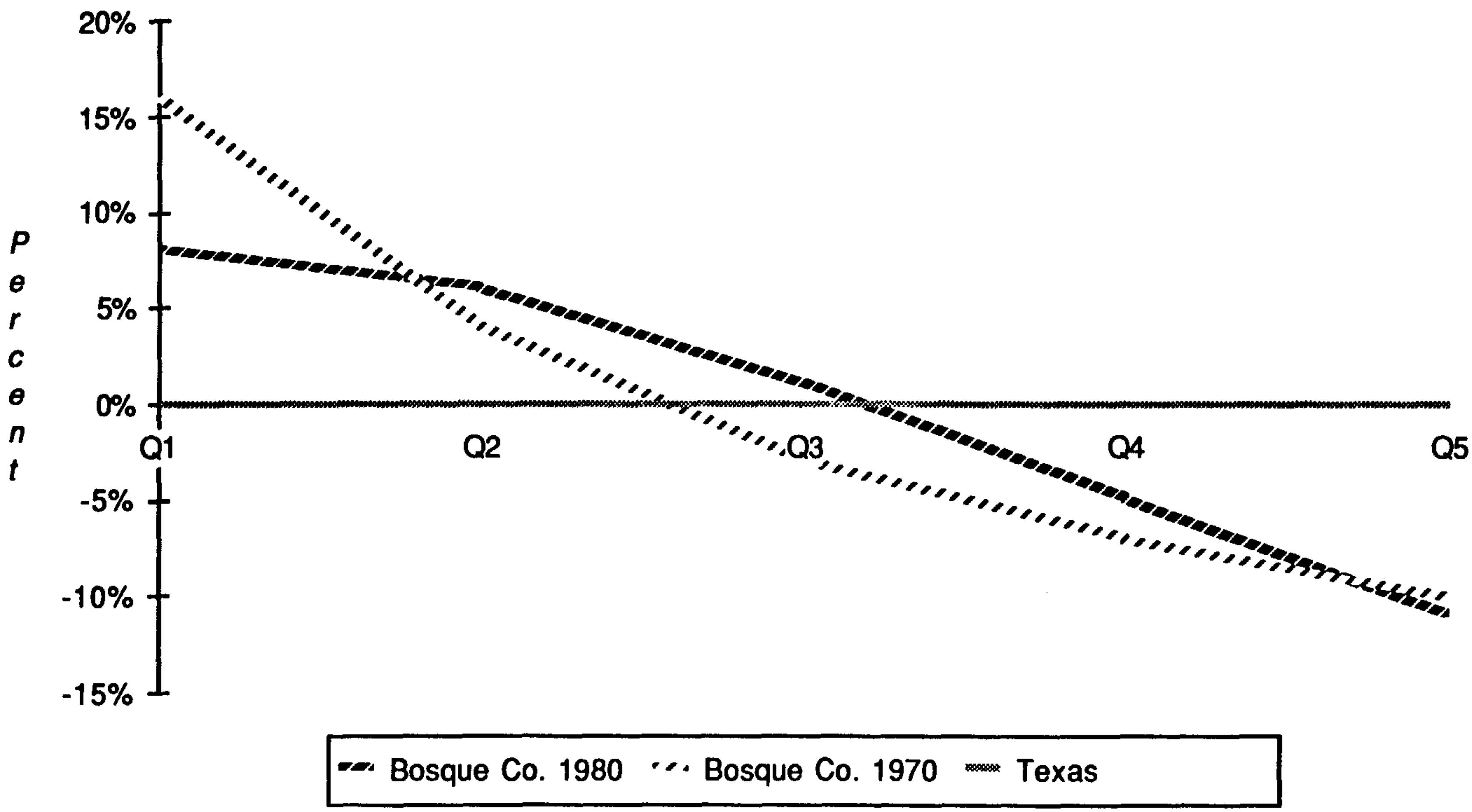


Figure 3 -4: Income Comparison for Texas and Bosque County - 1970, 1980



4.0 COMMUNITY SERVICES AND FACILITIES

4.1 INTRODUCTION

This section provides a baseline from which to judge the current level and future capability of community services and facilities in Bosque and McLennan Counties to absorb growth. Reported are statistics concerning educational services, public safety services and health services and facilities. Estimated is the amount of school taxes lost from the removal of land from school tax roles for the construction of the proposed Lake Bosque. Provided in this section is a summary of water and wastewater treatment statistics for project participating cities, and projections of future water demands for the proposed Lake Bosque. Also included in this section is a summary of transportation elements in the study area, include are: traffic counts for Bosque County roads and air and railroad services to the proposed Lake Bosque. Housing information detailing study area vacancy rates and market composition is provided.

4.2 EDUCATION

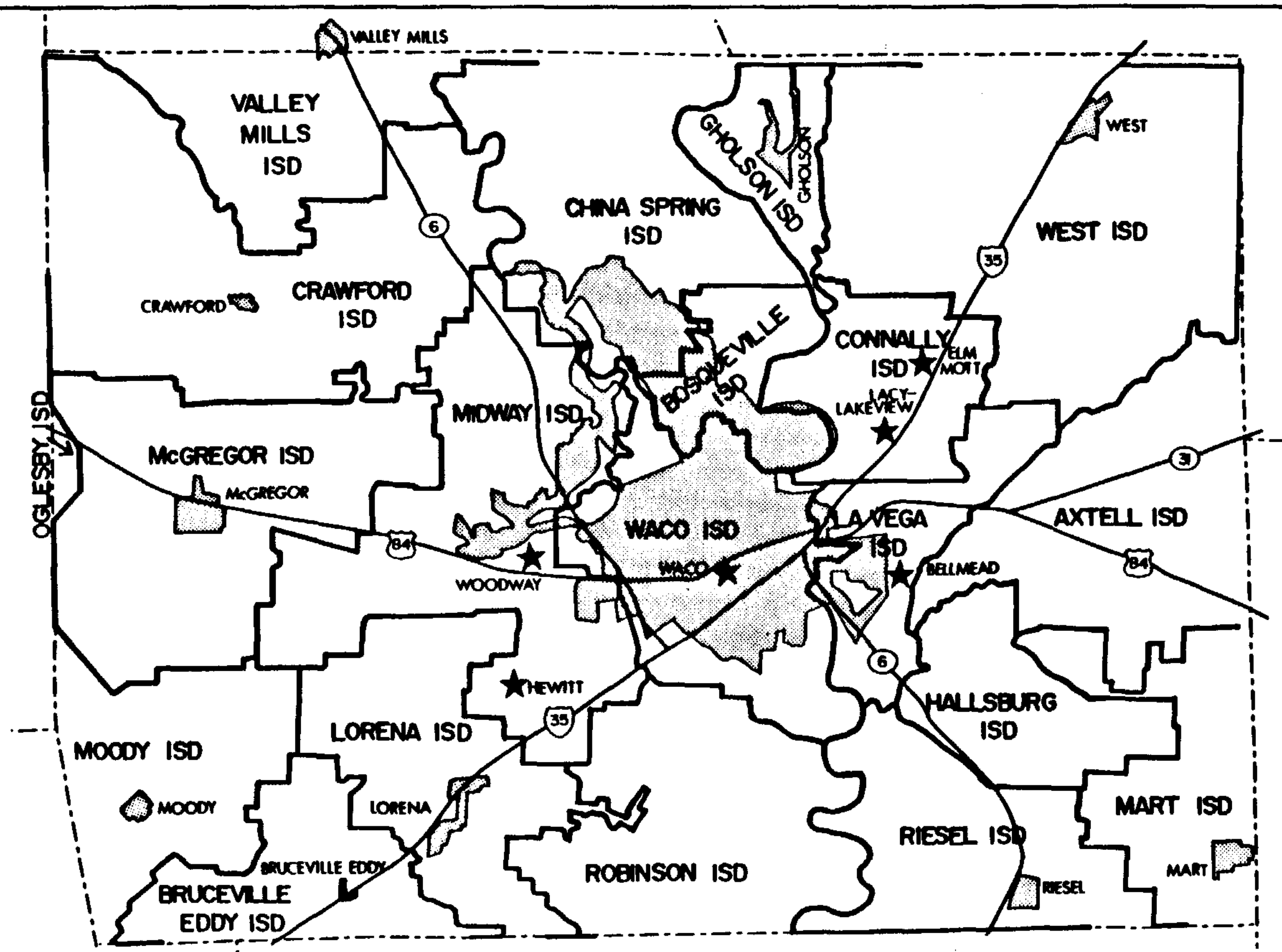
Independent school districts (ISDs) within the study area are listed in Table 4 - 1. Also shown are 1985 - 86 student to teacher ratios, total enrollment, number of teachers and expenditures per student. The location and geographic boundaries of each ISD are shown in Figures 4 - 1 and 4 - 2. Enrollment for 1985 - 1986 ranged from 15,182 in the Waco ISD to 113 in the Hallsburg District. Student-teacher ratios varied from 21.8 students per teacher in the Lorena ISD to 9.8 students per teacher in the Axtel ISD. Expenditures ranged from $5,022 per pupil in the Axtel ISD to $1,929 in the Lorena ISD.

Table 4 - 2 lists the operating tax rates for the three ISDs whose tax rolls will be reduced (due to lost property valuations) if the proposed Lake Bosque is built. The tax rate cannot exceed $1.50 per $100 valuation per Section 20.04 of the Texas Education Code unless specifically authorized by special legislative act. The three ISDs which will lose part of their tax base if Lake Bosque is built are: Walnut

Table 4 - 1. Bosque, McLennan County ISD Education Statistics, 1985 - 1986

County/ISD (1985 - 1986)	Enrollment	Teachers	Student/Teacher Ratio	Expenditures per Student
McLennan County				
Axtell	781	80	9.8	$5,022
Bosqueville	307	16	19.2	$2,309
Bruceville-Eddy	520	27	19.3	$2,476
China Spring	868	48	18.1	$2,205
Connally	2,389	117	20.4	$2,451
Crawford	343	20	17.2	$2,689
Gholson	160	6	26.7	$2,515
Hallsburg	113	8	14.1	$3,805
La Vega	2,398	118	20.3	$2,752
Lorena	936	43	21.8	$1,929
Mart	755	47	16.1	$2,670
McGregor	1,188	68	17.5	$2,809
Midway	5,026	237	21.2	$2,357
Moody	599	35	17.1	$2,847
Riesel	458	27	17.0	$2,407
Robinson	1,800	91	19.8	$2,160
Waco	15,182	879	17.3	$3,144
West	1,176	57	20.6	$2,053
County Totals	34,999	1,924	18.2	$2,790
Bosque County				
Clifton	948	52	18.2	$2,613
Cranfills Gap	156	14	11.1	$3,948
Iredell	155	12	12.9	$4,472
Kopperl	227	13	17.5	$3,357
Meridian	466	27	17.3	$3,071
Morgan	145	14	10.4	$4,089
Valley Mills	505	31	16.3	$3,066
Walnut Springs	190	15	12.7	$3,154
County Totals	2,792	178	15.7	$3,125

Source: Texas Education Agency, 1986.



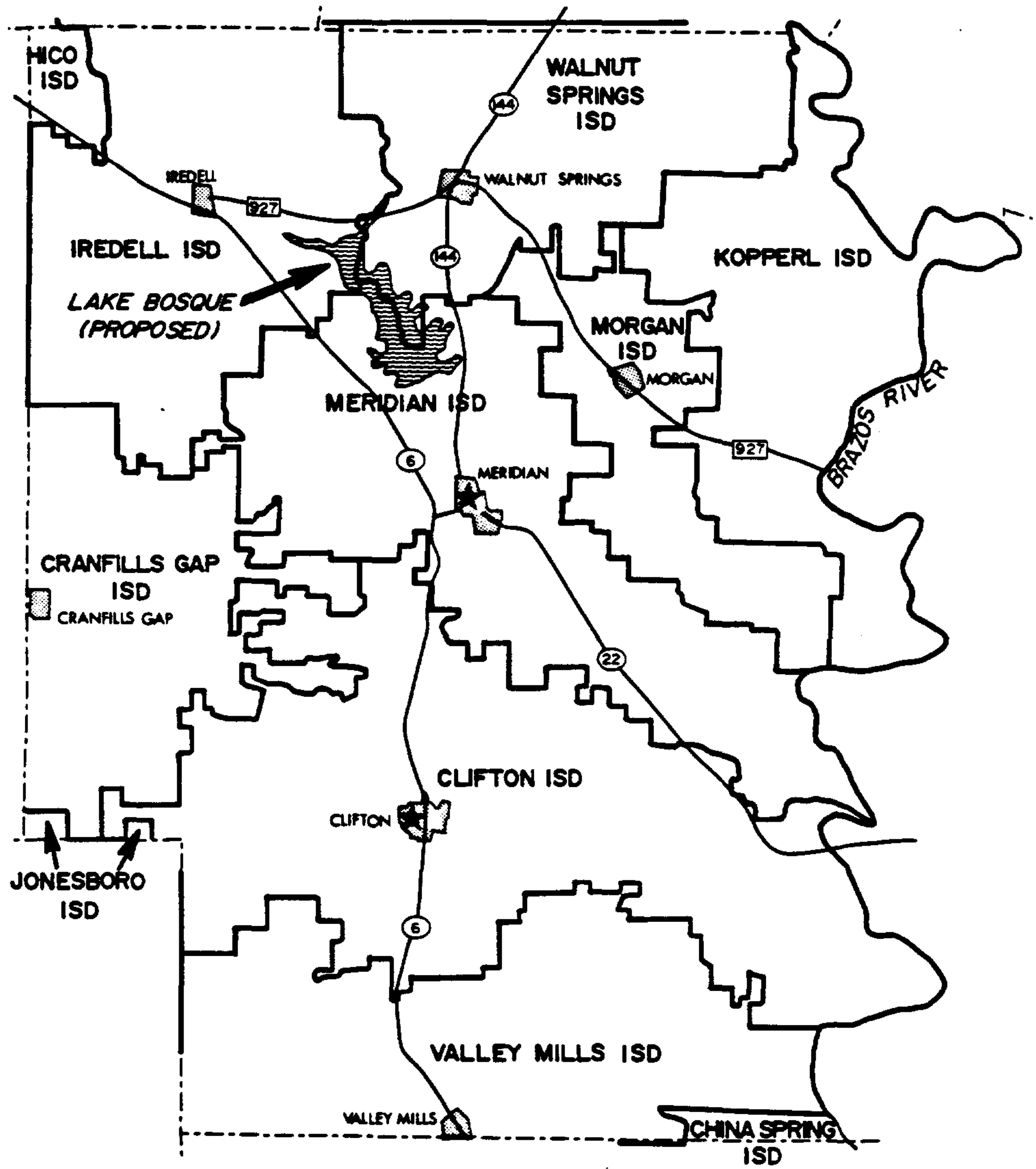
PAUL PRICE ASSOCIATES, INC.

Figure 4-1

McLennan County I.S.D. Boundaries

★ PROJECT PARTICIPATING COMMUNITIES

source: Texas Education Agency



PAUL PRICE ASSOCIATES, INC.

★ PROJECT PARTICIPATING COMMUNITIES

Figure 4-2

Bosque County I.S.D. Boundaries

source: Texas Education Agency

Springs, Iredell and Meridian. As shown in Table 4 - 2 the existing tax rate for each school district ranges from 40% to 55% of the allowable $1.50 tax rate. The percent of net ISD taxes accrued from the proposed Lake Bosque site ranges from 2.40% to 3.86% of each ISD's tax revenue.

Table 4 - 2

Independent School District Tax Rates, Budget Year 1986

ISD	Tax Rate	Remaining Margin	% of Net Taxes Attributed to Lake Bosque Site
Iredell	.834	$.67	3.71%
Meridian	.6484	$.85	2.40%
Walnut Springs	.607	$.89	3.86%

Source: Texas Education Agency, ISD Budgets 1986. Bosque County Appraisal District, 1986.

4.3 PUBLIC SAFETY

Table 4 - 3 lists the number of police officers, firemen and vehicles for the the study area's County Sheriff Departments and project participating municipalities. Standards for expanding populations estimate 2.1 police officers per 1,000 population as adequate protection (Golden et al., 1980). None of the municipalities satisfy that standard, although the police officer to population ratio for Woodway and Clifton at 1.97 is very close.

Fire protection in the study area is provided by volunteer and full-time paid firemen. Two full-time firemen per 1,000 population are recommended for expanding populations (Golden et al., 1980). As shown in Table 4 - 3, the ratio of firemen per 1,000 population for each project area municipality, except Waco, is higher than two, this is because volunteer firemen were included in the ratio calculation. Only Waco has a full-time paid fire department, Bellmead and Woodway have a combined volunteer and paid fire fighting department, while the remaining communities rely on volunteers for fire protection.

Table 4 - 3. Study Area Public Safety Statistics, Bosque and Mclennan Counties, 1986

County/City	Police Officers				Firemen		
	Police Personnel	1986* Population	per 1000 Population	Police Vehicles	Fire Personnel	per 1000 Population	Fire Vehicles
Mclennan County							
County Sheriff Δ	130	182,354	0.71	25	0	0.00	0
Bellmead	10	8,500	1.18	11	3 (p), 16 (v)	2.12	5
Hewitt	15	9,900	1.52	10	29 (v)	2.93	7
Lacy-lakevew	6	4,700	1.28	3	12 (v)	2.55	5
Mclennan Co. WCID # 2 (Elm Mott)	0	1,600	0.00	0	16 (v)	10.00	4
Waco	161	104,133	1.55	40	168	1.61	34
Woodway	14	7,091	1.97	10	22 (o), 30 (v)	7.76	4
Bosque County							
County Sheriff Δ	18	15,132	1.19	4	0	0.00	0
Clifton	6	3,067	1.96	3	28 (v)	9.13	9
Meridian	1	1,330	0.75	1	24 (v)	18.05	6

Source: Municipality Fire and Police Departments, County Sheriff Department, 1986.
Note: (p) Paid, (v) Volunteer, (o) Police Officers doubling as Firemen, (Δ) Includes jailors, dispatchers and reserve officers. * 1986 TDH population estimate.

4.4 HEALTH SERVICES AND FACILITIES

As shown in Table 4 - 4, the two county study area contains eight hospitals and 1,995 beds. McLennan County's ratio of 10.37 beds per 1,000 population is twice as high as the recommended 5 per 1,000 population (Golden et al., 1980). This is due to the presence of a federal Veterans Administrative hospital which accounts for more than one-half of the county's inventory of hospital beds. Bosque County's ratio of beds to population is also higher than the recommended ratio. The recommended standard for counties of 0.7 physicians per 1,000 population is exceeded in both counties (Golden et al., 1980).

4.5 EXISTING WATER AND WASTEWATER TREATMENT FACILITIES

Water and wastewater system data, for 1986, collected by the Texas Department of Health is shown in Table 4 - 5. Included in the table is the estimated population serviced by the system, number of connections, total water production, average daily consumption, total storage capacity, auxiliary production capacity, the water source, number of wells (when applicable), and the date of inspection.

Each of the project participants maintains a water system and provides wastewater treatment services. Except the City of Waco, all the participants rely on Trinity ground water for water supplies. These communities do not have developed facilities for treating surface water.

Table 4 - 4. Medical Facilities and Personnel Statistics

	McLennan County	Bosque County
Hospitals		
Number	6	2
Beds	1891	104
Hospital Beds per 1,000 population*	10.37	6.87
Physicians		
Number	303	15
per 1,000 population*	1.66	0.99
Nurses		
Number licensed	714	105
per 1,000 population*	3.92	6.94

Source: Texas Department of Health, 1984 and 1986*.

Table 4 - 5. Municipal Water and Wastewater Treatment Statistics

City/Authority	System Classification	No. of Connections	Total Production (MGD)	Avg. Daily Consumption (MGD)	Total Storage Capacity (MGD)	No. of Wells and Water Source	Percent Committed
Clifton	Water & Sewer	1,533	1.634	0.459	0.619	5 Trinity	28%
Meridian	Water & Sewer	650	0.828	0.227	0.100	3 Trinity	27%
Bellmead	Water & Sewer	3,200	2.592	0.897	1.600	3 Trinity	35%
Hewitt	Water & Sewer	3,540	2.716	1.188	2.619	5 Trinity	44%
Lacy-Lakeview	Water & Sewer	1,605	2.009	0.592	0.550	2 Trinity	29%
Elm Mott (McLennan County WCID # 2)	Water & Sewer	530	1.337	0.176	0.300	2 Trinity	13%
Waco	Water & Sewer	37,164	66.000	24.324	21.645	0 Lake Waco	37%
Woodway	Water & Sewer	2,947	4.449	1.700	7.125	6 Trinty	38%

Source: Texas Department of Health. Water Hygiene Inventory,1986.

4.6 FUTURE WATER REQUIREMENTS

4.6.1 Introduction

To prevent a situation of unmet demand requiring additional capital investment, and possibly more serious consequences, water demand projections should allow for the highest reasonable population growth and per capita water demand. Reservoir firm-yield supplies should accommodate an upper limit as well as satisfy the minimum projected demand. For the Lake Bosque Project, this range begins with Paul Price Associates' water demand projection and is capped by a projection using the Texas Water Development Board's (TWDB) High Series population projection, high per capita demand and high manufacturing demand (see Figure 4-3). These population projections incorporate the Texas Water Development Board's (TWDB) February 1987 revised county population projections.

Paul Price Associates, Inc. (PPA) prepared their own projections to 2040 of the future water needs of the communities currently participating in the Lake Bosque Project, as well as projected future water needs of probable customer entities, rural county areas and manufacturing in the two county study area. This section provides a description of the methodology and results of the water demand projections prepared by Paul Price Associates for the Lake Bosque Project. A more detailed description, equations and tables showing decadel water demand projections, projected supply and sources for each consumer entity and user category is found in the Appendix. Tables 4 - 6 and 4 - 7 lists Paul Price Associates' total projected water demand and per capita water demand for each consumer category, i.e.: Municipal, Other, and Manufacturing. Table 4 - 8 lists Paul Price Associates' projected demand for each user category for the Lake Bosque Project.

Lake Waco has a dependable yield of 59,100 acre feet per year. A proposed enlargement (occurring in year 2000) would increase the Lake's yield by 20,100 acre feet. As shown in Figure 4 - 3, Lake Waco and the proposed enlargement would not sufficiently satisfy projected minimum total demand in

Table 4-6 Paul Price Associates Demand Projections							
Demand Categories	**1980**	**1990**	**2000**	**2010**	**2020**	**2030**	**2040**
Municipal Demand (MGD)							
Project Participants (excludes City of Waco)	4.60	6.90	7.79	7.95	8.68	9.09	9.85
Potential Customers	1.07	1.61	1.73	1.76	1.83	1.97	2.13
Total Municipal Demand	5.67	8.51	9.52	9.71	10.51	11.06	11.98
City of Waco	26.44	30.53	30.93	31.46	32.82	35.33	38.02
Total Municipal Demand including the City of Waco	32.11	39.04	40.45	41.17	43.33	46.39	50.00
Other Demand (MGD)							
Mclennan Co.	3.13	4.19	4.29	4.34	4.48	4.77	5.11
Bosque Co.	0.84	1.37	1.55	1.72	1.89	2.09	2.30
Total	3.97	5.56	5.84	6.06	6.37	6.86	7.41
Total Municipal and Other Demand							
(Includes the City of Waco)							
MGD	36.08	44.60	46.29	47.23	49.70	53.25	57.41
Acre-feet Per Year	40,415	49,959	51,852	52,905	55,671	59,648	64,308
Manufacturing Demand (MGD) (Low Demand)							
Mclennan Co.	3.55	5.26	7.35	9.63	12.48	15.70	19.76
Bosque Co.	0.08	0.10	0.12	0.12	0.18	0.22	0.28
Total	3.63	5.36	7.47	9.75	12.66	15.92	20.04
Total Muncipal, Other and Manufacturing Demand							
Including the City of Waco							
MGD	39.71	49.96	53.76	56.98	62.36	69.17	77.45
Acre-feet per Year	44,481	55,963	60,219	63,826	69,853	77,481	86,756
Excluding the City of Waco							
MGD	13.27	19.43	22.83	25.52	29.54	33.84	39.43
Acre-feet per Year	14,864	21,765	25,573	28,586	33,089	37,906	44,168

Source: Paul Price Associates Inc., The Texas Water Development Board
NOTE: Demand is based on TWDB Low Series population projections, TWDB High series per capita water demand ratios, and TWDB Low series Manufacturing demand projections.
Demand projections are based on TWDB February1978 population projection revisions.

Table 4 - 7. Per Capita Water Demand Summary

Demand Categories	1980	1990	2000	2010	2020	2030	2040
Municipal Per Capita Demand (GPD)							
Project Participants *(excludes City of Waco)*	162	184	187	187	187	187	187
Potential Customers	159	189	190	190	190	190	190
City of Waco	261	280	285	285	285	285	285
All Municipalites	235	252	254	254	254	254	254
Other Per Capita Demand (GPD)							
McLennan Co.	125	180	186	185	183	181	180
Bosque Co.	108	161	166	166	166	166	166

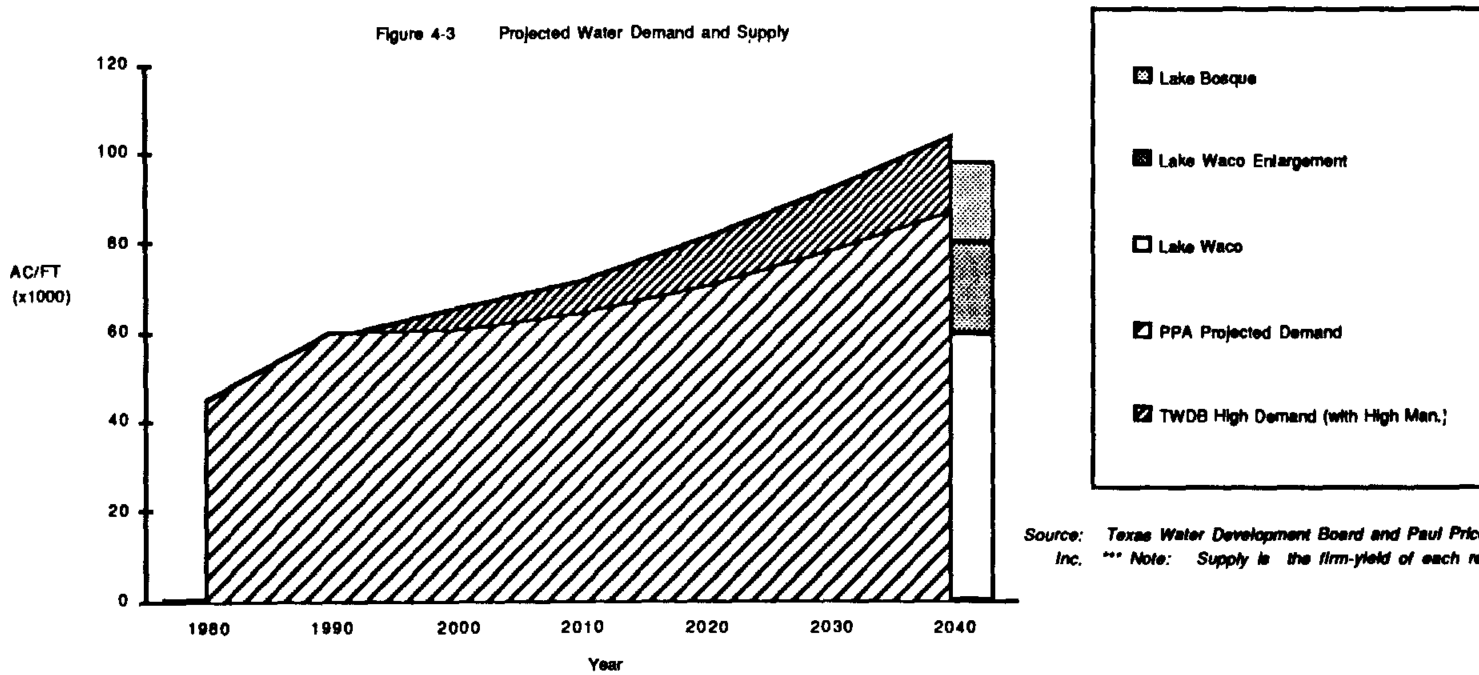
Source:
Texas Water Development Board, High Series Projections.
Note: Per Capita consumption rates are from the TWDB high series water demand projections.

Table 4-8 Projected Demand for Lake Bosque

Projected Demand for Lake Bosque 1990-2040	1990		2000		2010		2020		2030		2040	
	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD
Municipal Demand (Excludes City of Waco)												
Project Participants	6,831	6.10	7,777	6.94	7,907	7.06	8,680	7.75	9,138	8.16	10,203	9.11
Potential Customers	1,809	1.61	1,937	1.73	1,971	1.76	2.055	1.83	2,208	1.97	2,381	2.13
Total Municipal Demand	8,640	7.71	9,190	8.20	9,878	8.82	10,735	9.58	11,346	10.13	12,584	11.23
Other Demand												
McLennan County	4,146	3.70	4,263	3.81	4,320	3.86	4,475	4.00	4,799	4.28	5,176	4.62
Bosque County	24	0.02	108	0.10	356	0.32	634	0.57	1,424	1.27	1,663	1.48
Total Other Demand	4,170	3.72	4,371	3.90	4,676	4.17	5,109	4.56	6,223	5.56	6,838	6.10
Manufacturing Demand												
McLennan County												
High Series	5,825	5.20	8,744	7.81	11,921	10.64	6,259	5.59	0	0.00	5,613	5.01
Low Series	5,400	4.82	7,801	6.96	10,412	9.30	4,037	3.60	-3,025	-2.70	1,515	1.35
Bosque County												
High Series	0	0.00	148	0.13	186	0.17	233	0.21	288	0.26	356	0.32
Low Series	-4	-0.0036	137	0.12	168	0.15	206	0.18	252	0.22	308	0.28
Total Bi-County Manufacturing Demand												
High Series	5,825	5.20	8,892	7.94	12,107	10.81	6,492	5.80	288	0.26	5,969	5.33
Low Series	5,396	4.82	7,938	7.09	10,580	9.45	4,243	3.79	-2,773	-2.48	1,824	1.63
Total Demand for Lake Bosque												
Municipal, Other, High Manufacturing	18,635	16.64	22,453	20.04	26,661	23.80	22,336	19.94	17,857	15.94	25,391	22.67
Municipal, Other, Low Manufacturing	18,206	16.25	21,499	19.19	25,134	22.44	20,087	17.93	14,796	13.21	21,246	18.97

Source:
Paul Price Associates, Inc.
Texas Water Development Board
Revised Population Projections 2/1987

Figure 4-3 Projected Water Demand and Supply



*Source: Texas Water Development Board and Paul Price Associates Inc. *** Note: Supply is the firm-yield of each reservoir.*

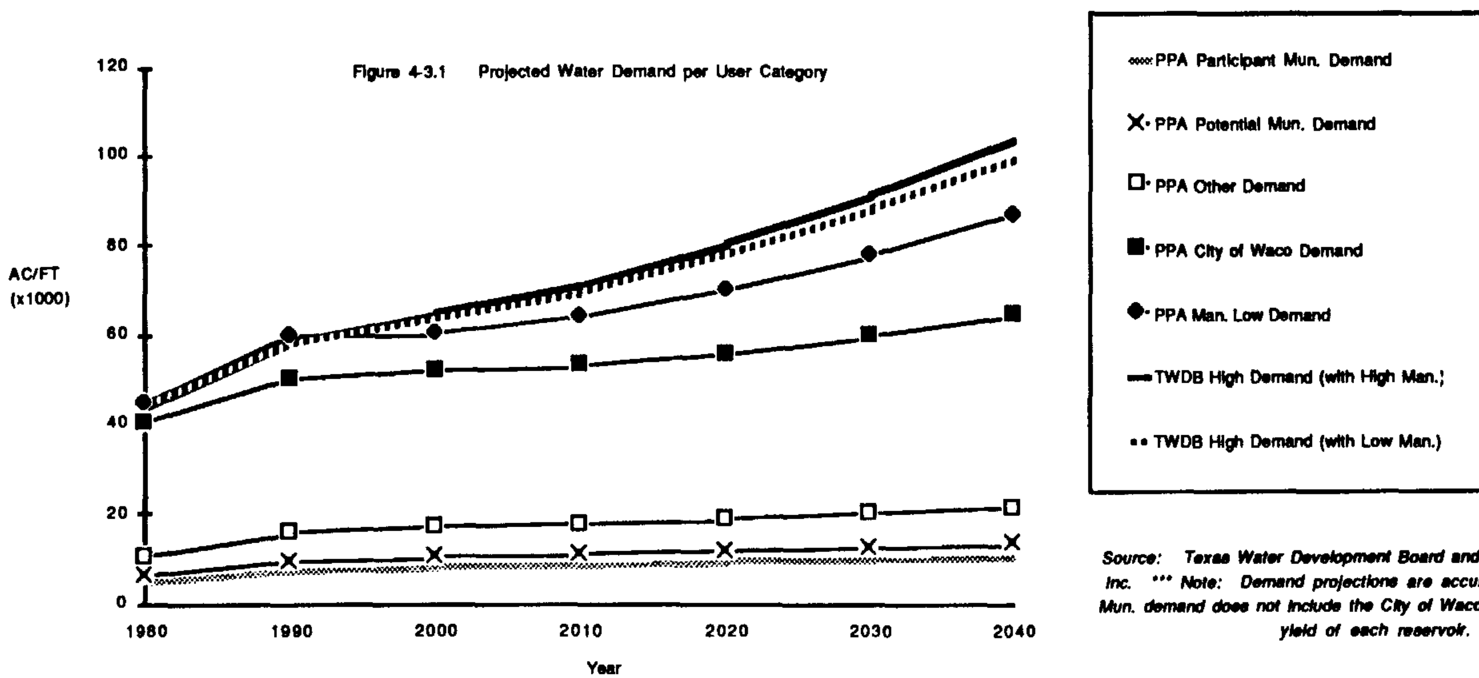


Figure 4-3.1 Projected Water Demand per User Category

*Source: Texas Water Development Board and Paul Price Associates Inc. *** Note: Demand projections are accumulative. Participant Mun. demand does not include the City of Waco. Supply is the firm-yield of each reservoir.*

year 2040. The discrepancy between projected demand and future supply is compounded because the City of Waco owns all the water rights to Lake Waco and does not intend to sell those rights to other municipalities. Therefore, as existing groundwater supplies become inadequate or unsuitable and as Lake Waco water is inaccessible, except to the City of Waco and Beverly Hills, other entities would have to participate in additional surface water development projects or else obtain water from other entities.

4.6.2 Water Demand Categories

There are currently eight cities participating in the Lake Bosque Project, they are: Bellmead, Clifton, Hewitt, Lacy-lakeview, McLennan Co. WCID #2 (Elm Mott), Meridian, Waco and Woodway. Classified as potential customers for the Lake Bosque Project are four municipalities located in either Bosque or McLennan County, who as reported in the TWDB Municipal Water Supply-Demand 1990 - 2030 summaries, currently rely or would in the future rely on Lake Waco surface water to supply all or a proportion of their water needs. These municipalities are: Mart, Moody, Northcrest and Bruceville-Eddy. Municipal water demand projections include commercial, residential, city service (swimming pools, parks, etc...) and some miscellaneous light industrial use within the municipal jurisdiction, but do not include industrial water requirements or sales to others outside the municipal jurisdiction.

The category of "Other" demand includes non-urban areas of Bosque and McLennan Counties. That proportion of Other demand identified by the TWDB Municipal Water Supply-Demand 1990-2030 as currently relying, or in the future relying, on Lake Waco for water supply was the basis for the projected Lake Bosque demand.

A high and low series manufacturing water demand projections were prepared by the TWDB in 1981 for each county. That proportion of Manufacturing Demand identified by the TWDB Municipal Water Supply-Demand 1990-2030 summary as currently relying, or in the future relying, on Lake Waco for water supply was the basis for Paul Price Associates' projected demand for Lake Bosque. The recommended water demand projection for the Manufacturing Demand category is the TWDB Low Series manufacturing projection. Incorporated into the Low Series projection is a slower growth rate than used in the High Series projection. Today, in view of the present downturn in the Texas economy, TWDB staff believe that the Low Series manufacturing projection is more appropriate. The manufacturing demand figures shown in Table 4 - 6 are the TWDB's low series projections.

4.6.3 Methodology

Driving PPA's water demand projections are the Texas Water Development Board (TWDB) Low Series population projections coupled with drought condition per capita consumption rates used in the TWDB High Series water demand projections.[1] The results are water demand projections based on the most conservative population projections and drought condition per capita water demand rates. Because TWDB projections were available only to 2030, PPA extended demand projections to 2040 by applying the percent change from 2020 - 2030 to 2030 base numbers.

The TWDB per capita use estimates were based upon water use data reported by suppliers of municipal and commercial water within each county and upon statistical analysis of trends in per capita water consumption rates through time. Per capita water demand estimates were made for each city and projected through the year 2000. Because of a historic trend of increased standards of living and the rapid rate of availability of public water service to a rapidly expanding affluent Texas population, 4 gallons of additional per capita water consumption per decade until year 2000 was assumed. After year 2000, due to conservation and improvement in technology, per capita water consumption was assumed to remain constant.

Two steps were required to calculate future demand for the Lake Bosque Project. The first step was to project total water demand for each project participating city, potential customer cities, other demand and manufacturing demand (see Table 4-6). The second step was to compare total demand for each category with available supplies as reported by the Brazos River Authority, HDR Engineering and water use projections for Lake Whitney and ground-water supplies as indicated in the TWDB City and County Water Supplies and Demand summary. Water available from ground-water and other supply sources, such as Lake

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[1] The Texas Water Development Board's water demand projections were based upon TWDB population projections for 1980 - 2030, one is a best case scenario, the other a worst case. The High Series water demand projection is driven by the High Series population projection and drought influenced per capita water consumption rates. The Low Series water demand projection is driven by the Low Series population projection and average climate per capita water consumption rates.

Whitney or Lake Aquilla (but not Lake Waco), was subtracted from each categories' total demand. The remaining demand was either excess demand (more demand than projected supply) or else demand satisfied by Lake Waco water. However, because the City of Waco does not intend to sell Lake Waco water, any demand projected against Lake Waco would be unmet. Therefore, any excess demand or demand for Lake Waco water was considered potential demand for the proposed Lake Bosque.

To project water demand for 2040, water demand projections per decade from 1980 to 2040 for each category: project participating municipalities, potential customer entities, other and manufacturing were prepared. The results are found in the Appendix (Tables A.1 - 1, A.1 - 2, and A.1 - 3). For each category and each city three characteristics were projected: population, per capita consumption (reported in gallons per day (gpd)), and total water consumption (reported in acre feet per year (Ac/ft) and million gallons per day (mgd)). Displayed in the tables are TWDB high and low case population and water demand projections and Paul Price Associates' projections for total demand. Because Paul Price Associates' water demand projections incorporate TWDB low series population projections and high series per capita water demand ratios, the results lie between the TWDB high and low series demand projections. Also shown for each category is projected demand for Lake Bosque. Projected demand for Lake Bosque was calculated by subtracting all water supplies, except Lake Waco, from the total projected demand (derived by multiplying high TWDB per capita consumption rates with TWDB low population projections). Any projected excess demand and demand for Lake Waco water was assumed to be demand for the proposed Lake Bosque.

In the Appendix are tables listing the source and amount of available water supply for each user (Tables A.1 - 4, A.1 - 5, A.1 - 6). Projected water supply data is from the TWDB projection high series. Supply projections for 2040 were not available from the TWDB. Therefore, it was assumed that 2040 water supplies would remain constant with supplies available in 2030.

4.6.4 Water Supplies and Demand Projection Results

4.6.4.1 Total Water Supplies and Demand Projections

Total water use in 1980 (includes project participants, potential customers, the City of Waco, other and manufacturing demand) was 39.71 million gallons per day (44,481 acre feet per year). Paul Price Associates' projection of 2040 total demand is 77.45 million gallons per day or 86,756 acre feet per year. As shown in Figure 4 - 3, the firm-yield of Lake Waco (59,100 acre feet per year) and the proposed enlargement (20,100 acre feet per year) would not sufficiently meet projected total demand in year 2040. Total 2040 projected demand of 86,756 acre feet per year is 7,756 acre feet per year higher than Lake Waco's firm-yield of 79,200 acre feet per year. The proposed Lake Bosque would increase firm-yield supplies by 18,189 acre feet per year sometime around year 1990. Due to proposed desalination of Lake Whitney the TWDB expects additional supplies to become available by year 2020. However, it is generally believed that desalination of Lake Whitney is not likely to occur, and if it does, that water rates would be prohibitive to most users. The United States Army Corp of Engineers estimates that the desalination project would cost $250 million and because of its high cost is not likely to be constructed anytime in the near future, if ever.

Municipal water demand (includes project participants, potential customers and the City of Waco) is projected to increase from 32.11 million gallons per day (35,968 acre feet per year) in 1980 to 50.00 million gallons per day (56,008 acre feet per year) in 2040 (see Table 4-6). As shown in Table 4 - 7 per capita consumption rates are different for each municipal category. In 1980 per capita demand was 162 gallons per day for project participants, 159 gallons per day for potential customers, and 261 gallons per day for the City of Waco. The aggregate municipal per capita demand (including project participants, potential customers and the City of Waco) was 235 gallons per day in 1980. Due to conservation, by year 2000 per capita demand is expected to peak and stabilize at 187 gallons per day, 190 gallons per day and 285 gallons per day respectively. Total municipal per capita demand peaks and remains level at 254 million gallons per day by year 2000.

In 1980, all of the municipalities (except the City of Waco) relied exclusively on ground-water as a supply source. The TWDB supply summary assigns Lake Waco as the future supply source for each of the communities. As shown in Figure 4 - 3, supply from Lake Waco and the proposed enlargement is not sufficient for projected demand. Compounding the problem of insufficient supply in 2040 is the fact that the City of Waco will not sell Lake Waco water to other entities. Therefore, if supply from Lake Waco (as assigned by the TWDB) is subtracted from total supply, projected demand beginning in year 1990 for project participants and potential customers would not be met. This unmet demand plus any projected shortages would be demand for Lake Bosque.

Total other demand in McLennan and Bosque Counties is projected to increase from 3.97 million gallons per day (4,447 acre feet per year) use in 1980 to 7.41 million gallons per day (8,300 acre feet per year) in 2040. Per capita consumption in rural McLennan County is projected to increase from 125 gallons per day in 1980 to 180 gallons per day in 2040; rural Bosque County per capita consumption is projected to increase from 108 gallons per day to 166 gallons per day in 2040. Identified water supply sources are Lake Waco, the Trinity Aquifer and other ground-water sources.

Manufacturing demand in the two county area is projected by the TWDB low projection series to increase from 3.63 million gallons per day (4,066 acre feet per year) use in 1980 to 20.04 million gallons per day (22,448 acre feet per year) in 2040. TWDB high projection series projects 2040 demand at 23.74 million gallons per day (26,592 acre feet per year). The low TWDB projection series was incorporated into Paul Price Associates' demand projections. Manufacturing water supplies were identified as Lake Waco, the Trinity Aquifer , and beginning in 2020, Lake Whitney.

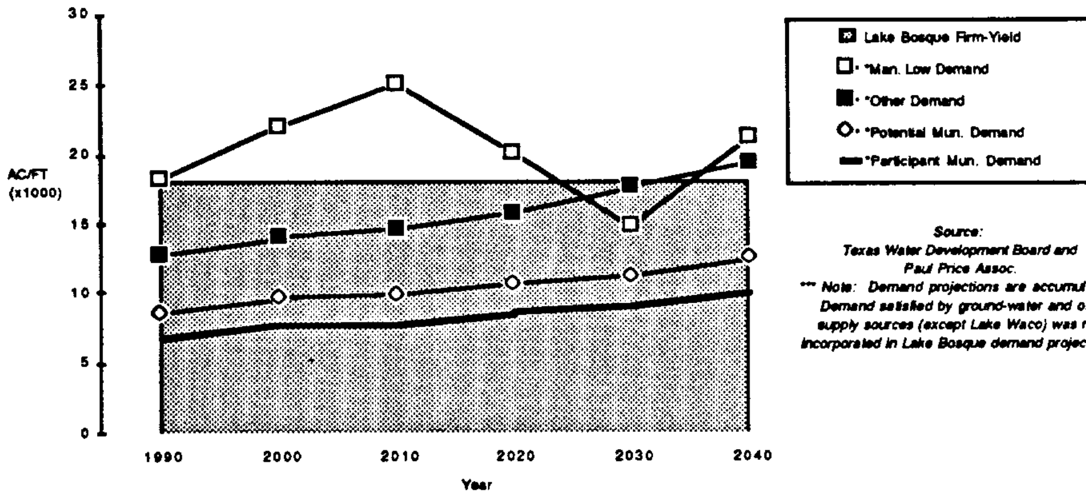
4.6.4.2 Water Demand Projections for Lake Bosque

Projected demand for Lake Bosque was derived by comparing total projected demand with firm-yield supplies and projected water supplies from Lake Waco, Lake Whitney, ground-water and other sources (Tables A.1 - 4, A.1 - 5, A.1 - 6). Because the City of Waco will not sell water from Lake Waco to other entities, demand that was assigned by the TWDB to Lake Waco was assumed to be potential demand for Lake Bosque. Demand satisfied by ground-water supplies, as indicated by the TWDB, was not included in demand projections for Lake Bosque. However, due to deteriorating ground-water quality, it is likely that users would switch to a surface-water supply source if available. As shown in Table 4 - 8 total municipal, other and manufacturing demand for Lake Bosque is projected for year 2040 at 18.97 million gallons per day (21,246 acre feet per year). That projection includes water needs for project participating communities, potential consumer communities, other demands and TWDB Low Series manufacturing demands. Municipal and other water demand accounts for 91.4% of total project demand.

Figure 4 - 4 illustrates projected accumulative demand for the Lake Bosque Project. The sharp decrease in manufacturing demand after 2010 is due to an assumption by the TWDB that a large increase in Lake Whitney supply, due to desalination, will become available. However, it is generally thought that the cost of desalination would be prohibitive and that resulting water would be too expensive for most users.

Project participating municipal demand for Lake Bosque is projected to increase from 6.10 million gallons per day (6,831 acre feet per year) in 1990 to 9.11 million gallons per day (10,203 acre feet per year) in 2040. Potential customer demand is projected to increase from 1.61 million gallons per day (1,809 acre feet per year) in 1990 to 2.13 million gallons per day (2,381 acre feet per year) in 2040. TWDB Low Series manufacturing demand is projected to decrease from 4.82 million gallons per day (5,396 acre feet per year) in 1990 to 1.63 million gallons per day (1,824 acre feet per year) in 2040. This decrease is due to the projected availability of Lake Whitney water. TWDB water demand and supply summaries indicate that by year 2020, 60% of Mclennan County's manufacturing water demand will be satisfied by

Figure 4-4 Lake Bosque Projected Demand and Supplies



Source:
Texas Water Development Board and
Paul Price Assoc.
**** Note: Demand projections are accumulative. Demand satisfied by ground-water and other supply sources (except Lake Waco) was not incorporated in Lake Bosque demand projections.*

Lake Whitney. Bosque County's manufacturing demand is projected to continue relying on Lake Waco as a supply source.

4.7 TRANSPORTATION

4.7.1 Roadway System

As shown in Figure 4 - 5 the proposed Bosque Reservoir site is located in the middle of a triangle whose points are formed by the communities of Meridian to the southeast, Iredell to the northwest and Walnut Springs to the north. The sides of the triangle are formed by State Highway 6 running between Meridian and Iredell, State Highway 144 connecting Meridian and Walnut Springs, and Ranch Road 927 between Walnut Springs and Iredell. Gravel surfaced county roads access the site to the major roadways.

As shown in Figure 4 - 5 traffic volume in 1985 for State Highway 6 between Meridian and Iredell, near the project site, averages 1,350 vehicles per day (average annual 24-hour traffic) (Texas Department of Highways and Public Transportation). Traffice volume for Ranch Road 927 averages 420 vehicles per day. Traffice volume for State Highway 144 averages 890 vehicles per day. Traffic volume on county roads within the county range from 35 to 100 vehicles per day (1984 traffice counts, Bosque County Highway Department, District 9).

Figure 4 - 6 summarizes the roadway and powerline changes associated with the proposed Lake Bosque project. As proposed, reservoir construction will require the relocation of small sections of county and state roadways (to skirt portions of the reservoir), as well as abandonment of county roads which cross the proposed site. Two powerlines located west and northeast of the site would also be relocated and a county road directly linking Highway 6 to the reservoir may be constructed.

There are no major road improvements planned for Bosque County area roads (Texas Department of Highways and Public Transportation, 1986).

4.7.2 Air Service

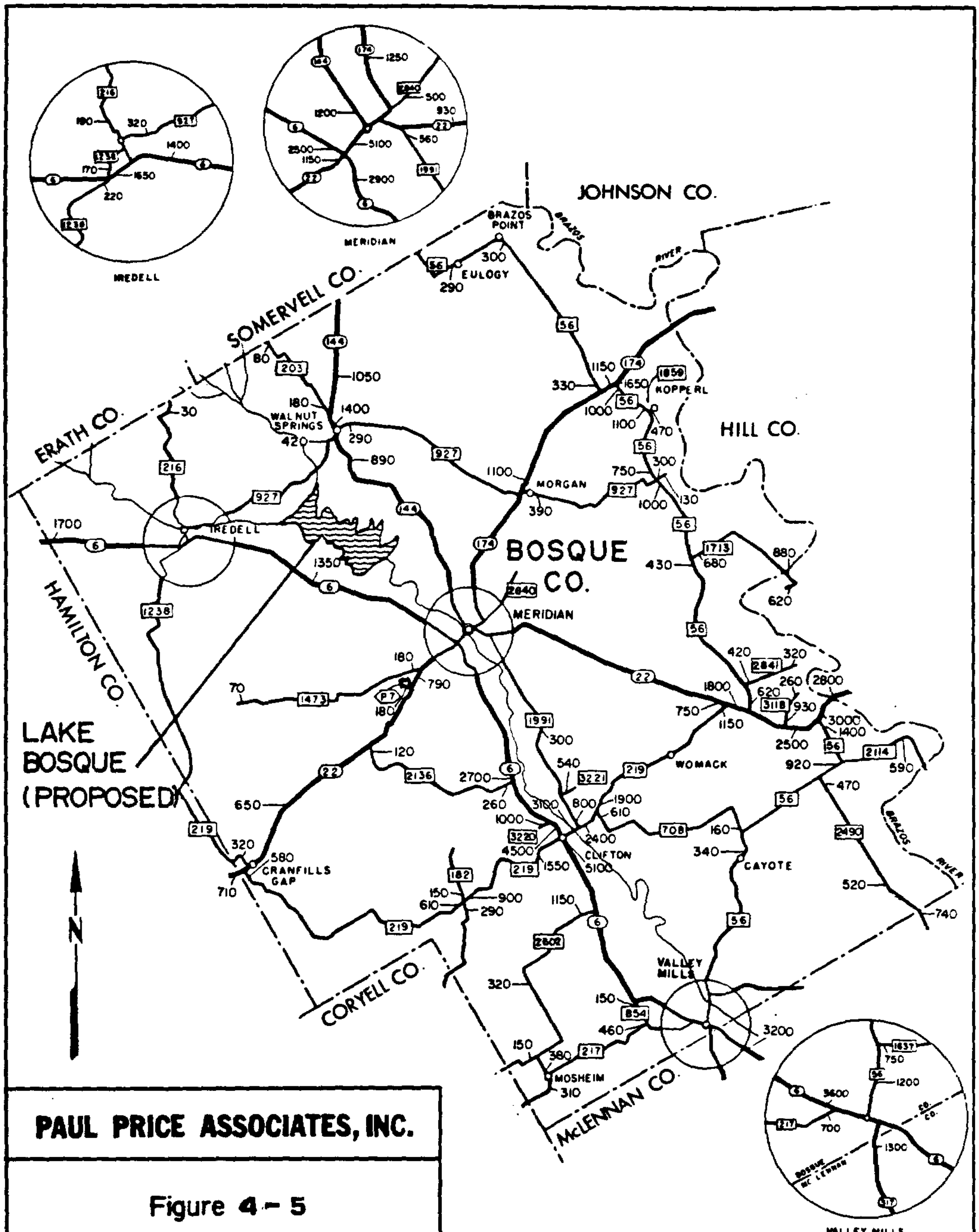
Air service is available in Clifton and Waco. The Clifton Municipal Airport, northeast of the City, approximately 16 miles from the proposed site, offers 3,000 feet of lighted and paved runway and comprehensive services including storage, major and minor repairs, jet fuel and aviation gasoline. Commercial flight service is not available. However, complete services and 13 commercial flights per day, with connections to major cities throughout the country, are available in Waco, approximately 40 miles east of the proposed site.

4.7.3 Rail Service

The Santa Fe Railway System, extending from Chicago to the Gulf Coast services the City of Clifton. Amtrack passenger rail service is available three times weekly from Temple, Dallas or Fort Worth, each city is approximately 70-100 miles from the proposed reservoir site.

4.8 HOUSING

Housing information for the two-county study area was derived from the U.S. Department of Commerce, 1980 Census of Housing, local municipal publications and local area realtors. Table 4 - 9 details 1980 housing conditions in McLennan and Bosque Counties. In both counties vacancy rates for owner-occupied housing units indicate a shortage of available housing, rental vacancy rates point to slightly larger supply of available rental units.



PAUL PRICE ASSOCIATES, INC.

Figure 4-5

Bosque Co. Traffic Volume Counts

source: Texas Department of Highways and Public Transportation, 1985

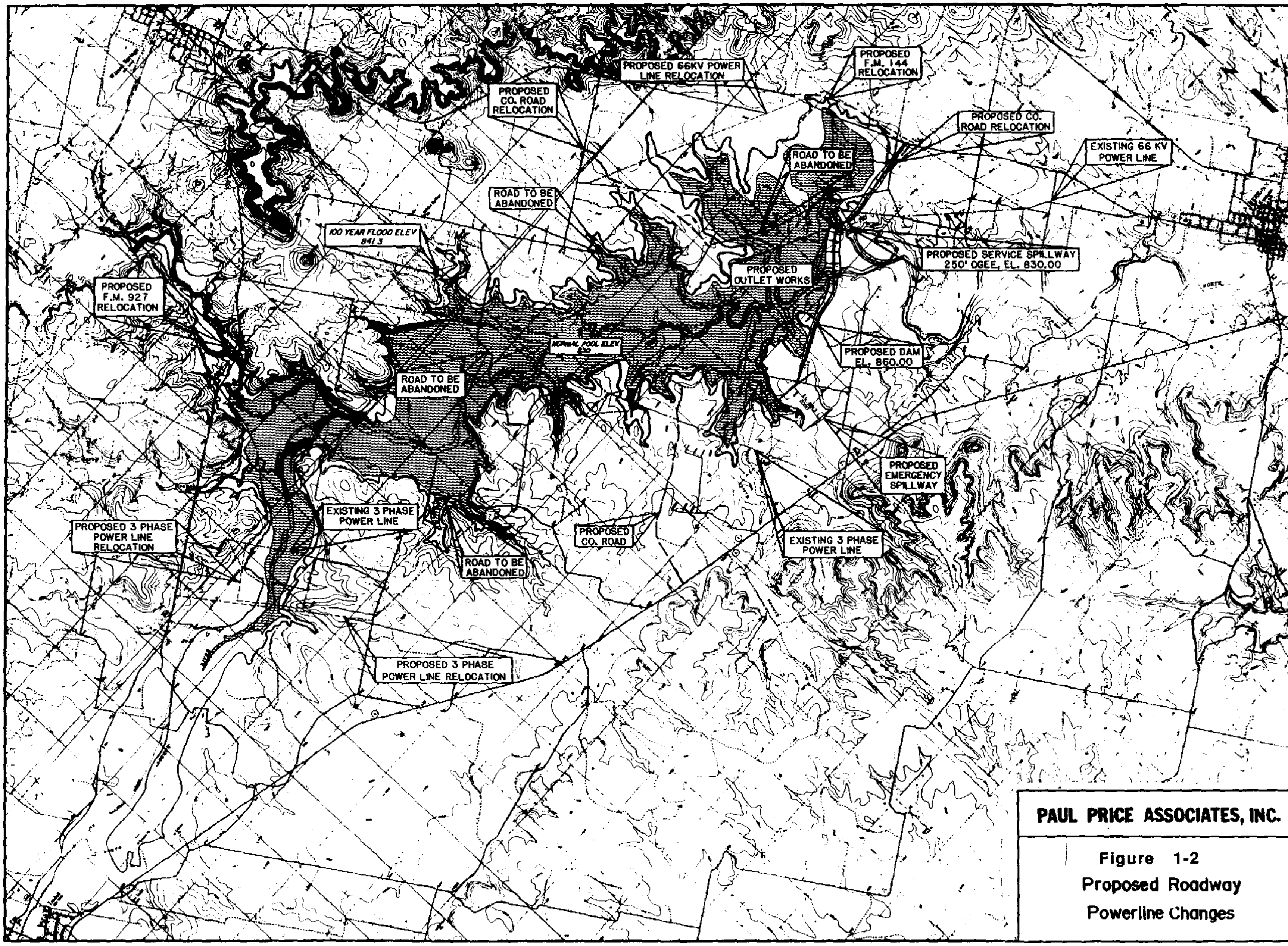


Figure 1-2
Proposed Roadway
Powerline Changes

Table 4 - 9

Housing Data for the Study Area, 1980

	McLennanCounty	Bosque County
Total Housing Units	65,934	7,439
Seasonal	113	86
Year-round	65,821 (99.8% of total)	7,353 (98.8% of total)
Vacant Housing Units	4,267	1,840
Occupied Housing Units		
Total	61,554	5,513
Persons per Occupied Unit	2.65	2.36
# One-person Households	14,488	1,527
Median value ($) / owner	$29,100	$23,400
Contract valued ($) / renter	$158.00	$88.00
Vacancy Rate		
Homeowner	1.7 %	2.0 %
Renter	7.0 %	7.4 %

Source: U. S. Department of Commerce, Census of Housing, 1980

Comparison of building permits issued annually is a method of assessing housing availability between census years. Tables 4 - 10 and 4 - 11 show the number and value of housing units permitted for construction in 1983, 1984 and 1985 in the study area. The value of permits issued in Bosque County was at its peak in 1984 but has since declined. The value of permits issued in McLennanCounty has decreased yearly since 1983. In both counties the number of residential permits decreased .

Local realtors in McLennanCounty report for December 1986 listings of approximately 1,290 new and relisted single family units. Average sales price for a three bedroom single-family home was $61,592. McLennanCounty, as of December 1986, had approximately 18,000 multi-family units, of which, 80% were estimated as occupied. Average monthly rent for a 3 bedroom apartment in the Waco area was $450. In areas skirting the City of Waco apartment rents were 10% to 25% less.

Local realtors in Bosque County reported approximately 50 new and relisted single-family homes since December 1986. The average sales price for a three bedroom single-family home was approximately $35,000. Other homes were available from $20,000 to $110,000. It was estimated that the county contains 250 apartment units, the majority located in the three most active communities, Clifton, Valley Mills, and Meridian. Of those apartments it was estimated that 95 - 100% were occupied. Average monthly rent for a 1 - 2 bedroom apartment in Bosque County was $162 - $236. The rental market was so tight that waiting lists for occupancy were common.

Table 4 - 10. Building Permits Issued in Bosque County: 1983, 1984, 1985

Building Permits Bosque County	1983	1984	1985
Total Value ($) of Building Permits	$880,000	$1,380,000	$1,121,000
Non-residential			
Value	$116,000	$176,000	$573,000
Residential			
Value	$709,000	$1,207,000	$545,000
Number of Units	19	32	11
Repair, Alterations, & Additions			
Value	$55,000	$5,000	$3,000

	1983	1984	1985
Non-residential			
Office	$0	$70,000	$60,000
Industrial	$7,000	$0	$0
Retail	$0	$0	$28,000
Public*	$0	$0	$300,000
Other Non-residential	$787,000	$106,000	$185,000
Residential			
Single-family			
Value	$559,000	$1,790	$545,000
Number of Units	11	20	11
2-4 plex			
Value	$0	$0	$0
Number of Units	0	0	0
Apartments			
Value	$150,000	$128,000	$0
Number of Units	8	12	0

Source: Texas Real Estate Research Center, 1986.
* Does not include highway or bridge construction.

Table 4 - 11. Building Permits Issued in McLennan County: 1983, 1984, 1985

McLennan County	1983	1984	1985
Total Value of Building Permits (in 1000s)	$157,900	$150,641	$114,851
Non-residential			
Value	$45,600	$36,234	$37,884
Residential			
Value	$90,300	$85,777	$50,664
Number of Units	2989	2183	1048
Repair, Alterations, & Additions			
Value	$22,000	$28,630	$26,303
Non-residential			
Office	$10,900	$16,515	$15,784
Industrial	$6,155	$5,003	$1,681
Retail	$5,255	$5,445	$7,530
Public*	$18,980	$2,367	$3,372
Other Non-residential	$4,000	$4,054	$5,967
Hotel	$0	$2,850	$3,550
Residential			
Single-family			
Value	$35,040	$44,766	$39,554
Number of Units	602	692	543
2-4 plex			
Value	$5,790	$8,082	$2,278
Number of Units	203	234	65
Apartments			
Value	$49,478	$32,929	$8,832
Number of Units	2184	1257	440

Source: Texas Real Estate Research Center, 1986.
* Does not include highway or bridge construction.

5.0 PUBLIC FINANCES

5.1 INTRODUCTION

The ability to finance capital improvements such as sewer, streets, parks and recreation facilities is an important measure of a city and county's ability to serve additional populations. Capital improvements may be financed through a variety of techniques including current revenue, reserve funds, general obligation (G.O.) bonds, revenue bonds (R.B.), authorities and special districts. This section examines current revenues, expenditures and indebtedness for fiscal year ended September 30, 1985 for Bosque and McLennan Counties and the seven project participating communities, Waco, Bellmead, Clifton, Meridian, McLennan County WCID # 2 (Elm Mott), Hewitt and Lacy- Lakeview. Data is from the Comprehensive Annual Financial Report for McLennan County, the Audited Combined Current Financial Statements for Bosque County, and Texas Municipal Reports for 1986. Also detailed in this report is the market value, assessed agricultural production value , assessed value, and taxable value of land proposed to be inundated by Lake Bosque.

5.2 COUNTY RESOURCES

Services and primary functions of McLennan and Bosque Counties include general government, public safety, county roads, health, welfare, culture and recreation, conservation, and public improvements. Total bi-county revenue for the year amounted to $24,081,188. Revenue and expenditures for Bosque and McLennan Counties, for the fiscal year ended September 30, 1985, as reported in each county's financial report are shown in Tables 5 - 1 and 5 - 2. The following text refers to those tables.

Current sources of county revenue in the study area for fiscal year ended September 10, 1985 include property taxes which accounted for 42% and 30% respectively of total revenue for McLennan and Bosque County. Intergovernmental transfers, a significant source of current revenue in McLennan County,

Table 5-1. McLennan County Revenues and Expenditures

MCLENNAN COUNTY	GOVERNMENTAL FUND TYPES				FIDUCIARY FUND TYPES		
	GENERAL REVENUES	SPECIAL REVENUE	DEBT SERVICE	CAPITAL PROJECTS	EXPENDABLE TRUST	Totals (Memorandum Only)	TOTAL GENERAL GOVERNMENT FUNDS
REVENUES:							
Taxes (property)	$6,018,039	$2,351,015	$762,700	$156,722	$0	$9,288,476	$9,131,754
Licenses and Permits	$64,342	$0	$0	$0	$0	$64,342	$64,342
Intergovernmental	$1,016,072	$2,412,388	$10,904	$2,324	$0	$3,441,688	$3,439,364
Charges for Services	$2,702,620	$763,421	$0	$0	$0	$3,466,041	$3,466,041
Fines and Forfeits	$518,275	$556,948	$0	$0	$0	$1,075,223	$1,075,223
Miscellaneous	$973,858	$492,304	$88,260	$11,944	$3,149,715	$4,716,081	$1,554,422
TOTAL REVENUE	**$11,293,206**	**$6,576,076**	**$861,864**	**$170,990**	**$3,149,715**	**$22,051,851**	**$18,731,146**
EXPENDITURES:							
CURRENT							
General Government	$5,204,410	$1,072,704	$0	$0	$0	$6,277,114	$6,277,114
Public Safety	$3,105,639	$1,582,113	$0	$0	$0	$4,687,752	$4,687,752
Public Transportation	$0	$3,719,093	$0	$0	$0	$3,719,093	$3,719,093
Health	$360,580	$0	$0	$0	$0	$360,580	$360,580
Welfare	$1,239,404	$109,622	$0	$0	$0	$1,349,026	$1,349,026
Culture-Recreation	$284,804	$0	$0	$0	$0	$284,804	$284,804
Education	$0	$0	$0	$0	$3,038	$3,038	$0
Conservation	$111,521	$0	$0	$105,813	$0	$217,334	$111,521
CAPITAL PROJECTS	$0	$0	$0	$951,126	$0	$951,126	$0
DEBT SERVICE:							
Principle Retirement	$115,922	$46,536	$520,000	$0		$682,458	$682,458
Interest and Fiscal Charges	$27,172	$11,513	$327,600	$0		$366,285	$366,285
MISCELLANEOUS	$0	$0	$0	$0	$3,180,725	$3,180,725	
TOTAL EXPENDITURES	**$10,449,452**	**$6,541,581**	**$847,600**	**$1,056,939**	**$3,183,763**	**$22,079,335**	**$17,838,633**
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES	$843,754	$34,495	$14,264	($885,949)	($34,048)	($27,484)	$892,513
OTHER FINANCING SOURCES	$19,317	$111,697	$0	$752,563	$3,086	$886,663	$131,014
EXCESS (DEFICIENCY) OF REVENUES AND OTHER SOURCES OVER EXPENDITURES AND OTHER USES	$863,071	$146,192	$14,264	($133,386)	($30,962)	$859,179	$1,023,527
Fund Balance at Beginning of Year	$5,676,044	$2,599,777	$734,603	$127,404	$794,382	$9,932,210	$9,010,424
Fund Balance at End of Year	**$6,539,115**	**$2,745,969**	**$748,867**	**($5,982)**	**$763,420**	**$10,791,389**	**$10,033,951**

Source: Comprehensive Annual Financial Report for Mclennan County, fiscal year ended 9/86.

Table 5-2. Bosque County Revenues and Expenditures

BOSQUE COUNTY	GOVERNMENTAL FUND TYPES				CAPITAL PROJECTS	TRUST and AGENCY	TOTAL	TOTAL GENERAL GOVERNMENTAL FUNDS
	GENERAL REVENUES	ROAD & BRIDGE	SPECIAL REVENUE	DEBT SERVICE				
REVENUES:								
Taxes	$371,182	$241,718	$0	$0	$0	$0	$612,900	$612,900
Fees of Office	$203,481	$0	$0	$0	$0	$17,886	$221,367	$203,481
Fines and Forfeits	$196,367	$0	$0	$0	$0	$0	$196,367	$196,367
Intergovernmental	$0	$0	$80,044	$0	$0	$0	$80,044	$80,044
License and Permits	$0	$474,725	$0	$0	$0	$0	$474,725	$474,725
Interest and Other	$199,149	$44,543	$0	$1,732	$15,507	$5,436	$266,367	$245,424
Trust Deposits Received	$0	$0	$0	$0	$0	$177,567	$177,567	$0
TOTAL REVENUE	**$970,179**	**$760,986**	**$80,044**	**$1,732**	**$15,507**	**$200,889**	**$2,029,337**	**$1,812,941**
EXPENDITURES:								
General Administration	$292,245	$0	$0	$0	$0	$0	$292,245	$292,245
Administration of Justice	$415,922	$0	$0	$0	$0	$1,415	$417,337	$415,922
Public Welfare	$77,627	$0	$0	$0	$0	$0	$77,627	$77,627
Health and Sanitation	$963	$0	$0	$0	$0	$0	$963	$963
Appraisal Board	$71,572	$0	$0	$0	$0	$0	$71,572	$71,572
State Extension Service	$18,945	$0	$0	$0	$0	$0	$18,945	$18,945
Emergency Management Fund	$18,312	$0	$0	$0	$0	$0	$18,312	$18,312
County Wide Road and Bridge	$0	$470,095	$36,869	$0	$0	$0	$506,964	$506,964
Debt Service								
Principal Retirement	$6,000	$15,000	$0	$2,000	$0	$0	$23,000	$23,000
Interest Expense	$6,000	$2,517	$0	$495	$0	$0	$9,012	$9,012
Capital Outlay	$25,218	$29,200	$0	$0	$653	$0	$55,071	$54,418
Payment of Trust Deposits	$0	$0	$0	$0	$0	$177,133	$177,133	$0
Total Expenditures	**$932,804**	**$516,812**	**$36,869**	**$2,495**	**$653**	**$178,548**	**$1,668,181**	**$1,488,980**
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES	$37,375	$244,174	$43,175	($763)	$14,854	$22,341	$361,156	$323,961
Fund Balance, 10/1	$92,432	$357,951	$0	$15,332	$384	$104,808	$570,907	$465,715
Fund Balance, 9/11	**$129,807**	**$602,125**	**$43,175**	**$14,569**	**$15,238**	**$127,149**	**$932,063**	**$789,676**

Source: Bosque County
Financial Statement, Year Ended September 30, 1985

contributed 16% of the general budget but only 4% in Bosque County. The second largest revenue contributor in Bosque County, Licenses and Permits, accounted for 24% of total revenue .

Nationally, since the 1970s municipal financing has relied less on property taxes and more on other revenue sources such as user charges and bond issuance for municipal expenditures. A popular method of financing infrastructure is through the issuance of general obligation (G.O.) and/or revenue bonds. General obligation bonds are backed by the taxing power of the jurisdiction and often require voter approval. General obligation bonds are primarily used to pay interest and principal on capital improvements, such as schools, recreation facilities and parks. In contrast, revenue bonds are supported by revenue producing capital improvements such as water and sewer treatment plants. The interest and principle on revenue bonds are financed through service charges and user fees. Interest rates on revenue bonds are higher than those of G.O. bonds but do not require voter approval.

Authorities and special districts are another way of financing development. Municipal Utility Districts (MUD), Water Conservation and Improvement Districts (WCID), and Hospital Districts are examples of special districts that provide necessary services. These districts are often financed through revenue bonds which are retired through user fees. Some special districts such as MUDs have the power to float tax-free revenue bonds and G.O. bonds. As legal subdivisions of the state, MUDS have the power to levy taxes to pay off bond debt. Special districts in the two-county study area include McLennan County WCID #3, McLennan County WCID #2, and 32 Independent School Districts .

The revenue generating methods described above are used to support local municipal and county expenditures, including educational services, transportation, and capital improvements. Principal county expenditures for Bosque County was for Public Safety, in McLennan County major expenditures were for General Government services. Approximate per capita expenditure in McLennan County for year ended September 1985 was $121, in Bosque County per capita expenditure was $110.

Annual county financial reports are organized on the basis of fund and account groups, each of which is considered a separate accounting entity. Annual county financial reports record all fund and account groups (revenues and expenditures) of the county. Usually the various accounts are organized into generic fund types within broad category and account groups. For the purpose of this report the account of primary interest is the broad category of Governmental Funds and the sub-category funds: General Fund, Special Revenue Fund, Debt Service Fund, Capital Projects Fund. Of further interest is the General Long-Term Debt Account Group which reports bonded indebtedness and other long-term liabilities. This account group is not a "fund" per se, but is concerned only with the measurement of financial position.

5.2.1 The General Fund

5.2.1.1 Revenues

The General Fund is the general operating fund of the county. It is used to account for all financial resources except those by requirement accounted for in another fund. In McLennan County total revenue for general governmental purposes (General Fund) amounted to $18,731,146, a decrease of 2.20% from the preceding year. Nearly 49% of general revenues was accounted for by property taxes and penalties, while Intergovernmental and Service Charges each raised approximately 18% of general revenues. In Bosque County the General Fund for fiscal year ended September 30, 1985 was $1,812,941. Property taxes accounted for 34% of General Governmental Funds, Licenses and Permits accounted for 26% of revenues, and Intergovernmental transfers accounted for only 4% of total revenues.

As of 1982 all taxable property in both counties was assessed at 100% of its appraised value. Counties are permitted by the State Constitution and Statutes to levy property taxes up to $.80 per $100 of assessed valuation for general governmental services and for the payment of principal and interest on long-term debt other than road bonds. In addition, $.30 per $100 of assessed valuation may be levied for farm-to-market road construction and maintenance. This would allow a total rate of $1.10 per $100 of assessed valuation to finance general governmental services, farm-to-market roads and payment of principal and interest on long-term debt other than road bonds.

In McLennan County assessed 1985 property valuations of $3.4299 billion represent an increase of 6.84% from the preceding year. Excluding exemptions, the net taxable value in McLennan County was $2,734,250,075. Currently, the tax rate assessed on the 1984 tax roll to finance general governmental services for the year ended September 30, 1985, was $.3013 per $100 of assessed valuation. Thus, the County has a tax rate margin of $.4987 per $100 of assessed valuation and could raise $13,635,704 in additional tax revenue before reaching the legal limit

The McLennan County tax rate assessed on the 1984 tax roll to finance the construction and maintenance of farm-to-market roads for the year ended September 30,1985, was $.0554 per $100 of assessed valuation. This means the County has a tax rate margin for $.2446 per $100 of assessed valuation and could raise $6,687,976 in additional tax revenue before reaching the legal limit.

As detailed in the preceding paragraphs a combined total of $20,323,680 in additional tax revenue could be raised in McLennan County by levying the maximum tax rate allowed to finance general governmental services and the construction and maintenance of farm-to-market roads. No road bonds were outstanding at publication time of the Comprehensive Annual Financial Report for fiscal year ended September 30,1985.

Property taxes for Bosque County accounted for 30% of the total revenues for fiscal year 1985. Assessed 1985 property valuations stood at $385.6 million. Currently, the tax rate assessed on the 1984 tax roll was $.1531 per $100 of assessed valuation. This means the County has a tax rate margin of $.6469 per $100 of assessed valuation and could raise $2,494,642 in additional tax revenue before reaching the legal limit.

5.2.1.2 Expenditures

As shown in Table 5 -1 expenditures by McLennan County for general governmental purposes amounted to $17,944,446 (excluding capital expenditures from Capital Projects Funds and Trust and Agency Funds expenditures) for the year ended September 30. 1985, an increase of 3.63% over expenditures for the preceding year. General Government, Public Safety and Public Transportation functions accounted for over 81% of total expenditures. Debt service expenditures amounted to only 5.84% of total expenditures.

Table 5 - 2 details Bosque County's 1985 fiscal expenditures; as shown, general governmental expenditures amounted to $1,488,980 with an excess of revenues over expenditures. Administration of Justice and General Governmental Administration functions accounted for over 48% of general governmental expenditures. Debt service expenditures accounted for 2.1% of all expenditures.

5.2.2 The Special Revenue Fund (The Road and Bridge Fund)

Special Revenue Funds are used to account for resources which are legally restricted to expenditures for specified current operation purposes or for the acquisition of relatively minor or comparatively short-lived fixed assets. The Road and Bridge fund (a Special Revenue Fund), established to account for current funds used for the purpose of constructing and maintaining roads and bridges, is of particular significance to the question of accommodating future growth. The principal source of revenues

Table 5 - 3. Study Area Road and Bridge Funds

ROAD AND BRIDGE FUND	Mclennan County	Bosque County
REVENUES		
Taxes	$2,212,575	$241,718
Intergovernmental	$433,324	$0
Charges for Services	$50	$474,725
Fines and Forfeits	$556,948	$0
Miscellaneous	$395,426	$44,543
TOTAL REVENUES	**$3,598,323**	**$760,986**
EXPENDITURES		
CURRENT		
County Wide Road and Bridge Fund	--	$470,095
General Government	$0	$0
Public Safety	$0	$0
Public Transportation	$3,719,093	$0
Welfare	$0	$0
CAPITAL PROJECTS	$0	$29,200
DEBT SERVICE		
Principal Retirements	$39,280	$15,000
Interest and Fiscal Charges	$8,132	$2,517
TOTAL EXPENDITURES	**$3,766,505**	**$516,812**
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES	**($168,182)**	**$244,174**

Source: 1985 Annual Financial Statement
Bosque and Mclennan Counties.

for this fund are ad valorem taxes, fines, forfeits and intergovernmental revenues. The financial statement for the County Road Bridge Fund for Bosque and McLennan Counties is shown in Table 5 - 3.

5.2.3 The Debt Service Fund

Debt service funds are used to account for the accumulation of resources for and the payment of general long-term debt principal, interest and related costs. A separate Debt Service Fund is established for each long-term debt issue except for such items serviced directly from the General Fund or from Special Revenue Funds. Three Debt Service Funds currently exist for McLennan County: Refunding Bonds - Series 1983, Certificate of Obligation - Series 1985, Certificate of Obligation - Series 1985-A. Bosque County has only one Debt Service Fund. Tables 5 - 1 and 5 - 2 show the combined statement of revenues, expenditures and changes in Debt Service Funds for each county.

5.2.4 The Capital Projects Fund

Capital Projects Funds are used to account for the purchase or construction of major capital facilities. Capital Projects Funds are not usually used to acquire short-lived general fixed assets such as furniture, machinery, etc. There are two Capital Projects Funds in use by McLennan County. One is the Permanent Improvement Fund which accounts for the acquisition and improvement of land and buildings on a continuing basis. The principal source of revenues for this fund are ad valorem taxes. The second fund is the Road Bond Fund - Series 1961, it consists of the remaining proceeds from the sale of road bonds and is available for the purchase of right-of-way and the construction of roads. Tables 5 - 1 and 5 - 2 detail expenditures and revenues of the Capital Projects Funds for McLennan and Bosque Counties.

5.2.5 The General Long-term Debt Account Group

Bonded indebtedness and certain other types of liabilities due more than one year after the balance sheet date are accounted for in the General Long-Term Debt Account Group.

The ratio of net long-term general obligation debt to assessed valuation and the amount of net long-term general obligation debt per capita are useful indicators of a county's debt position to county management, citizens and investors. This information for Bosque and McLennan counties as of September 30, 1985 is shown in Table 5 - 4.

Table 5 - 4

Debt Administration

	Net Debt Amount	Ratio of Debt to Assessed Value	Ratio of Debt to Estimated Market	Debt per Capita
MCLENNAN COUNTY				
Direct Debt:				
Net Bonded Debt	$4,071,133	0.1187%	0.1187%	$22.35
Other Direct Debt	619,200	0.0181%	0.0181%	3.40
Subtotal Debt	4,690,33	0.1368%	0.1368%	25.75
Overlapping Debt	48,628,516	1.4178%	1.4178%	267.02
TOTAL	$53,318,849	1.5546%	1.5546%	$292.77
BOSQUE COUNTY				
Direct Debt:				
Net Bonded Debt	-	-	-	-
Other Direct Debt	-	-	-	-
Subtotal Debt	$46,931	-	-	-
Overlapping Debt	-	-	-	-
TOTAL	$46,931	.01217%	-	$3.10

Source: Comprehensive Annual Financial Report, McLennan County and Bosque County, September 30, 1985.

Outstanding general obligation bonds as of September 30, 1985, for McLennan County totaled $4,820,000. The Debt Service Funds balance of $748,867 reduces the net bonded debt to

$4,071,133. The general laws of The State of Texas limit the issuance of bonds for the construction of courthouses, jails, and for certain other purposes to 5% of the assessed total taxable value of all property within the county. The legal debt margin for McLennan County is $167,421,639 for limited tax bonds. The legal limit on the annual tax rate for purposes of the General Fund, Road and Bridge Fund, Jury Fund, and Permanent Improvement Fund including debt service is $.80 per $100 of assessed valuation. However, the Attorney General of Texas will not approve the issuance of bonds which require a levy of more than $.40 of this limit for debt service on limited tax bonds. For fiscal year ended September 30, 1985, McLennan County levied a tax rate of $.0292 per $100 of assessed valuation for debt service on these bonds. The County has no outstanding debt for unlimited tax road bonds, therefore the legal debt margin as of September 30, 1985 is the full amount allowable by law, 25% of the assessed valuation of the real property in the County or $645,742,067. As of September 30, 1985 there were no general obligation bonds authorized but unissued by McLennan County, and there were no revenue bonds either authorized or outstanding.

Outstanding general obligation debt for Bosque County, as of September 1985, amounted to $46,931. Bosque County's Road Bonds for $11,000 are payable at variable amounts through 1993, with interest at 5.25% to %5.5- depending upon the maturity date. The bonds are fully funded by Debt Service fund assets.

5.2.6 County Debt Rating

McLennan County's bond and credit rating is very solid. Certificates of Obligation - Series 1985 - A were assigned a rating of A-1 by Moody's Investors. An A-1 rating is an upper medium quality bond rating, indicating a strong capacity to pay principal and interest. According to credit standards published by the International City Management Association (ICMA) a ratio of net bonded debt to assessed property valuation of less than 5% is very good. The ratio for McLennan County is 1.5546%. Other indications of a sound credit rating for McLennan County is a per capita debt of $292.77,much less than the recommended $550 (ICMA).

To further support the statement that McLennan County is a strong financial entity is a comparison of net debt growth rates against tax base and per capita income growth rates for two periods 1980 - 81 and 1983 - 84. The comparison reveals that the growth rate of net debt does not rise excessively over tax base or personal income growth rates. In fact, the growth rate of McLennan County's net debt is about half of that for the tax base.

Bosque County's credit rating is also solid. Its ratio of bonded debt to assessed value (.01%) is much lower than the 5% "very good" credit standard ratio published by the International City Management Association (ICMA). Other indications of a sound credit rating for Bosque County is a per capita debt of $3.10, much less than the recommended $550 (ICMA).

5.3 MUNICIPAL FINANCES

5.3.1 Property Taxes

Table 5 - 5 lists assessed property valuations, applied property tax rates and remaining tax margins for each subject municipality. Also shown is the degree of bond indebtedness (total and per capita) of each municipality and the results of different methods of analyzing municipal creditability.

Additional tax revenue available to municipalities (statutory tax limit - actual tax rate) ranges from a low of $180,000 for Meridian to $29,917,642 for the City of Waco. None of the property tax rates reach the legal property tax limit. Property tax rates range from a high of $.56 per $100 for the City of Waco to a low of $.22 for Clifton. A majority of the subject municipalities property tax rates are approximately $.30 per $100 valuation.

Table 5 - 5. Municipal Finances and Credit Ratings

MUNICIPALITIES	Bellmead	Hewitt
Assessed Valuation* (A.V.)	$77,761,361	$151,090,148
(date of valuation)	1985	1985
Property Tax Rate (per $100 A.V.)	$0.3000	$0.3150
Property Tax Limit (per $100 A.V.)	$2.50	$2.50
Property Tax Margin (per $100 A.V.)	$2.20	$2.19
Additional Tax Revenue Available	$1,710,750	$3,301,320
% of A.V. Paid by 10 Principal Taxpayers	16%	14%
General Obligation Bond Debt	$1,779,000	$2,325,000
% of G.O. Debt Self-supporting	100%	65%
Debt Service Requirement	$21,738	$289,256
Value of Authorized but Unissued G.O .Bonds	none	none
Net Debt	$0	$710,194
Net Debt per Capita	$0.00	$135.35
Payment Record	never defaulted	never defaulted
Revenue Bond Debt	$232,000	$4,873,000
Avg. Ann. Req. Debt Service	$59,100	$305,041
Net System Revenue Available Fiscal Year '85	$297,417	$630,231
Authorized but Unissued Revenue Bonds	none	none
Debt Service/Total Revenue from Sources	19.87%	48.40%
Total Debt		
Total Direct & Overlapping Debt	$266,684,773	$2,981,745
Per Capita Debt	$354.71	$568.28
Credit Rating		
Total Debt/Market Value of Property Tax Base less than 5% = very good more than 10% = trouble	3.43%	0.02%
Revenue Debt Service/Total Revenue from Sources less than 20-25% = very good	19.87%	48.40%
Date of Financial Statement	5/30/86	9/30/86

Source: Texas Municipal Reports,
Municipal Advisory Council of Texas
Notes: Italics indicate estimated data.
NA = Not applicable.

Table 5 - 5. (Continued) Municipal Finances and Credit Ratings

MUNICIPALITIES	Meridian	Lacy-Lakeview
Assessed Valuation* (A.V.)	*$19,000,000*	$73,252,395
(date of valuation)	1985	1986
Property Tax Rate (per $100 A.V.)	*$0.5500*	$0.3000
Property Tax Limit (per $100 A.V.)	$1.50	$1.50
Property Tax Margin (per $100 A.V.)	$0.95	$1.20
Additional Tax Revenue Available	$180,500	$879,029
% of A.V. Paid by 10 Principal Taxpayers	23%	38%
General Obligation Bond Debt	$599,000	$70,000
% of G.O. Debt Self-supporting	100%	100%
Debt Service Requirement	$55,912	$16,850
Value of Authorized but Unissued G.O .Bonds	none	none
Net Debt	$129,438	$0
Net Debt per Capita	$97.32	$0.00
Payment Record	never defaulted	never defaulted
Revenue Bond Debt	$23,000	$1,035,000
Avg. Ann. Req. Debt Service	$8,278	$92,713
Net System Revenue Available Fiscal Year '85	$52,773	$356,649
Authorized but Unissued Revenue Bonds	none	$155,000
Debt Service/Total Revenue from Sources	15.69%	26.00%
Total Debt		
Total Direct & Overlapping Debt	$138,465	$1,660,070
Per Capita Debt	$104.11	$603.22
Credit Rating		
Total Debt/Market Value of Property Tax Base less than 5% = very good more than 10% = trouble	0.01%	0.02%
Revenue Debt Service/Total Revenue from Sources less than 20-25% = very good	15.69%	26.00%
Date of Financial Statement	9/30/85	7/1/86

Source: Texas Municipal Reports,
Municipal Advisory Council of Texas
Notes: Italics indicate estimated data.
NA = Not applicable.

Table 5 - 5. (Continued) Municipal Finances and Credit Ratings

MUNICIPALITIES	Clifton	Woodway
Assessed Valuation* (A.V.)	$50,592,713	$239,263,970
(date of valuation)	1983	1985
Property Tax Rate (per $100 A.V.)	$0.2200	$0.3400
Property Tax Limit (per $100 A.V.)	$1.50	$2.50
Property Tax Margin (per $100 A.V.)	$1.28	$2.16
Additional Tax Revenue Available	$647,587	$5,168,102
% of A.V. Paid by 10 Principal Taxpayers	21%(1984 A.V.)	5%
General Obligation Bond Debt	$180,000	$965,000
% of G.O. Debt Self-supporting	100%	100%
Debt Service Requirement	$33,995	$119,201
Value of Authorized but Unissued G.O .Bonds	none	none
Net Debt	$157,410	$4,626
Net Debt per Capita	$51.39	$0.65
Payment Record	never defaulted	never defaulted
Revenue Bond Debt	none	$1,745,000
Avg. Ann. Req. Debt Service	$0	$110,374
Net System Revenue Available Fiscal Year '85	$36,887	$455,605
Authorized but Unissued Revenue Bonds	none	none
Debt Service/Total Revenue from Sources	0.00%	24.23%
Total Debt		
Total Direct & Overlapping Debt	$421,903	$3,012,884
Per Capita Debt	--	$424.89
Credit Rating		
Total Debt/Market Value of Property Tax Base less than 5% = very good more than 10% = trouble	0.01%	0.01%
Revenue Debt Service/Total Revenue from Sources less than 20-25% = very good	0.00%	24.23%
Date of Financial Statement	9/30/83	9/30/85

Source: Texas Municipal Reports,
Municipal Advisory Council of Texas
Notes: Italics indicate estimated data.
NA = Not applicable.

Table 5 - 5. (Continued) Municipal Finances and Credit Ratings

MUNICIPALITIES	Mclennan County WCID # 2 (Elm Mott)
Assessed Valuation* (A.V.)	$18,658,293
(date of valuation)	1985
Property Tax Rate (per $100 A.V.)	$0.3100
Property Tax Limit (per $100 A.V.)	NA
Property Tax Margin (per $100 A.V.)	NA
Additional Tax Revenue Available	NA
% of A.V. Paid by 10 Principal Taxpayers	27%
General Obligation Bond Debt	$405,000
% of G.O. Debt Self-supporting	100%
Debt Service Requirement	$56,560
Value of Authorized but Unissued G.O .Bonds	none
Net Debt	$0
Net Debt per Capita	--
Payment Record	never defaulted
Revenue Bond Debt	none
Avg. Ann. Req. Debt Service	none
Net System Revenue Available Fiscal Year '85	none
Authorized but Unissued Revenue Bonds	none
Debt Service/Total Revenue from Sources	none
Total Debt	
Total Direct & Overlapping Debt	$386,224
Per Capita Debt	--
	$514.97 per acre
Credit Rating	
Total Debt/Market Value of Property Tax Base less than 5% = very good more than 10% = trouble	0.02%
Revenue Debt Service/Total Revenue from Sources less than 20-25% = very good	none
Date of Financial Statement	9/30/85

Source: Texas Municipal Reports,
Municipal Advisory Council of Texas
Notes: Italics indicate estimated data.
NA = Not applicable.

Table 5 - 5. (Continued) Municipal Finances and Credit Ratings

MUNICIPALITIES	Waco
Assessed Valuation* (A.V.)	$2,322,798,323
(date of valuation)	1985
Property Tax Rate (per $100 A.V.)	$0.5620
Property Tax Limit (per $100 A.V.)	$1.85
Property Tax Margin (per $100 A.V.)	$1.29
Additional Tax Revenue Available	$29,917,642
% of A.V. Paid by 10 Principal Taxpayers	12%
General Obligation Bond Debt	$22,704,000
% of G.O. Debt Self-supporting	100%
Debt Service Requirement	$2,987,386
Value of Authorized but Unissued G.O .Bonds	none
Net Debt	$7,658,902
Net Debt per Capita	$75.64
Payment Record	never defaulted
Revenue Bond Debt	$24,753,763
Avg. Ann. Req. Debt Service	$2,897,230
Net System Revenue Available Fiscal Year '85	$7,496,247
Authorized but Unissued Revenue Bonds	none
Debt Service/Total Revenue from Sources	38.65%
Total Debt	
Total Direct & Overlapping Debt	$17,449,196
Per Capita Debt	$173.32
Credit Rating	
Total Debt/Market Value of Property Tax Base less than 5% = very good more than 10% = trouble	0.01%
Revenue Debt Service/Total Revenue from Sources less than 20-25% = very good	38.65%
Date of Financial Statement	9/30/86

Source: Texas Municipal Reports,
Municipal Advisory Council of Texas
Notes: Italics indicate estimated data.
NA = Not applicable.

5.3.2 Municipal Credit Rating

One measure of a strong credit rating (International City Management Association) is if total debt per capita is less than less than $550, if per capita debt is higher than $1,300 financial instability is likely. All the subject municipalities fit this criteria for a good credit rating except the communities of Hewitt and Lacy-lakeview whose net per capita debt is slightly higher than the recommended $550 but much lower than the danger zone above $1,300.

A second method of measuring credit soundness recommended by the International City Management Association is to compare total debt to the market value of the entity's property tax base: a ratio of less than 5% is very good, more than 10% signals possible trouble. As shown in Table 5 - 5 all the municipalities fit this criteria for a sound credit rating.

A third method provided by the International City Management Association of determining credit stability is to compare the revenue debt service with total revenue from sources, if the ratio is less than 20-25% the credit rating is considered good. When this method of of credit analysis was applied three municipalities were shown to have a higher than desirable debt service to revenue ratio; those cities were, Hewitt, Lacy-Lakeview and Waco.

5.4 TAXABLE VALUE OF LANDS POTENTIALLY INUNDATED

Approximately fifty-four landowners owning 13,351 acres will be impacted to some extent by the proposed construction of Lake Bosque. In some cases all of a particular land parcel will be inundated, in other cases only a portion of the parcel. Approximately nine homes and 6,143.26 acres of the 13,251 acres will be affected by the proposed lake Bosque's conservation pool and 100 year floodplain.

The Bosque County Financial Statement for year ended 1985 reports total property assessments at $385,630,342. The proposed project would remove about 6,143 acres from the county tax roles. The assessed value of property removed from the tax roles by the construction of the proposed reservoir is about 45% of the assessed value of the 13,629 acres partially affected by the project. As shown in Table 5 - 6 the assessed property value for the 13,629 acres partially affected by the proposed reservoir was $2,827,655. Forty-five percent of the assessed valuation of the 13,629 acres is $1,272,455 or .33% of the county's tax base. Thus, the construction of the proposed reservoir would remove about .33% of the county's tax base.

5.5 SUMMARY

Property taxes accounted for the majority of McLennan and Bosque Counties' tax revenues. Other major revenue sources in McLennan County were Intergovernmental Transfers and Service Charges; in Bosque County an important revenue source was Licenses and Permits.

Property valuations in McLennan County for 1985 increased slightly from the preceding year. Legally McLennan County could more than double the tax rate for financing general government services and quadruple the current tax rate for financing the construction and maintenance of farm-to-market roads and still fall below the ceiling limit. Bosque County could increase property tax revenues by increasing the current tax rate by five and still fall below the legal limit.

Measures for calculating bond and credit rating strength reveal that both counties are secure, as per capita debt and the ratio of debt to assessed value are both low. In addition, McLennan County was assigned a rating of A-1 by Moody's investors. An A-1 rating is an upper medium quality bond rating indicating a strong capacity to pay principal and interest.

None of the seven project participating communities' property tax rates are close to the legal ceiling of $2.50 per $100 valuation. Four of the communities have property tax rates which fluctuate around $.30 per $100 valuation. Those communities could increase property tax rates by seven to eight times and still fall below the legal limit. Two of the communities could triple their property tax rates and one community could increase its tax rate by five and each would still remain under the ceiling limit.

Three methods of analyzing credit soundness were applied. The first criteria was a per capita debt of less than $550. All the subject communities complied with this criteria except the communities of Hewitt and Lacy-Lakeview. However, the net per capita debt of those communities was only slightly higher than the recommended value and much lower than the danger zone above $1,300. The second method of measuring credit soundness compared total debt to the communities' property market valuations. The results showed all the subject communities in good standing. The third method of determining credit stability compared revenue debt service with total revenue from sources. The results of this application revealed three communities with a higher than desirable debt service to revenue ratio; those communities were Hewitt, Lacy-Lakeview and Waco.

In short, the financial position of Bosque and McLennan Counties is good. Both have strong credit ratings and if needed, have ample tax margins allowing major increases in property tax revenues. The subject municipalities are also in good financial condition, with relatively low property tax rates, ample tax margins and low per capita debt ratios.

Table 5-6. Land Values for Proposed Lake Bosque Site

ID #	Landowner	Abstract	Total Acres	Land Use	Market Value	Production Value	Assessed Value	Taxable Value
A-183	MCKNIGHT, LELA	NICHOLS, E.B.	1	HS	$236,550	- -	$236,550	$236,550
A-183	MCKNIGHT, LELA	NICHOLS, E. B.	1	HS	$36,890	- -	$36,890	$36,890
A-183	MCKNIGHT, LELA	NICHOLS, E.B/GREEN	875	AG	$688,790	$87,590	$139,520	$139,520
A-183	MCKNIGHT, LELA	HOLLINGSWORTH JAS.	253	AG	$194,180	$15,470	$15,470	$15,470
A-183	MCKNIGHT, LELA	HOLLINGSWORTH JAS.	1	HS	$23,350	- -	$23,350	$23,350
A-183	MCKNIGHT, LELA	JAMES ROURKE	1	HS	$23,150	- -	$23,150	$23,150
A-183	MCKNIGHT, LELA	JAMES ROURKE	390	AG	$296,810	$22,360	$24,160	$24,160
A-183	MCKNIGHT, LELA	J. GRIFFEN	417	AG	$315,750	$22,370	$33,950	$33,950
A-183	MCKNIGHT, LELA	L. DAVIS	741	AG	$591,470	$76,530	$144,810	$144,810
A-183	MCKNIGHT, LELA	L. DAVIS	1	HS	$26,300	- -	$26,300	$26,300
A-183	MCKNIGHT, LELA	L. DAVIS	1	HS	$28,390	- -	$28,390	$28,390
A-183	*TOTAL- MCKNIGHT, LELA*	- -	*2,681*		*$2,461,430*	*$224,320*	*$732,540*	*$732,540*
A-209	COCHRAN, JIM	NA	NA	NA	NA	NA	NA	NA
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	440	AG	$338,700	$41,180	$49,260	$49,260
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	1	HS	$11,310	- -	$11,310	$11,310
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	1	HS	$44,240	- -	$44,240	$29,240
A-252	MARTIN, CHARLOTTE	JAS. HOLLINGSWORTH	720	AG	NA	- -	- -	- -
A-26	GAUNTT, H.W.	NA	100	AG	$69,000	$4,700	$4,700	$4,700
A-266	RICH, EARL E.	J. GRIFFEN	100	AG	$73,960	$5,870	$9,170	$9,170
A-266	RICH, EARL E.	J. GRIFFEN	1	HS	$33,470	- -	$33,470	$33,470
A-277	HILLARD C.T.	NA	NA	NA	NA	NA	NA	NA
A-286	MOORE, PAUL	DAVID RYAN	152	AG	$117,950	$13,440	$13,440	$13,440
A-286	MOORE, PAUL	DAVID RYAN	1	HS	$23,550	- -	$23,550	$23,550
A-290	GILLELAND, A. J.	JOHN GRIFFEN	49	AG	$38,200	$3,950	$7,580	$7,580
A-290	GILLELAND, A. J.	JOHN GRIFFEN	1	HS	$35,070	- -	$35,070	$35,070
A-291	SPEER, BIRDIE	NA	103	AG	NA	- -	- -	- -
A-295	VICKERY, JACK	DAVID GREEN	68	AG	$51,000	$3,740	$3,740	$3,740
A-295	VICKERY, JACK	DAVID GREEN	1	HS	NA	- -	- -	- -
A-296	REEVES, CHARLES H.	J. GRIFFEN	99	AG	$44,380	$4,370	$4,780	$4,780
A-296	REEVES, CHARLES H.	J. GRIFFEN	1	HS	$50,350	- -	$50,350	$5,000
A-30	MONNICH, DAVID H.	JONATHON HOAK	69	AG	$5,280	$4,180	$14,180	$14,180
A-300	LEATHERWOOD, W. J.	WM. B. LOFTON	186	AG	$142,130	$14,650	$28,110	$28,110
A-305	NA	NA	NA	NA	NA	NA	NA	NA
A-309	CAREY, DAN B.	NA	NA	NA	NA	NA	NA	NA
A-318	NICKELS, ROY L.	JUANA DIAZ	533	AG	$169,890	$15,040	$22,170	$22,170
A-318	NICKELS, ROY L.	JUANA DIAZ	1	HS	$15,190	- -	$15,190	$15,190
A-319	HENDRIX, DAVID M. JR.	LITTLE JONAS	106	AG	$80,980	$6,680	$6,680	$6,680
A-319	HENDRIX, DAVID M. JR.	C.E. ANDERSON	205	AG	$162,750	$20,030	$20,030	$20,030
A-319	HENDRIX, DAVID M. JR.	JOHN GRIFFIN SR.	366	AG	$286,580	$27,810	$80,160	$80,160
A-319	HENDRIX, DAVID M. JR.	JOHN GRIFFIN SR.	1	HS	$27,190	- -	$27,190	$27,190
A-323	KLUTS, FRED	NA	42	NA	NA	NA	NA	NA
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	1	HS	$21,980	- -	$21,980	$21,980
A-325	THOMPSON, JOHN R.	JAMES ROURKE	146	AG	$109,770	$11,390	$11,390	$11,390
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	5	AG	$9,450	$690	$690	$690
A-325	THOMPSON, JOHN R.	EDWARDS, T. E.	15	AG	$11,560	$850	$850	$850
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	781	AG	$590,830	$58,820	$82,160	$82,610
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	1	AG	$60,490	$0	$60,490	$60,490
A-339	BARTON, DAVID B.	NA	11	NA	NA	NA	NA	NA
A-379	PIERCE, J.V.	HOLLINGSWORTH JAS.	57	AG	$44,380	$4,370	$4,780	$4,780
A-379	PIERCE, J.V.	HOLLINGSWORTH JAS.	1	HS	$50,300	- -	$50,300	$5,000
A-414	MCKNIGHT, DAVID	HOLLINGSWORTH, JAS	38	AG	$28,830	$2,110	$2,110	$2,110
A-56	WEBB, MAE	JOHNATHON HOAK	140					
A-58	HOWARD, T.D.	BAKER, HANCE	156	AG	$116,930	$7,020	$7,570	$7,570
A-65	MOORE, ERVIN W.	JOHNATHON HOAK	121	AG	$93,310	$8,090	$16,150	$16,150
A-700	NA	NA	NA	NA	NA	NA	NA	NA
A-701	NA	NA	NA	NA	NA	NA	NA	NA
A-702	NA	NA	NA	NA	NA	NA	NA	NA
A-703	NA	NA	NA	NA	NA	NA	NA	NA
A-704	JAGGERS, W. FRED	WILLIAM RIDDLES	50	AG	$37,500	$2,750	$2,750	$2,750
A-704	NA	NA	NA	NA	NA	NA	NA	NA
A-73	WOODY, H. E.	NA	NA	NA	NA	NA	NA	NA
A-76	FOSTER, RANDELL R.	NA	NA	NA	NA	NA	NA	NA
A-84	O'BRIAN, FOSTER D.	NA	44	NA	NA	NA	NA	NA
A-88	HOLLAN, CHARLES N.	GEO. LAWERENCE	150	AG	$112,880	$6,770	$6,770	$6,770
A-91	PIKE ALBERT	BAKER, HANCE	42	AG	$31,780	$2,800	$2,800	$3,620
B-277	BEECHERL, LOUIS A. JR.	DAVID RYAN	262	AG	$196,820	$14,430	$14,430	$14,320
C-1	NA	NA	NA	NA	NA	NA	NA	NA
C-128	HANNA, JEFFEIE F.	WILLIAM PARVIN	3	HS	$78,280	- -	$78,280	$78,280
C-128	HANNA, JEFFEIE F.	WILLIAM PARVIN	160	AG	NA	NA	NA	NA

Table 5-6. (continued)

ID #	Landowner	Abstract	Total Acres	Land Use	Market Value	Production Value	Assessed Value	Taxable Value
C-14	JENKINS, TOM Z.	JOHN K. MCLENNAN	67	AG	$51,650	$6,350	$9,140	$9,140
C-14	JENKINS, TOM Z.	JOHN K. MCLENNAN	1	HS	$16,270	- -	$16,270	$16,270
C-154	NAGEL, RICHARD C.	JESSE P. HITCHCOCK	166	AG	$129,360	$13,310	$19,540	$19,540
C-154	NAGEL, RICHARD C.	JESSE P. HITCHCOCK	1	HS	$14,960	- -	$14,960	$14,960
C-19	VICK, THOMAS	SAMUEL K. LEWIS	253	AG	$196,100	$23,140	$53,270	$53,270
C-19	VICK, THOMAS	SAMUEL K. LEWIS	1	HS	$84,460	- -	$84,460	$5,000
C-196	ALLEN, EUGENE	WILLIAM MEDLIN	237	AG	$179,000	$14,860	$14,860	$14,860
C-197	LACY-FEED CO.	J. HOWE	1	HS	$14,360	- -	$14,360	$14,360
C-197	LACY-FEED CO.	J. HOWE	179	AG	$119,330	$8,750	$368,260	$368,260
C-204	MANISON, THOMAS	ANDREW H. LONG	90	AG	$80,720	$16,140	$16,140	$16,140
C-204	MANISON, THOMAS	ANDREW H. LONG	1	HS	$75,040	- -	$75,040	$75,040
C-204	MANISON, THOMAS	ANDREW H. LONG	1	HS	$23,230	- -	$23,230	$23,230
C-204	MANISON, THOMAS	ANDREW H. LONG	1	HS	$23,650	- -	$23,650	$23,650
C-204	MANISON, THOMAS	ANDREW H. LONG	1,213	AG	$917,470	$82,020	$82,020	$82,020
C-205	HARDCASTLE, J.W.	LONG, ANDREW H.	137	AG	$102,900	$6,170	$6,170	$6,170
C-210	GRIMM, FURMAN A.	RUNDEL BENJ. F.	95	AG	$73,070	$6,800	$6,800	$6,800
C-23	HAMILTON, J.J.	DANIEL C. THOMAS	88	AG	NA	NA	NA	NA
C-27	HALL, GLADYS	DANIEL C. THOMAS	17	AG	$13,390	$1,300	$1,300	$1,300
C-27	HALL, GLADYS	WM. ECHELBERGER	102	AG	$79,250	$7,800	$9,780	$9,780
C-27	HALL, GLADYS	WM. ECHELBERGER	1	HS	$21,290	- -	$21,290	$21,290
C-27	HALL, GLADYS	HITCHCOCK, JESSE B.	40	AG	$31,020	$3,050	$3,050	$3,050
C-33	RANDOLPH, ROBERT M.	NA	NA	NA	NA	NA	NA	NA
C-41	FARRELL, B.E.	DAVID D. GREEN	157	AG	$117,750	$8,640	$8,640	$8,640
C-41	FARRELL, B.E.	JACOB, EYLER	692	AG	$525,150	$43,300	$43,300	$43,300
C-418	GIPSON, WILLIAM E.	WM. ECHELBERGER	263	AG	$200,690	$20,770	$24,230	$24,230
C-418	GIPSON, WILLIAM E.	JESSE P. HITCHCOCK	120	AG	$89,760	$6,580	$6,580	$6,580
C-44	WILLIAMS, HARVEY	WM. PARVIN	466	AG	$349,500	$20,970	$31,920	$31,920
C-44	WILLIAMS, HARVEY	WM. PARVIN	1	HS	$50,735	- -	$50,735	$51,735
C-450	MORRIS, ROBERT	BENJ. L. RUNDEL	100	AG	NA	NA	NA	NA
C-493	REINKE, ERNEST W. JR.	PATCHING, L.Y. DEC'D	1	HS	$69,040	- -	$69,040	$69,040
C-493	REINKE, ERNEST W. JR.	PATCHING, L.Y. DEC'D	159	AG	$122,780	$14,910	$20,260	$20,260
C-59	HARDCASTLE B.R.	JESSE HITCHCOCK	40	NA	NA	NA	NA	NA
C-59	HARDCASTLE B. R.	SAMUEL K. LEWIS	178	AG	$138,390	$11,720	$11,720	$11,720
C-59	HARDCASTLE B. R.	RUNDEL, BENJ. F.	16	AG	$12,530	$1,340	$1,340	$1,340
C-66	BICE, DON	HOWE, JAMES	70	AG	$52,550	$69,040	$69,040	$3,850
C-68	ROYAL, EARL	DANIEL C. THOMAS	200	AG	NA	NA	NA	NA
C-700	NA	NA	NA	NA	NA	NA	NA	NA
C-701	NA	NA	NA	NA	NA	NA	NA	NA
D-196	HAMPE, LOUISE L., & A.W.	DANIEL C. THOMAS	1	HS	$11,090	- -	$11,090	$11,090
D-196	HAMPE, LOUISE L., & A.W.	DANIEL C. THOMAS	117	AG	$88,470	$6,130	$6,130	$6,130
D-196	HAMPE, LOUISE L., & A.W.	SAMUEL K. LEWIS	143	AG	$108,180	$9,630	$9,630	$9,630
	TOTAL		13,629		$10,060,825	$912,770	$2,827,655	$2,579,515
	Lake Bosque acreage (proposed) (Δ)		6,143					
	Percent of Landowners' Total Acreage		45%					
	Percent of Dollar Values Removed By Proposed Proj		45%		$4,527,371	$410,747	$1,272,445	$1,160,782

Notes: Na = not available, Ag = agriculture, HS = homesite, NHS = not a homesite.
Source: Bosque County Appraisal District, (Δ) Technical Consulting Associates, 1985.

6.0 RECREATION AND AESTHETICS

6.1 INTRODUCTION

This section provides a baseline from which to assess the impact of the proposed reservoir on recreation and aesthetics in the study area. Recreational demand was described in terms of baseline conditions and projected needs for future populations. Regional recreational facilities were identified and characterized in terms of use statistics. The primary source of information was the 1985 Texas Outdoor Recreation Plan. The existing visual environment was evaluated with respect to standard aesthetic parameters including uniqueness, diversity, landforms and historic value by sampling a representative selection of viewsheds.

6.2 RECREATION

6.2.1 The Texas Outdoor Recreation Plan

The 1985 Texas Outdoor Recreation Plan (TORP) is the fifth statewide comprehensive outdoor recreation plan since 1965. The goal of the plan is to improve the outdoor recreation opportunities preferred by Texas residents and visitors. Objectives of the plan are numerous, however, the most important in relation to the proposed Bosque Reservoir are the issues of optimal utilization of resources for outdoor recreation and the coordination of outdoor recreation planning in Texas. TORP highlights four recreation issues and problems specific to the Heart of Texas, Region 11, in which the proposed Lake Bosque lies.

The first issue concerns the recreational needs of the elderly. In 1980, 17% of the region's population were 65 years or older, compared to 10% statewide. Population projections indicate that this trend will continue. Therefore, TORP recommends active support of facilities and programs that cater to senior citizens, i.e.: trails with benches, community centers, shaded picnic areas, gardening and birdwatching programs.

The second issue concerns municipal budgets that do not include parks and recreation directors or provisions for future expansion of park systems. To reduce budget constraints TORP recommends alternative funding sources, such as fundraising events, civic support and fee systems.

The third issue is that of vandalism and crime in parks. Vandalism is costly, repairs drain funds away from new facilities and park acquisitions. Real or perceived threats of crime keep park users away and reduce the attractiveness of parks. TORP notes that some park managers with hopes of discouraging crime and vandalism have started special programs and events with the intent of attracting more families to parks.

The fourth and perhaps most pertinent issue in relation to the Lake Bosque project, is that public access to water for swimming, boating and fishing is limited. TORP states that increased public access to water is crucial in meeting Region 11's recreational needs. Despite the numerous lakes in Region 11 public access is so limited that of the 24 TORP regions only 2 others show a greater needs per thousand population for freshwater swimming areas. An additional problem is the lack of storage facilities, slips and stalls capable of handling large boats.

6.2.2 Recreational Resources

6.2.2.1 Land and Water

Figure 6 - 1 shows the Texas Outdoor Recreation Plan Heart of Texas, Region 11 in which the study area is located. Also shown are the region's State recreational and historical areas and facilities as compiled by the U.S. Army Corps of Engineers (USCE). Table 6 - 1 lists the recreational and historic areas and facilities found in Region 11. In Table 6 - 1, the numbers next to the recreational areas correspond to the sites marked in Figure 6 - 1.

Table 6 - 1

Heart of Texas, Region 11, Recreational Resources

Parks & Recreation Areas	Streams	Lakes
Fairfield Lake State Rec. Area (1)	Bosque River	Fairfield Lake
Fort Parker State Rec. Area (2)	Brazos River	Fort Parker State Park Lake
Jeff Davis State Rec. Area (3)	Hog Creek	Lake Limestone
Lake Whitney State Rec. Area (4)	Navasota River	Lake Mexia
Meridian State Rec. Area (5)	Nolan River	Lake Waco
Confederate Reunion Grounds State Historical Park (1)	Richland Creek	Lake Whitney
Old Fort Parker State Historic Site (2)	Trinity River	Tradinghouse Creek Reservoir

Land

6 counties
5,560 square miles
Recreation Land 40,132 acres
Developed Recreation Land 7,834 acres
Elevation: 300' - 1,200'

Source: Texas Outdoor Recreation Plan, 1985

As detailed in Table 6 - 1, Region 11 includes 6 counties, Bosque, McLennan , Hill, Falls, Limestone and Freestone. The region covers 5,560 square miles, of which 40,132 acres or 1% were designated by TORP as recreational acres. Of the recreation land, 7,834 acres or 19% were classified as developed recreation land. The term developed recreation land describes land developed for recreational

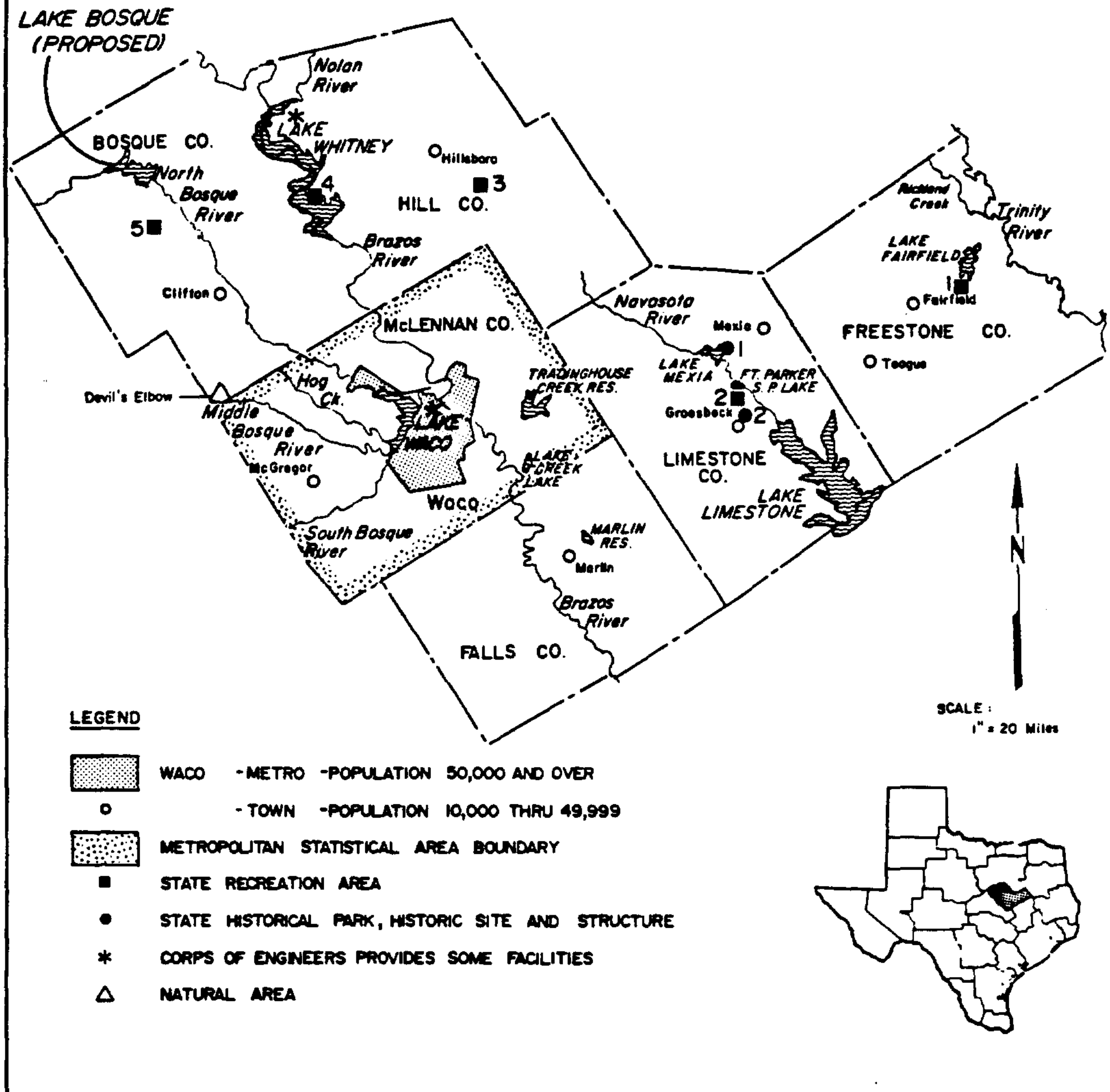


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Figure 6-1

Heart of Texas, Region II

source: Texas Outdoor Recreation Plan, 1985 purposes, included are nature trails but not land adjacent to them, excluded are open areas unless specifically designed to provide recreation. The region contains seven lakes or reservoirs which cover 50,885 surface acres.

The USCE owns 63% of the region's recreation land acres, most of which are located adjacent to Lakes Whitney and Waco. The bulk of the regional population is within an hours drive of the most popular lake resources. Compared to the State, Region 11 has an above average number of parks for its population . The federal government supplies the greatest share of developed parkland, about 35%, but the local sector manages 55% of the parks in the region and maintains the greatest number of facilities. Texas Parks and Wildlife Department attracts visitors to the region with seven park sites, but the state sector, including river authorities, only supplies 9% of the developed recreation land (TORP).

6.2.2.2 Regional Recreation Attractions

Within Region 11 there are many regional recreation attractions. In contrast to the neighborhood park which generally attracts users from the immediate local area, regional recreation attraction areas serve the recreational needs of a large area and attract visitors from far away. TORP identifies nine regional recreation attractions in Region 11: five recreation areas, two historic parks and two park systems around Lake Waco and Lake Whitney. In Bosque County, Meridian State Park is considered a recreational attraction. Water regional attractions include five rivers: the Bosque (Main, Middle, and North Forks), Brazos, Navasota, Nolan, and the Trinity; two creeks: the Hog and Richland; and seven lakes or reservoirs covering 50,885 surface acres. None of the waterways are recommended for inclusion in a natural river system, presumably due to the degree of adjacent development and lack of significant features. Three of the rivers (the Brazos, Richland Creek and the Trinity) are considered permanently floatable while the remainder (the Bosque River and its Middle and North Forks, Hogg Creek, Navasota Creek, Navasota River, and the Nolan River) are considered seasonably floatable, primarily after rains. As is typical in Texas, public access to the rivers is severely restricted.

6.2.2.3 Natural Areas

Region 11 contains five "natural areas" or sites which represent a partial inventory of the state's natural areas and are significant for their relatively undisturbed ecosystems. Those five natural areas include the Balcones Escarpment, Bird Hollow, Bluff Creek, Devil's Elbow, and Caney Creek Triangle. The first three of those regions are in McLennan County, Devil's Elbow straddles the Bosque and McLennan County border, and Caney Creek Triangle is in Freestone County. Devil's Elbow is located on private property in the northwest corner of McLennan County adjacent to Bosque County on the Middle Bosque River (see Figure 6 - 1). The three mile long area includes floodplain lands and canyon walls and is described by the 1973 Texas Natural Areas Survey as the most scenic of McLennan County's limestone canyons.

TORP designates four areas as potential trail development sites because of their scenic or historic qualities and/or linear characteristics. Two of the trail sites are in McLennan County, one is in Bosque County and one in both counties. Those sites are:

> The Brazos River Corridor, (McLennan County). Along both banks of the river and Lake Brazos from the dam upstream to the Bosque River confluence. 18 miles of bike, hike, nature study and walking trials.
>
> Lake Waco, (McLennan County). Following the shoreline of Lake Waco. 60 miles of backpacking, hiking and horseback riding.
>
> Lake Whitney, (Hill and Bosque Counties). 28 miles of backpacking, hiking, horseback riding, and nature study trails.
>
> Morgan to Waco, (Bosque, Hill and McLennan Counties). 47 miles of bike, hiking and horseback riding trail following an abandoned railroad ROW from Morgan to Whitney to Waco.

6.2.3 Recreational Demand

TORP projections[1] indicate that in 1990 the top ranking activities in Region 11, in terms of percent of the population participating, are walking, fishing, picnicking, swimming in freshwater and camping. The popularity of these activities which are less strenuous and more relaxing than most may be influenced by the high numbers of senior citizens in the region.

Region 11 is characterized by an above average participation in water related activities. The region ranks in the top five for boating, fishing, skiing, and swimming in freshwater.

6.2.4 Recreational Supply Deficits

TORP estimates that by 1990, Region 11 will have regional deficits for all types of facilities except boat ramps and lake acres. Compounding the problem of supply deficits is the problem of distribution and changing user needs, for example: because boaters are purchasing larger boats and despite that boat ramp access on area lakes is good, what is needed are additional storage facilities, marina slips and stalls, or dry docks that can handle boats that are too large to be pulled by an automobile.

Compared to state averages, Region 11 shows above average 1990 needs for ten facilities: baseball fields, campsites, football fields, golf holes, horseback riding trails, picnic tables, soccer fields, softball fields, swimming, walking, hiking trails. Only two other regions in the state show greater needs per thousand population for freshwater swimming areas. TORP suggests that since Region 11 has an abundance of lakes, this need can be met by improving shoreline access and designating areas for swimmers. The Bosque River used to have one public access point known as Jackson Crossing which according to

[1]TORP participation projections are based on the Texas Water Development Board High Series population projections.

local informants and other sources was a popular fishing hole and picnic spot (Technical Consulting Associates, 1985). The landowner has since closed the area to the public.

6.2.5 Torp Recommendations

TORP recommends that the federal government, because it owns the largest share of undeveloped recreation land in Region 11, should shoulder the largest role in supplying hiking and horseback riding trails. Commercial providers report the second largest inventory of undeveloped recreation land in the region. TORP recommends that this sector, especially when located on freshwater bodies, should increase its role in providing campsites, boat storage facilities, fishing and swimming access. TORP also recommends that the local sector, municipalities, civic clubs, leagues, and school districts continue their primary role in supplying sports fields and courts.

6.3 AESTHETICS

6.3.1 Introduction

An aesthetic survey of the land area included within the proposed Lake Bosque was conducted in February of 1985. Aesthetic values considered include topographical variation, prominence of water features, coloration, vegetational diversity and vividness, unique geological formations (blufflines, hilltops, exposed rock), man-made structures and uniqueness of view with respect to the region. Five viewsheds, the locations shown in Figure 6 - 1.1, were photographed and evaluated. The survey emphasized views presently available to the public along roadsides.

6.3.2 Study Area Characteristics

The surveyed area is located in a transitional zone and includes rolling pasture and farmland with interspersed forests and grasslands. The Bosque River valley characterized by river-bottom lands leveling out at about 800 feet mean elevation, is dotted with 900 - 1,050 foot high hills and encompassed by an 800 - 1,000 foot high ridge line. The areas immediately adjacent to the Bosque River are characterized by riparian woodlands, however these areas are private property and not accessible to the public. Excluding the western side of the proposed reservoir site along Highway 6 and areas where the view is obstructed by vegetation or some other object, panoramic views of the proposed reservoir site are accessible anywhere at elevations above 850 feet. Viewsheds are obstructed along Highway 6 due to intervening elevations and dense vegetation.

At the time of the survey the weather was rainy and overcast. Because of unusually heavy rainfall earlier in the month vegetation was greener than usual. Natural vegetation includes indian grass, little bluestem grass, buffalo grass, cedar, oak woodland, prickly pear cactus, pale-leaf yucca and mountain laurel. According to area promotional brochures, wildflowers grow profusely along the roadsides; in April

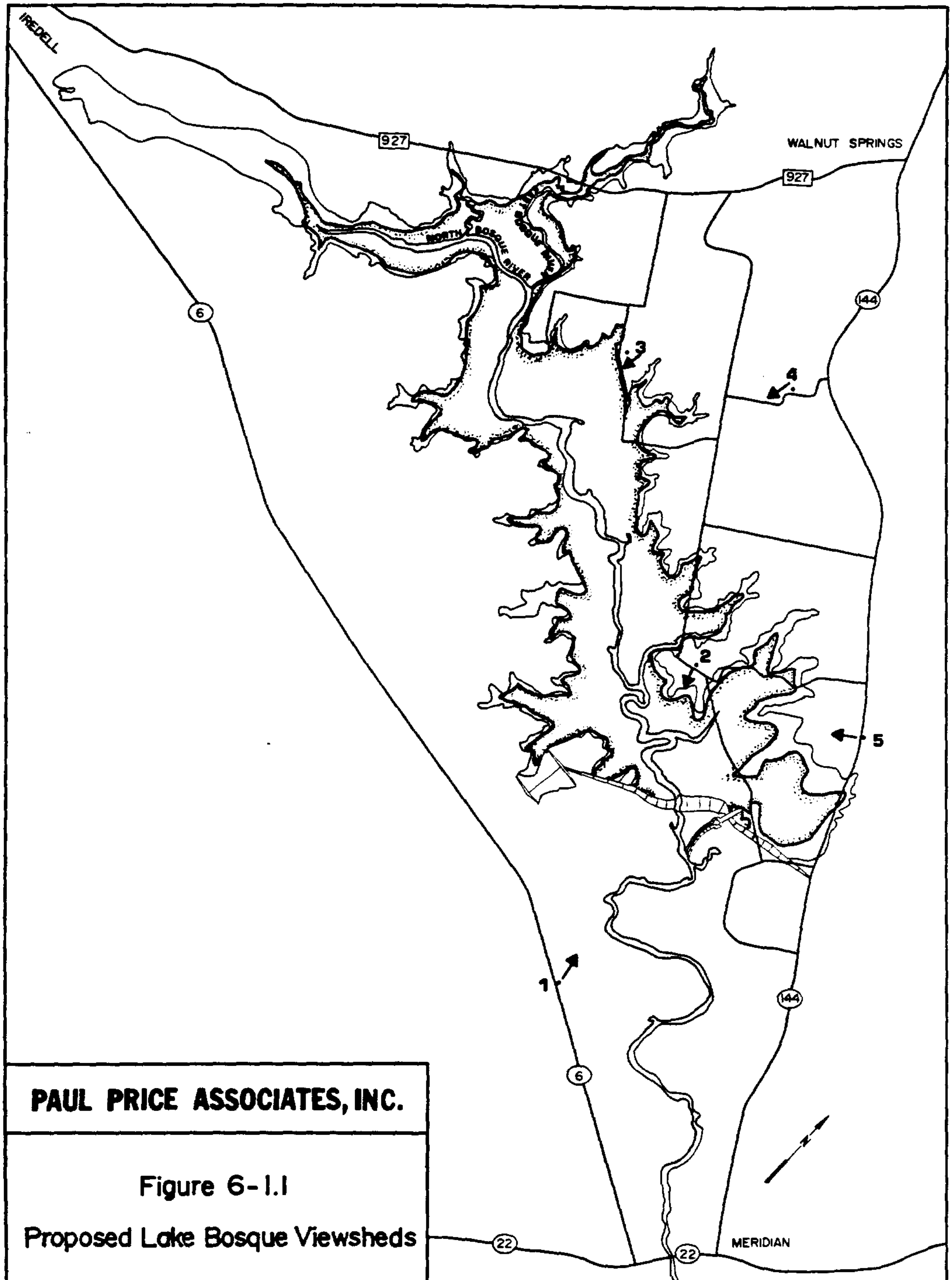

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Figure 6-1.1

Proposed Lake Bosque Viewsheds

and May, abundant species include mountain pink, indian paintbrush, bluebonnets, gaillardia and white rock daisy. Mammals common to the area are livestock, raccoons, fox, and white-tail deer. Meridian State Recreation Park, located four miles southwest of Meridian on Texas Highway 22, contains mature juniper stands, critical habitat for the rare golden-cheeked warbler, an endangered species which nests nowhere but the Edwards Plateau region of Texas. Many other birds are present including the ladder-backed woodpecker, black-capped vireo, rufous-crowned sparrow and canyon wren. In winter many waterfowl are present in areas with appropriate aquatic habitat.

6.3.3 Viewsheds

Viewshed #1 (see Figure 6 - 2) is from a Roadside Park at mean elevation 817 feet, located along Highway 6, approximately three and one-half miles northwest of Meridian, south of the proposed dam. Several covered picnic tables are available. The view, although partially obstructed by power lines and trees, provides limited visual access of the Bosque River valley croplands and pasturelands, the surrounding ridge line and the proposed reservoir site. From this vantage point 7 to 9 farm houses and accompanying structures are visible.

Viewshed #2 (Figure 6 - 3) is located one and one-half miles west of a roadway intersection approximately five miles north of Meridian on Highway 144. Elevation is about 850 feet and the viewshed is towards the southeast and encompasses the distant ridgeline and valley basin pasturelands. The area is relatively flat with some gentle increases in elevation. Barbed wire fences, farm machinery and cattle are visible.

Viewshed #3 (Figure 6 - 4) is located at the northern end of the proposed reservoir, approximately one and one-half miles south of an unmarked roadway intersection on Highway 144 two and one-quarter miles west of the intersection of Highways 144 and 927. The viewshed is directed towards the south, elevation is approximately 870 feet. Visible is river blackland soil prepared for crop planting, the

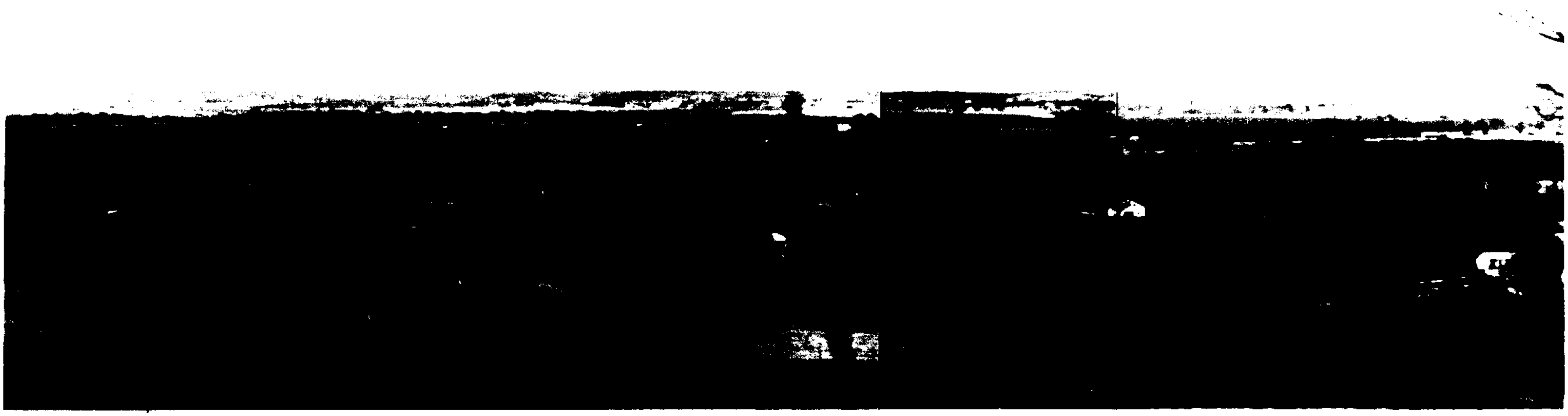
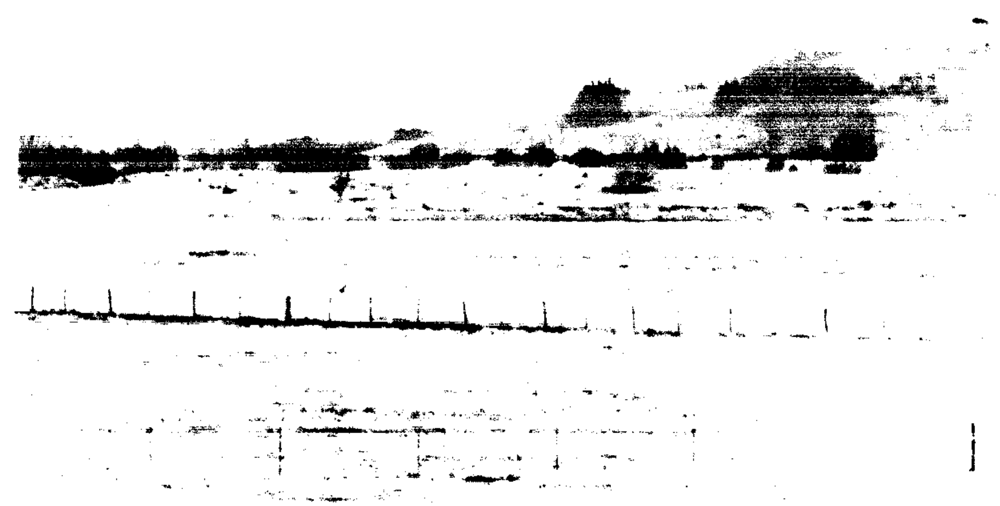


FIGURE 6-2
VIEWSHED #1



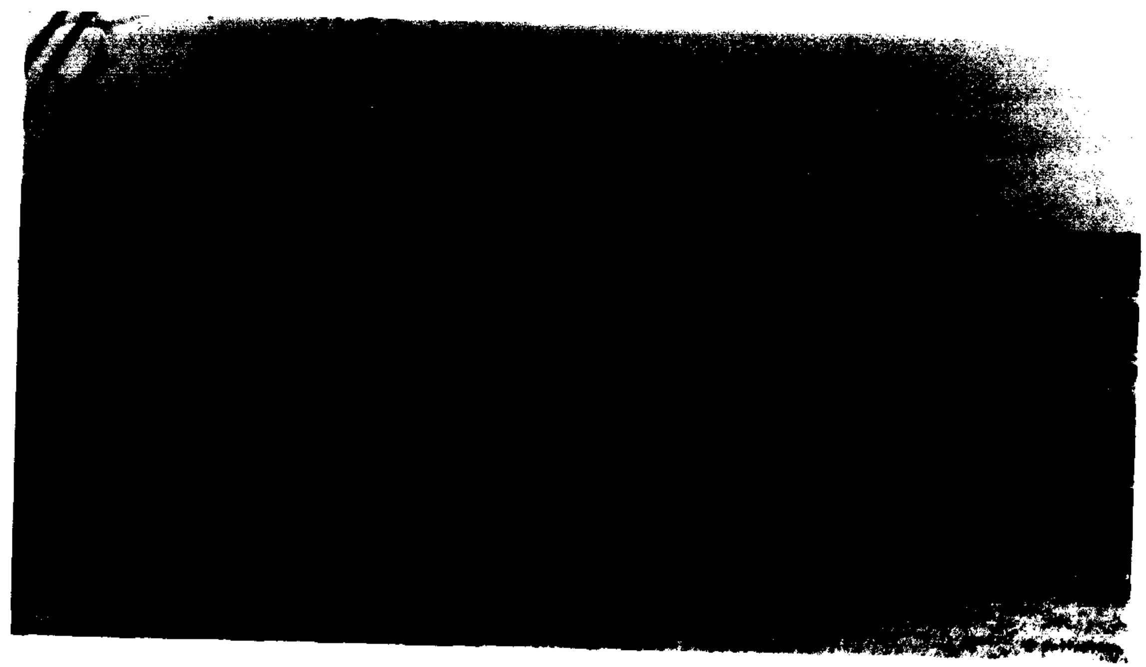


FIGURE 6-3
VIEWSHED #2

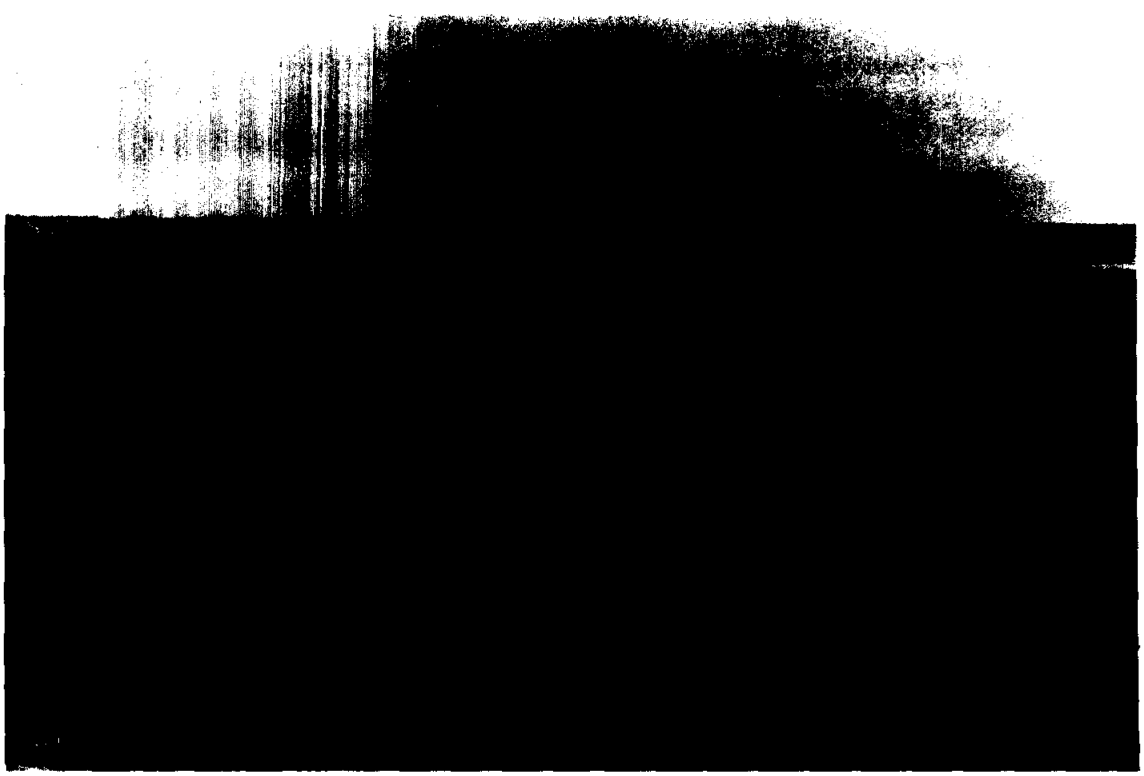


FIGURE 6-4
VIEWSHED #3

surrounding ridgeline and some trees. Access to the river is prohibited by barbed wire fences.

Viewshed #4 (Figure 6 - 5) is from a large hill (Page Hill) located approximately one-eighth of a mile west of a roadway intersection two and one-quarter miles south of the intersection of Highways 144 and 927. Public hill top access to the top of the hill is not available, roadside elevation is approximately 1,000 feet, the viewshed is westward. Visible is the valley plain and the surrounding ridgeline. The land is dotted with trees and used as pastureland and cropland.

Viewshed #5 (Figure 6 - 6) is located five miles north of Meridian along Highway 144. Elevation is approximately 900 feet, the viewshed is towards the west, and the encompassing ridge line is visible. Landscape characteristics, typical of the roadside scenery throughout the proposed Lake Bosque area, barbed wire fences, an occasional farm house, farm equipment, scrub oak, brush, cactus, pastureland and some cropland, are visible .

The scenario along Highway 6 between Meridian and Iredell, south of the proposed reservoir site, is very similar to Viewshed #5 except that pastureland is not as prominent and there are densely wooded areas that would obstruct views of the proposed reservoir.

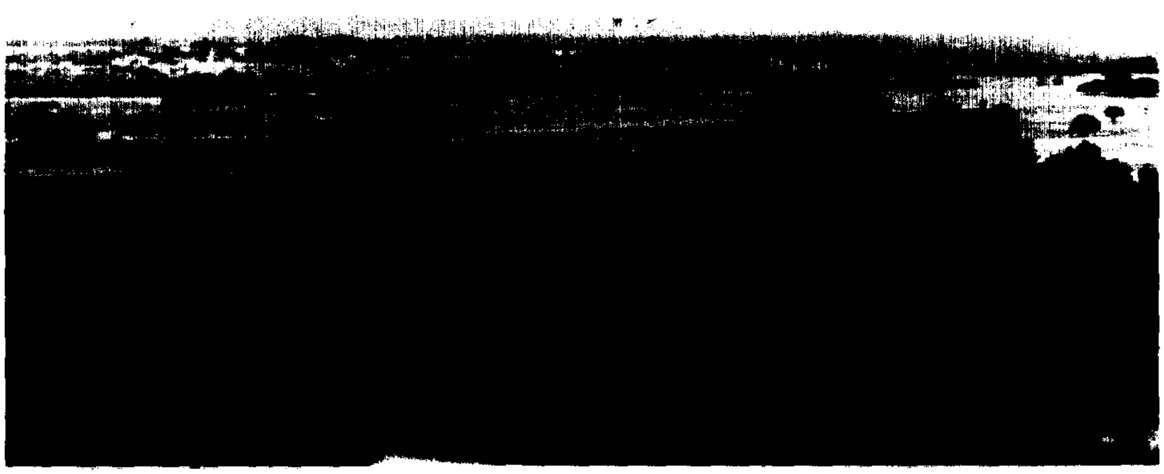


FIGURE 6-5
VIEWSHED #4

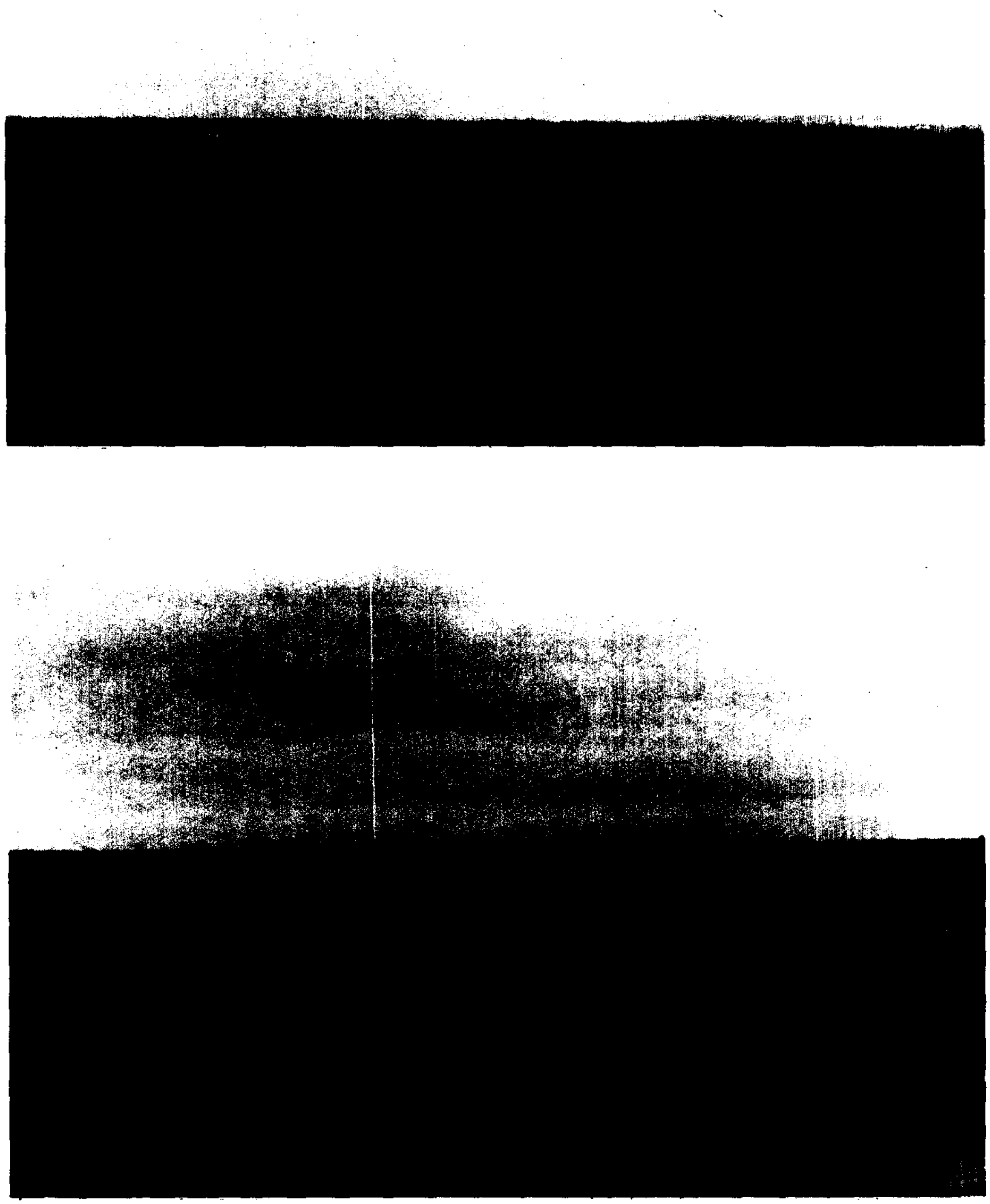


FIGURE 6-6
VIEWSHED #5

7.0 LAND USE

7.1 INTRODUCTION

This section provides a description of land uses occurring at the site of the proposed Lake Bosque. Included are Bosque County land use trends from 1958 to 1987 and land use productivity as measured by cash receipts from farm marketings from 1970 to 1985. Also shown in this section is the estimated financial impact of the proposed Lake Bosque on area land values, agricultural productivity and tax base.

7.2 CURRENT LAND USE OF PROPOSED LAKE BOSQUE SITE

Land uses identified in the evaluation of the proposed Lake Bosque site include cropland, pastureland, woodland, residential, wetlands and stockponds. The resulting land use maps (Figures 7 - 1, 7 - 2, 7 - 3) are found in the map pocket.

The identification of major land uses was determined through photo-interpretation of an October 1984 aerial photograph (1" = 1000') and a May 1985 vegetation map prepared by Technical Consulting Associates, Inc., (1" = 1000") confirmed with an on-ground survey in February 1987.

7.3 BOSQUE COUNTY LAND USE TRENDS

As shown in Table 7 - 1 Bosque County contains 595,172 acres of cropland, pastureland, hayland and rangeland. The proposed reservoir would remove about 6,143 acres or 1.03% of the county's agricultural land.

The Soil Conservation Service in Bosque County reports that as of January 9, 1987 the following land use occurred in Bosque County:

Table 7 - 1

Bosque County Land Use, 1987

Land Use	Acres	% of Total Land Use
Cropland	141,863	22%
Pasture and Hayland	50,855	8%
Otherland (includes water, urban, roads & railroads)	23,681	4%
Rangeland	402,454	63%
Recreationland	12,484	2%
Wildlife	10,000	1%
TOTAL land and water area	641,337	100%

Source: U.S. Department of Agriculture, Soil Conservation Service

Table 7 - 2 lists land use in Bosque County as reported by the Bosque County Conservation Needs Inventory for 1958 and 1967. As shown, rangeland, the major land use in the county for both time periods, accounted for 62 - 63% of all land uses. That trend has continued to 1987. The only significant change in land use in Bosque County since 1958 has been an increase in pasture and hayland and a decrease in cropland.

Table 7 - 2

Bosque County Land Use, 1958 and 1967

Land Use	Acres		% of Total Land	
	1958	1967	1958	1967
Cropland	211,587	185,499	33%	29%
Pasture and Hayland	396	8,618	0.06%	1%
Rangeland	398,904	403,423	62%	63%
Otherland (includes Federal land,water, urban, roads & railroads)	30,450	43,743	5%	7%
TOTAL land and water area	641,337	641,337	100%	100%

Source: U.S. Department of Agriculture, Soil Conservation Service
Bosque County Conservation Needs Inventory, 1958 and 1967.

7.4 LAND USE PRODUCTIVITY

7.4.1 Bosque County

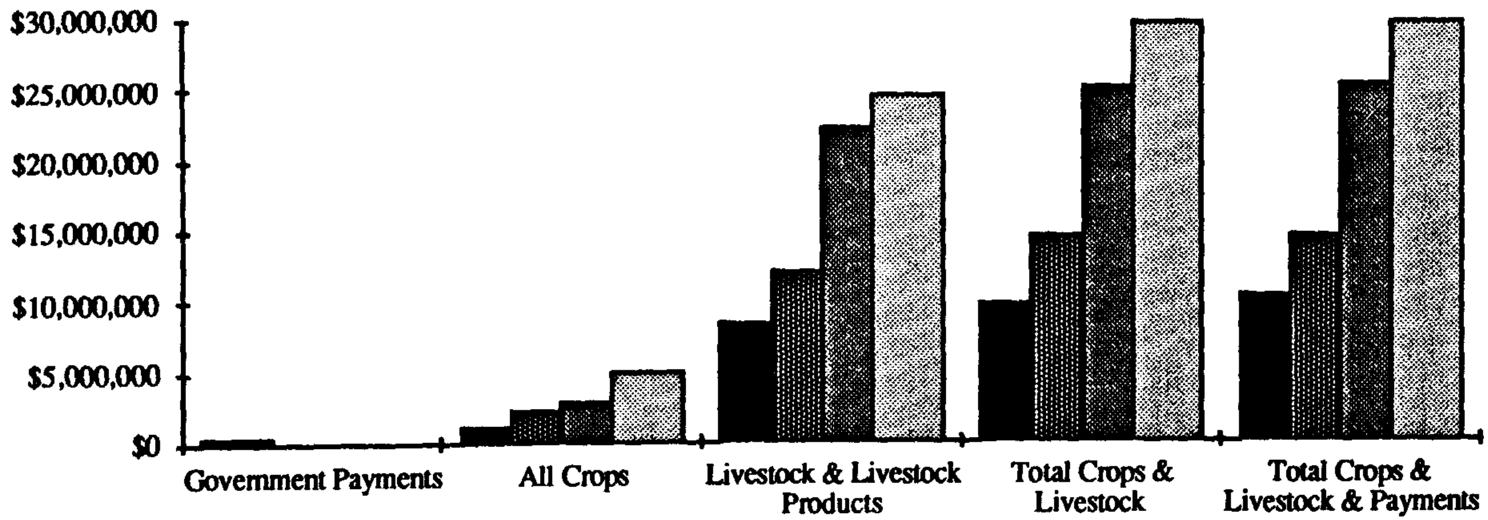
Figure 7 - 4 shows Bosque County's total cash receipts from farm marketings for 1970, 1975, 1980 and 1985. During each five year period market receipts from livestock and livestock products accounted for the majority of Bosque County total market receipts. Shown in Table 7 - 3 is Bosque County's proportion of District 4 Blacklands' total market receipts and county figures for farm marketing cash receipts from 1970 to 1985. There are 25 counties in the Blackland District, therefore, the average county should account for 4% of total cash receipts. When compared to other counties in the Blacklands Region, Bosque County's performance was slightly above average for livestock & livestock products' cash receipts and below average for crop cash receipts and total crops and livestock cash receipts.

7.4.2 Current Land Values of Proposed Lake Bosque Site

Figure 7 - 5 shows the proposed reservoir site and existing land parcels affected by the proposed conservation pool (830 ft. MSL), dam, spillways and the occasionally inundated zone between the conservation pool elevation and the 100 year flood level (841.3 ft MSL). The proposed Lake Bosque will affect approximately 6,143.8 acres of cropland, pastureland, woodlands, wetlands and at least 9 homesites. As proposed, about 4,564 acres at the 830 ft (MSL) conservation pool level will be inundated; an additional 191.46 acres will be occupied by the dam and two spillways; an,d about 1,387 acres will be included in the occasionally inundated zone between the conservation pool elevation and the 100 year flood level (841.3 ft) (Technical Consulting Associates, 1985).

Approximately 54 landowners own about 13,629 acres which will be impacted to some extent by either the proposed conservation pool, the dam and spillways or the occasionally inundated flood zone. In some cases all of a particular land parcel will be affected in other cases only a portion of the parcel.

Figure 7 - 4. Bosque County: Historic Farm Marketing Cash Receipts, 1970 - 1985



Source: United States Department of Agriculture

1970 1975 1980 1985

Table 7 - 3. Bosque County Market Cash Receipts

BOSQUE COUNTY CASH RECIEPTS FROM FARM MARKETINGS	1970	1975	1980	1985
Government Payments	$573,000	$98,000	$177,000	NA
All Crops	$1,206,000	$2,366,000	$2,958,000	$5,143,000
Livestock & Livestock Products	$8,574,000	$12,154,000	$22,058,000	$24,436,000
Total Crops & Livestock	$9,780,000	$14,520,000	$25,043,000	$29,579,000
Total Crops & Livestock & Payments	$10,353,000	$14,618,000	$25,193,000	$29,579,000

PERCENT OF DISTRICT 4 BLACKLANDS' CASH RECEIPTS FROM FARM MARKETINGS	1970	1975	1980	1985
Government Payments	1.0%	1.1%	1.4%	NA
All Crops	1.0%	1.2%	1.0%	1.4%
Livestock & Livestock Products	3.7%	3.8%	3.9%	4.3%
Total Crops & Livestock	2.8%	2.8%	2.9%	3.2%
Total Crops & Livestock & Payments	2.6%	2.8%	2.9%	NA

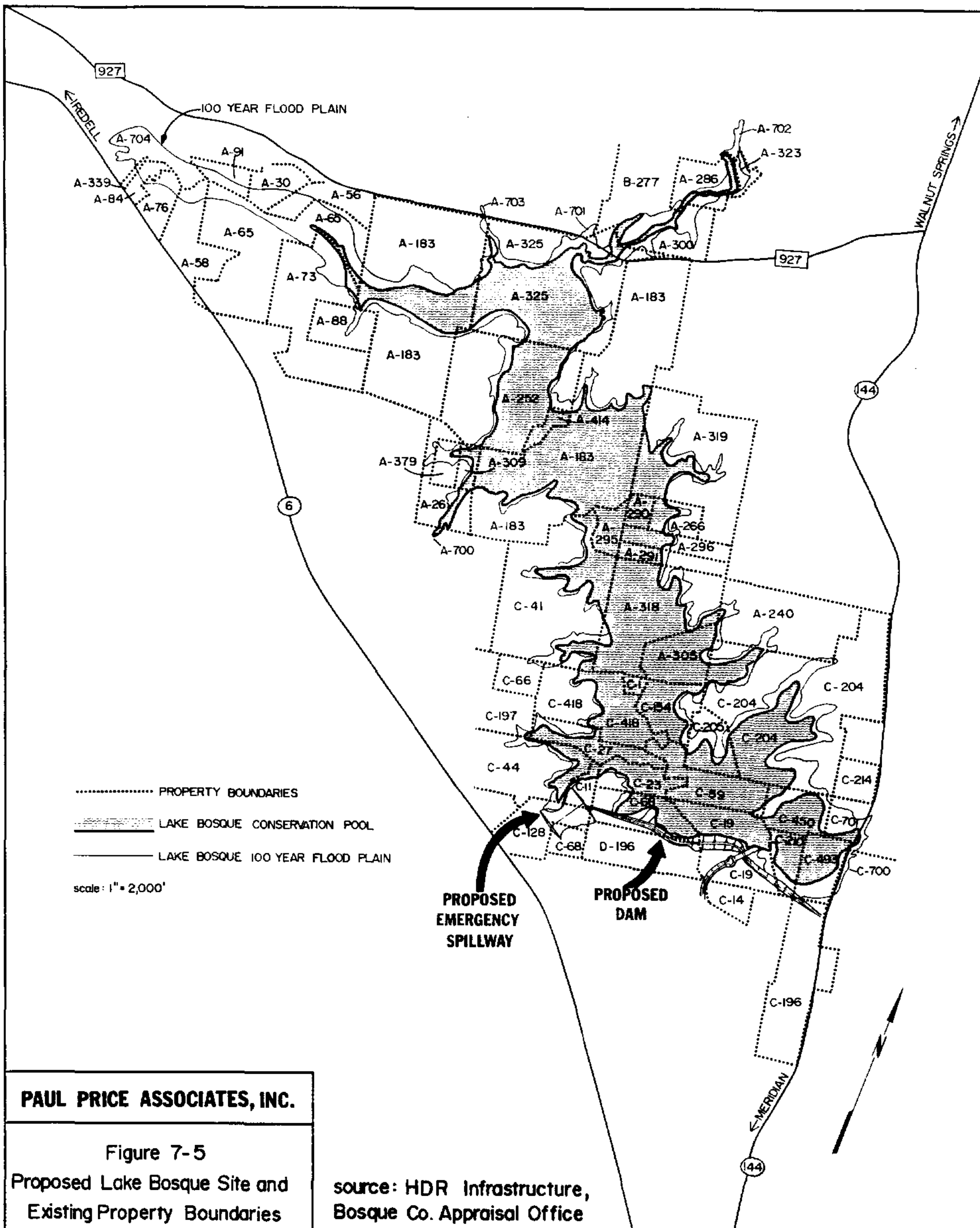
Note: NA = not available
Source: United States Department of Agriculture, Texas Crop & Livestock Reporting Service, 1987.

Seven of the 54 land parcels will be completely encompassed by the proposed project while the remaining parcels will be partially affected (Figure 7 - 5).

Information concerning some land parcels and ownership titles was not available (Audited Combined Financial Statements, Bosque County, 1985). The sum of planimetered estimates for the proportion of each land parcel affected by the proposed reservoir was not consistent with the known total acreage of the proposed reservoir and in several cases with the County Appraisal's recorded total parcel acreage. Because of these problems we were able to record information for only 80% of the land affected by the proposed reservoir.

The financial impact of the proposed reservoir on area land values and tax base was estimated by listing land parcels and their respective dollar values (market value, production value, assessed value, tax value) which lie totally or partially below the 100 year flood level (841.3 ft MSL). The acreage and dollar values of those parcels was summed and then multiplied by the ratio of the proposed reservoir acreage to the total land acreage partially or totally affected by the proposed project (the ratio is 6,143.8/13,629 or .45). As just described, about 45% of the 13,629 acres will be impacted by the proposed reservoir, dam and spillways, and occasionally inundated flood zone. Thus, approximately 45% of the summed values for the original 13,629 acres will be removed from Bosque County's tax base. Table 7 - 4 lists the reported land use of the parcel, homestead value (if applicable), the market value for the total land parcel as well as the production value, the assessed value and the taxable value. Property acreage, land value, production value, assessed and tax values were compiled from Bosque County Appraisal District's 1986 tax roles.

The Bosque County Financial Statement for year ended 1985 reports total property assessments at $385,630,342. The proposed project would remove about 6,143 acres from the county tax roles. The assessed value of property removed from the tax roles by the construction of the proposed reservoir is about 45% of the assessed value of the 13,629 acres partially affected by the project. As shown in Table 7 - 4 the assessed property value for the 13,629 acres partially affected by the proposed reservoir



PAUL PRICE ASSOCIATES, INC.

Figure 7-5
Proposed Lake Bosque Site and Existing Property Boundaries

Table 7 - 4. Land Values for Proposed Lake Bosque Site

ID #	Landowner	Abstract	Total Acres	Land Use	Market Value	Production Value	Assessed Value	Taxable Value
A-183	MCKNIGHT, LELA	NICHOLS, E.B.	1	HS	$236,550	- -	$236,550	$236,550
A-183	MCKNIGHT, LELA	NICHOLS, E. B.	1	HS	$36,890	- -	$36,890	$36,890
A-183	MCKNIGHT, LELA	NICHOLS, E.B./GREEN	875	AG	$688,790	$67,590	$139,520	$139,520
A-183	MCKNIGHT, LELA	HOLLINGSWORTH JAS.	253	AG	$194,180	$15,470	$15,470	$15,470
A-183	MCKNIGHT, LELA	HOLLINGSWORTH JAS.	1	HS	$23,350	- -	$23,350	$23,350
A-183	MCKNIGHT, LELA	JAMES ROURKE	1	HS	$23,150	- -	$23,150	$23,150
A-183	MCKNIGHT, LELA	JAMES ROURKE	390	AG	$296,610	$22,360	$24,160	$24,160
A-183	MCKNIGHT, LELA	J. GRIFFEN	417	AG	$315,750	$22,370	$33,950	$33,950
A-183	MCKNIGHT, LELA	L. DAVIS	741	AG	$591,470	$76,530	$144,810	$144,810
A-183	MCKNIGHT, LELA	L. DAVIS	1	HS	$26,300	- -	$26,300	$26,300
A-183	MCKNIGHT, LELA	L. DAVIS	1	HS	$28,390	- -	$28,390	$28,390
A-183	*TOTAL- MCKNIGHT, LELA*	- -	*2,681*		*$2,461,430*	*$224,320*	*$732,540*	*$732,540*
A-209	COCHRAN, JIM	NA	NA	NA	NA	NA	NA	NA
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	440	AG	$338,700	$41,180	$49,260	$49,260
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	1	HS	$11,310	- -	$11,310	$11,310
A-240	SCHLEGEL, N. L.	LONG, ANDREW H.	1	HS	$44,240	- -	$44,240	$29,240
A-252	MARTIN, CHARLOTTE	JAS. HOLLINGSWORTH	720	AG	NA	- -	- -	- -
A-26	GAUNTT, H.W.	NA	100	AG	$69,000	$4,700	$4,700	$4,700
A-266	RICH, EARL E.	J. GRIFFEN	100	AG	$73,960	$5,870	$9,170	$9,170
A-266	RICH, EARL E.	J. GRIFFEN	1	HS	$33,470	- -	$33,470	$33,470
A-277	HILLARD C.T.	NA	NA	NA	NA	NA	NA	NA
A-286	MOORE, PAUL	DAVID RYAN	152	AG	$117,950	$13,440	$13,440	$13,440
A-286	MOORE, PAUL	DAVID RYAN	1	HS	$23,550	- -	$23,550	$23,550
A-290	GILLELAND, A. J.	JOHN GRIFFEN	49	AG	$38,200	$3,950	$7,580	$7,580
A-290	GILLELAND, A. J.	JOHN GRIFFEN	1	HS	$35,070	- -	$35,070	$35,070
A-291	SPEER, BIRDIE	NA	103	AG	NA	- -	- -	- -
A-295	VICKERY, JACK	DAVID GREEN	68	AG	$51,000	$3,740	$3,740	$3,740
A-295	VICKERY, JACK	DAVID GREEN	1	HS	NA	- -	- -	- -
A-296	REEVES, CHARLES H.	J. GRIFFEN	99	AG	$44,380	$4,370	$4,780	$4,780
A-296	REEVES, CHARLES H.	J. GRIFFEN	1	HS	$50,350	- -	$50,350	$5,000
A-30	MONNICH, DAVID H.	JONATHON HOAK	69	AG	$5,280	$4,180	$14,180	$14,180
A-300	LEATHERWOOD, W. J.	WM. B. LOFTON	186	AG	$142,130	$14,650	$28,110	$28,110
A-305	NA	NA	NA	NA	NA	NA	NA	NA
A-309	CAREY, DAN B.	NA	NA	NA	NA	NA	NA	NA
A-318	NICKELS, ROY L.	JUANA DIAZ	533	AG	$169,890	$15,040	$22,170	$22,170
A-318	NICKELS, ROY L.	JUANA DIAZ	1	HS	$15,190	- -	$15,190	$15,190
A-319	HENDRIX, DAVID M. JR.	LITTLE JONAS	106	AG	$80,980	$6,680	$6,680	$6,680
A-319	HENDRIX, DAVID M. JR.	C.E. ANDERSON	205	AG	$162,750	$20,030	$20,030	$20,030
A-319	HENDRIX, DAVID M. JR.	JOHN GRIFFIN SR.	366	AG	$286,580	$27,810	$80,160	$80,160
A-319	HENDRIX, DAVID M. JR.	JOHN GRIFFIN SR.	1	HS	$27,190	- -	$27,190	$27,190
A-323	KLUTS, FRED	NA	42	NA	NA	NA	NA	NA
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	1	HS	$21,980	- -	$21,980	$21,980
A-325	THOMPSON, JOHN R.	JAMES ROURKE	146	AG	$109,770	$11,390	$11,390	$11,390
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	5	AG	$9,450	$690	$690	$690
A-325	THOMPSON, JOHN R.	EDWARDS, T. E.	15	AG	$11,560	$850	$850	$850
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	781	AG	$590,830	$58,820	$82,160	$82,610
A-325	THOMPSON, JOHN R.	CALVERT, HUGH H.	1	AG	$60,490	$0	$60,490	$60,490
A-339	BARTON, DAVID B.	NA	11	NA	NA	NA	NA	NA
A-379	PIERCE, J.V.	HOLLINGSWORTH JAS.	57	AG	$44,380	$4,370	$4,780	$4,780
A-379	PIERCE, J.V.	HOLLINGSWORTH JAS.	1	HS	$50,300	- -	$50,300	$5,000
A-414	MCKNIGHT, DAVID	HOLLINGSWORTH, JAS	38	AG	$28,830	$2,110	$2,110	$2,110
A-56	WEBB, MAE	JOHNATHON HOAK	140					
A-58	HOWARD, T.D.	BAKER, HANCE	156	AG	$116,930	$7,020	$7,570	$7,570
A-65	MOORE, ERVIN W.	JOHNATHON HOAK	121	AG	$93,310	$8,090	$16,150	$16,150
A-700	NA	NA	NA	NA	NA	NA	NA	NA
A-701	NA	NA	NA	NA	NA	NA	NA	NA
A-702	NA	NA	NA	NA	NA	NA	NA	NA
A-703	NA	NA	NA	NA	NA	NA	NA	NA
A-704	JAGGERS, W. FRED	WILLIAM RIDDLES	50	AG	$37,500	$2,750	$2,750	$2,750
A-704	NA	NA	NA	NA	NA	NA	NA	NA
A-73	WOODY, H. E.	NA	NA	NA	NA	NA	NA	NA
A-76	FOSTER, RANDELL R.	NA	NA	NA	NA	NA	NA	NA
A-84	O'BRIAN, FOSTER D.	NA	44	NA	NA	NA	NA	NA
A-88	HOLLAN, CHARLES N.	GEO. LAWERENCE	150	AG	$112,880	$6,770	$6,770	$6,770
A-91	PIKE ALBERT	BAKER, HANCE	42	AG	$31,780	$2,800	$2,800	$3,620
B-277	BEECHERL, LOUIS A. JR.	DAVID RYAN	262	AG	$196,820	$14,430	$14,430	$14,320
C-1	NA	NA	NA	NA	NA	NA	NA	NA
C-128	HANNA, JEFFEIE F.	WILLIAM PARVIN	3	HS	$78,280	- -	$78,280	$78,280
C-128	HANNA, JEFFEIE F.	WILLIAM PARVIN	160	AG	NA	NA	NA	NA

Table 7 - 4. (Continued) Land Values for Proposed Lake Bosque Site

ID #	Landowner	Abstract	Total Acres	Land Use	Market Value	Production Value	Assessed Value	Taxable Value
C-14	JENKINS, TOM Z.	JOHN K. MCLENNAN	67	AG	$51,650	$6,350	$9,140	$9,140
C-14	JENKINS, TOM Z.	JOHN K. MCLENNAN	1	HS	$16,270	- -	$16,270	$16,270
C-154	NAGEL, RICHARD C.	JESSE P. HITCHCOCK	166	AG	$129,360	$13,310	$19,540	$19,540
C-154	NAGEL, RICHARD C.	JESSE P. HITCHCOCK	1	HS	$14,960	- -	$14,960	$14,960
C-19	VICK, THOMAS	SAMUEL K. LEWIS	253	AG	$196,100	$23,140	$53,270	$53,270
C-19	VICK, THOMAS	SAMUEL K. LEWIS	1	HS	$84,460	- -	$84,460	$5,000
C-196	ALLEN, EUGENE	WILLIAM MEDLIN	237	AG	$179,000	$14,860	$14,860	$14,860
C-197	LACY-FEED CO.	J. HOWE	1	HS	$14,360	- -	$14,360	$14,360
C-197	LACY-FEED CO.	J. HOWE	179	AG	$119,330	$8,750	$368,260	$368,260
C-204	MANISON, THOMAS	ANDREW H. LONG	90	AG	$80,720	$16,140	$16,140	$16,140
C-204	MANISON, THOMAS	ANDREW H. LONG	, 1	HS	$75,040	- -	$75,040	$75,040
C-204	MANISON, THOMAS	ANDREW H. LONG	1	HS	$23,230	- -	$23,230	$23,230
C-204	MANISON, THOMAS	ANDREW H. LONG	1	HS	$23,650	- -	$23,650	$23,650
C-204	MANISON, THOMAS	ANDREW H. LONG	1,213	AG	$917,470	$82,020	$82,020	$82,020
C-205	HARDCASTLE, J.W.	LONG, ANDREW H.	137	AG	$102,900	$6,170	$6,170	$6,170
C-210	GRIMM, FURMAN A.	RUNDEL BENJ. F.	95	AG	$73,070	$6,800	$6,800	$6,800
C-23	HAMILTON, J.J.	DANIEL C. THOMAS	88	AG	NA	NA	NA	NA
C-27	HALL, GLADYS	DANIEL C. THOMAS	17	AG	$13,390	$1,300	$1,300	$1,300
C-27	HALL, GLADYS	WM. ECHELBERGER	102	AG	$79,250	$7,800	$9,780	$9,780
C-27	HALL, GLADYS	WM. ECHELBERGER	1	HS	$21,290	- -	$21,290	$21,290
C-27	HALL, GLADYS	HITCHCOCK, JESSE B.	40	AG	$31,020	$3,050	$3,050	$3,050
C-33	RANDOLPH, ROBERT M.	NA	NA	NA	NA	NA	NA	NA
C-41	FARRELL, B.E.	DAVID D. GREEN	157	AG	$117,750	$8,640	$8,640	$8,640
C-41	FARRELL, B.E.	JACOB, EYLER	692	AG	$525,150	$43,300	$43,300	$43,300
C-418	GIPSON, WILLIAM E.	WM. ECHELBERGER	263	AG	$200,690	$20,770	$24,230	$24,230
C-418	GIPSON, WILLIAM E.	JESSE P. HITCHCOCK	120.	AG	$89,760	$6,580	$6,580	$6,580
C-44	WILLIAMS, HARVEY	WM. PARVIN	466	AG	$349,500	$20,970	$31,920	$31,920
C-44	WILLIAMS, HARVEY	WM. PARVIN	1	HS	$50,735	- -	$50,735	$51,735
C-450	MORRIS, ROBERT	BENJ. L. RUNDEL	100	AG	NA	NA	NA	NA
C-493	REINKE, ERNEST W. JR.	PATCHING, L.Y. DEC'D	1	HS	$69,040	- -	$69,040	$69,040
C-493	REINKE, ERNEST W. JR.	PATCHING, L.Y. DEC'D	159	AG	$122,780	$14,910	$20,260	$20,260
C-59	HARDCASTLE B.R.	JESSE HITCHCOCK	40	NA	NA	NA	NA	NA
C-59	HARDCASTLE B. R.	SAMUEL K. LEWIS	178	AG	$138,390	$11,720	$11,720	$11,720
C-59	HARDCASTLE B. R.	RUNDEL, BENJ. F.	16	AG	$12,530	$1,340	$1,340	$1,340
C-66	BICE, DON	HOWE, JAMES	70	AG	$52,550	$69,040	$69,040	$3,850
C-68	ROYAL, EARL	DANIEL C. THOMAS	200	AG	NA	NA	NA	NA
C-700	NA	NA	NA	NA	NA	NA	NA	NA
C-701	NA	NA	NA	NA	NA	NA	NA	NA
D-196	HAMPE, LOUISE L. & A.W.	DANIEL C. THOMAS	1	HS	$11,090	- -	$11,090	$11,090
D-196	HAMPE, LOUISE L. & A.W.	DANIEL C. THOMAS	117	AG	$88,470	$6,130	$6,130	$6,130
D-196	HAMPE, LOUISE L. & A.W.	SAMUEL K. LEWIS	143	AG	$108,180	$9,630	$9,630	$9,630
	TOTAL		13,629		$10,080,825	$912,770	$2,827,655	$2,579,515
	Lake Bosque acreage (proposed) (Δ)		6,143					
	Percent of Landowners' Total Acreage		45%					
	Percent of Dollar Values Removed By Proposed Proj		45%		$4,527,371	$410,747	$1,272,445	$1,160,782

Notes: Na = not available, Ag = agriculture, HS = homesite, NHS = not a homesite.
Source: Bosque County Appraisal District, (Δ) Technical Consulting Associates, 1985.

was $2,827,655. Forty-five percent of the assessed valuation of the 13,629 acres is $1,272,455 or .33% of the county's tax base. Thus, the construction of the proposed reservoir would remove about .33% of the county's tax base.

Another method of estimating the value of land impacted by the proposed Lake Bosque is to multiply the average selling price of bottomland and cropland in the project area by the number of bottomland and cropland acres impacted by the proposed lake. Approximately 898.76 acres of bottomland woodland and 1,279.52 acres of cropland lie within the proposed conservation pool, the 100 year flood pool, dam and spillway area. Local realtors reported recent sales of bottomland and cropland in the project area from $1,200 to $1,500 per acre. If the maximum price of $1,500 per acre is assumed, the value of 2,178.28 acres of combined bottomland and cropland is $3,267,420.

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A.1.0 LAKE BOSQUE RESERVOIR PROJECT WATER DEMAND PROJECTION METHODOLOGY AND DATA SOURCES SUMMARY

A.1.1 DATA SOURCES

The following sources were used to prepare water demand projections, found in Tables A.1 - 1, A.1 - 2, A.1 - 3, A.1 - 4, A.1 - 5, and A.1 - 6. Population

1. Texas Water Development Board, Projections of Population and Municipal Water Requirements, High Case and Low Case.

2. Texas Water Development Board, Municipal Demand and Supply Summary, High Set Demand and Supply, 04-29-84.

3. Texas Water Development Board, County Supply and Demand Summary, High Demand Set as of 02-2-83 using 1990 supply Try-9.

4. Texas Water Development Board, revised County population projections, February 1987.

A.1.2 METHODOLOGY

Paul Price Associates' water demand projections were based on revised Texas Water Development Board Low Series Population projections and TWDB High Series water demand per capita consumption rates. This was done because the Texas Water Development Board's (TWDB) water demand projections present a worst case and a best case scenario. The high series TWDB water demand projections were based on the revised high series population projection and drought influenced per capita water consumption rates; the revised low case water demand projections were based on the low series population projection and average climate per capita water consumption rates. Paul Price Associates' water demand projections provide a more conservative scenario of future water demands by taking into account a slower population growth rate as well as drought condition per capita water demand rates.

Table A.1-1 Municipal 1980 Water Use and 1990-2040 Demand Projections

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	1980 Population	Water Use Per Capita GPD	Water Use Acre-feet per year	Water Use MGD	1990 Projected Population	Water Demand Projections Per Capita GPD	Water Demand Projections Acre-feet per year	Water Demand Projections MGD
Project Participants								
Municipal Demand								
Bellmead								
Revised TWDB High Case	7,569	117	996	0.89	10,766	162	1,954	1.74
Revised TWDB Low Case	7,569	117	996	0.89	10,249	104	1,194	1.07
Paul Price Associates Projection	7,569	117	996	0.89	10,249	162	1,860	1.66
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	1,860	1.66
Clifton								
Revised TWDB High Case	3,063	197	677	0.60	3,737	219	917	0.82
Revised TWDB Low Case	3,063	197	677	0.60	3,738	161	674	0.60
Paul Price Associates Projection	3,063	197	677	0.60	3,738	219	917	0.82
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	504	0.45
Hewitt								
Revised TWDB High Case	5,247	144	844	0.75	6,158	166	1,145	1.02
Revised TWDB Low Case	5,247	144	844	0.75	5,862	108	709	0.63
Paul Price Associates Projection	5,247	144	844	0.75	5,862	166	1,090	0.97
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	1,090	0.97
Lacy-Lakeview								
Revised TWDB High Case	2,752	207	639	0.57	3,443	181	698	0.62
Revised TWDB Low Case	2,752	207	639	0.57	3,277	123	451	0.40
Paul Price Associates Projection	2,752	207	639	0.57	3,277	181	664	0.59
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	664	0.59
Mclennan Co. WCID #2								
Revised TWDB High Case	1,300	126	183	0.16	1,275	180	257	0.23
Revised TWDB Low Case	1,300	126	183	0.16	1,213	132	179	0.16
Paul Price Associates Projection	1,300	126	183	0.16	1,213	180	245	0.22
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	62	0.05
Meridian								
Revised TWDB High Case	1,330	77	115	0.10	1,662	171	318	0.28
Revised TWDB Low Case	1,330	77	115	0.10	1,613	113	204	0.18
Paul Price Associates Projection	1,330	77	115	0.10	1,613	171	309	0.28
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	4	0.00
Waco								
Revised TWDB High Case	101,261	261	29,618	26.44	114,555	280	35,929	32.07
Revised TWDB Low Case	101,261	261	29,618	26.44	109,056	222	27,119	24.21
Paul Price Associates Projection	101,261	261	29,618	26.44	109,056	280	34,204	30.53
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	-1,709	-1.53
Woodway								
Revised TWDB High Case	7,091	213	1,695	1.51	12,170	204	2,781	2.48
Revised TWDB Low Case	7,091	213	1,695	1.51	11,586	146	1,895	1.69
Paul Price Associates Projection	7,091	213	1,695	1.51	11,586	204	2,648	2.36
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	2,648	2.36
Potential Customer Entities								
Municipal Demand								
Mart								
Revised TWDB High Case	2,324	257	669	0.60	2,669	249	744	0.66
Revised TWDB Low Case	2,324	257	669	0.60	2,541	191	544	0.49
Paul Price Associates Projection	2,324	257	669	0.60	2,541	249	709	0.63
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	709	0.63
Moody								
Revised TWDB High Case	1,385	102	159	0.14	1,730	163	316	0.28
Revised TWDB Low Case	1,385	102	159	0.14	1,707	105	201	0.18
Paul Price Associates Projection	1,385	102	159	0.14	1,707	163	312	0.28
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	312	0.28
Northcrest								
Revised TWDB High Case	1,944	79	173	0.15	3,240	162	588	0.52
Revised TWDB Low Case	1,944	79	173	0.15	3,085	104	359	0.32
Paul Price Associates Projection	1,944	79	173	0.15	3,085	162	560	0.50
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	560	0.50
Bruceville-Eddy								
Revised TWDB High Case	1,101	165	203	0.18	1,290	166	240	0.21
Revised TWDB Low Case	1,101	165	203	0.18	1,228	108	149	0.13
Paul Price Associates Projection	1,101	165	203	0.18	1,228	166	228	0.20
Projected Demand for Lake Bosque	--	--	0	0.00	--	--	228	0.20

Table A.1-1

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	2000 Projected Population	Water Demand Projections: Per Capita GPD	Water Demand Projections: Acre-feet per year	Water Demand Projections: MGD	2010 Projected Population	Water Demand Projections: Per Capita GPD	Water Demand Projections: Acre-feet per year	Water Demand Projections: MGD
Project Participants								
Municipal Demand								
Bellmead								
Revised TWDB High Case	11,708	164	2,151	1.92	12,353	164	2,269	2.03
Revised TWDB Low Case	10,961	106	1,301	1.16	11,152	106	1,324	1.18
Paul Price Associates Projection	10,961	164	2,014	1.80	11,152	164	2,049	1.83
Projected Demand for Lake Bosque	--	--	2,014	1.80	--	--	2,049	1.83
Clifton								
Revised TWDB High Case	4,793	224	1,203	1.07	5,332	224	1,338	1.19
Revised TWDB Low Case	4,244	166	789	0.70	4,750	166	883	0.79
Paul Price Associates Projection	4,244	224	1,065	0.95	4,750	224	1,192	1.06
Projected Demand for Lake Bosque	--	--	652	0.58	--	--	779	0.70
Hewitt								
Revised TWDB High Case	6,395	168	1,203	1.07	6,747	168	1,270	1.13
Revised TWDB Low Case	5,987	110	738	0.66	6,091	110	751	0.67
Paul Price Associates Projection	5,987	168	1,127	1.01	6,091	168	1,146	1.02
Projected Demand for Lake Bosque	--	--	1,127	1.01	--	--	1,146	1.02
Lacy-Lakeview								
Revised TWDB High Case	3,626	185	751	0.67	3,826	185	793	0.71
Revised TWDB Low Case	3,394	127	483	0.43	3,454	127	491	0.44
Paul Price Associates Projection	3,394	185	703	0.63	3,454	185	716	0.64
Projected Demand for Lake Bosque	--	--	703	0.63	--	--	716	0.64
Mclennan Co. WCID #2								
Revised TWDB High Case	1,286	185	266	0.24	1,357	184	280	0.25
Revised TWDB Low Case	1,203	138	186	0.17	1,224	137	188	0.17
Paul Price Associates Projection	1,203	185	249	0.22	1,224	184	252	0.23
Projected Demand for Lake Bosque	--	--	66	0.06	--	--	69	0.06
Meridian								
Revised TWDB High Case	2,142	175	420	0.37	2,383	175	467	0.42
Revised TWDB Low Case	2,383	117	312	0.28	1,978	117	259	0.23
Paul Price Associates Projection	2,383	175	467	0.42	1,978	175	388	0.35
Projected Demand for Lake Bosque	--	--	111	0.10	--	--	-10	-0.01
Waco								
Revised TWDB High Case	115,909	285	37,003	33.03	122,297	285	39,042	34.85
Revised TWDB Low Case	108,518	227	27,593	24.63	110,408	227	28,074	25.06
Paul Price Associates Projection	108,518	285	34,644	30.93	110,408	285	35,247	31.46
Projected Demand for Lake Bosque	--	--	-2,343	-2.09	--	--	-3,779	-3.37
Woodway								
Revised TWDB High Case	14,368	206	3,315	2.96	15,160	206	3,498	3.12
Revised TWDB Low Case	13,452	148	2,230	1.99	13,686	148	2,269	2.03
Paul Price Associates Projection	13,452	206	3,104	2.77	13,686	206	3,158	2.82
Projected Demand for Lake Bosque	--	--	3,104	2.77	--	--	3,158	2.82
Potential Customer Entities								
Municipal Demand								
Mart								
Revised TWDB High Case	2,718	252	767	0.68	2,868	252	810	0.72
Revised TWDB Low Case	2,545	194	553	0.49	2,590	194	563	0.50
Paul Price Associates Projection	2,545	252	718	0.64	2,590	252	731	0.65
Projected Demand for Lake Bosque	--	--	718	0.64	--	--	731	0.65
Moody								
Revised TWDB High Case	1,912	167	358	0.32	2,018	167	377	0.34
Revised TWDB Low Case	1,790	109	219	0.20	1,822	109	222	0.20
Paul Price Associates Projection	1,790	167	335	0.30	1,822	167	341	0.30
Projected Demand for Lake Bosque	--	--	335	0.30	--	--	341	0.30
Northcrest								
Revised TWDB High Case	3,741	165	691	0.62	3,947	165	730	0.65
Revised TWDB Low Case	3,503	107	420	0.37	3,563	107	427	0.38
Paul Price Associates Projection	3,503	165	647	0.58	3,563	165	659	0.59
Projected Demand for Lake Bosque	--	--	647	0.58	--	--	659	0.59
Bruceville-Eddy								
Revised TWDB High Case	1,340	168	252	0.23	1,414	168	266	0.24
Revised TWDB Low Case	1,255	110	155	0.14	1,278	110	157	0.14
Paul Price Associates Projection	1,255	168	236	0.21	1,278	168	241	0.21
Projected Demand for Lake Bosque	--	--	236	0.21	--	--	241	0.21

Table A.1-1

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	2020 Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD	2030 Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD
Project Participants								
Municipal Demand								
Bellmead								
Revised TWDB High Case	13,517	164	2,483	2.22	14,790	164	2,717	2.43
Revised TWDB Low Case	11,634	106	1,381	1.23	12,522	106	1,487	1.33
Paul Price Associates Projection	11,634	164	2,137	1.91	12,522	164	2,300	2.05
Projected Demand for Lake Bosque	--	--	2,137	1.91	--	--	2,300	2.05
Clifton								
Revised TWDB High Case	5,932	224	1,488	1.33	6,620	224	1,661	1.48
Revised TWDB Low Case	6,620	166	1,231	1.10	5,971	166	1,110	0.99
Paul Price Associates Projection	6,620	224	1,661	1.48	5,971	224	1,498	1.34
Projected Demand for Lake Bosque	--	--	1,248	1.11	--	--	1,139	1.02
Hewitt								
Revised TWDB High Case	7,383	168	1,389	1.24	8,078	168	1,520	1.36
Revised TWDB Low Case	6,355	110	783	0.70	6,839	110	843	0.75
Paul Price Associates Projection	6,355	168	1,196	1.07	6,839	168	1,287	1.15
Projected Demand for Lake Bosque	--	--	1,196	1.07	--	--	1,287	1.15
Lacy-Lakeview								
Revised TWDB High Case	4,187	185	868	0.77	4,581	185	949	0.85
Revised TWDB Low Case	3,604	127	513	0.46	3,878	127	552	0.49
Paul Price Associates Projection	3,604	185	747	0.67	3,878	185	804	0.72
Projected Demand for Lake Bosque	--	--	747	0.67	--	--	804	0.72
Mclennan Co. WCID #2								
Revised TWDB High Case	1,484	183	304	0.27	1,624	182	331	0.30
Revised TWDB Low Case	1,277	137	196	0.17	1,375	135	208	0.19
Paul Price Associates Projection	1,277	183	262	0.23	1,375	182	280	0.25
Projected Demand for Lake Bosque	--	--	79	0.07	--	--	97	0.09
Meridian								
Revised TWDB High Case	2,650	175	519	0.46	2,958	175	580	0.52
Revised TWDB Low Case	2,168	117	284	0.25	2,376	117	311	0.28
Paul Price Associates Projection	2,168	175	425	0.38	2,376	175	466	0.42
Projected Demand for Lake Bosque	--	--	-21	-0.02	--	--	-35	-0.03
Waco								
Revised TWDB High Case	133,813	285	42,719	38.13	146,413	285	46,741	41.72
Revised TWDB Low Case	115,171	227	29,285	26.14	123,961	227	31,520	28.14
Paul Price Associates Projection	115,171	285	36,767	32.82	123,961	285	39,574	35.33
Projected Demand for Lake Bosque	--	--	-5,936	-5.30	--	--	-7,151	-6.38
Woodway								
Revised TWDB High Case	16,581	206	3,826	3.42	18,143	206	4,187	3.74
Revised TWDB Low Case	16,587	148	2,750	2.45	18,149	148	3,009	2.69
Paul Price Associates Projection	14,277	206	3,294	2.94	15,366	206	3,546	3.17
Projected Demand for Lake Bosque	--	--	3,294	2.94	--	--	3,546	3.17
Potential Customer Entities								
Municipal Demand								
Mart								
Revised TWDB High Case	3,138	252	886	0.79	3,434	252	969	0.87
Revised TWDB Low Case	2,701	194	587	0.52	2,907	194	632	0.56
Paul Price Associates Projection	2,701	252	762	0.68	2,907	252	821	0.73
Projected Demand for Lake Bosque	--	--	762	0.68	--	--	821	0.73
Moody								
Revised TWDB High Case	2,208	167	413	0.37	2,416	167	452	0.40
Revised TWDB Low Case	1,900	109	232	0.21	2,045	109	250	0.22
Paul Price Associates Projection	1,900	167	355	0.32	2,045	167	383	0.34
Projected Demand for Lake Bosque	--	--	355	0.32	--	--	383	0.34
					--	--	383	0.34
Northcrest								
Revised TWDB High Case	4,319	165	798	0.71	4,725	164	868	0.77
Revised TWDB Low Case	3,716	107	445	0.40	4,000	107	479	0.43
Paul Price Associates Projection	3,716	165	687	0.61	4,000	164	735	0.66
Projected Demand for Lake Bosque	--	--	687	0.61	--	--	735	0.66
Bruceville-Eddy								
Revised TWDB High Case	1,547	168	291	0.26	1,692	168	318	0.28
Revised TWDB Low Case	1,332	110	164	0.15	1,434	110	177	0.16
Paul Price Associates Projection	1,332	168	251	0.22	1,434	168	270	0.24
Projected Demand for Lake Bosque	--	--	251	0.22	--	--	270	0.24

Table A.1-1

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	2040** Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD
Project Participants				
Municipal Demand				
Bellmead				
Revised TWDB High Case	16,183	164	2,973	2.65
Revised TWDB Low Case	13,478	106	1,600	1.43
Paul Price Associates Projection	13,478	164	2,476	2.21
Projected Demand for Lake Bosque	--	--	2,476	2.21
Clifton				
Revised TWDB High Case	7,388	224	1,854	1.65
Revised TWDB Low Case	6,707	166	1,247	1.11
Paul Price Associates Projection	6,707	224	1,683	1.50
Projected Demand for Lake Bosque	--	--	1,533	1.37
Hewitt				
Revised TWDB High Case	8,838	168	1,663	1.48
Revised TWDB Low Case	7,359	110	907	0.81
Paul Price Associates Projection	7,359	168	1,385	1.24
Projected Demand for Lake Bosque	--	--	1,385	1.24
Lacy-Lakeview				
Revised TWDB High Case	5,012	185	1,039	0.93
Revised TWDB Low Case	4,173	127	594	0.53
Paul Price Associates Projection	4,173	185	865	0.77
Projected Demand for Lake Bosque	--	--	865	0.77
Mclennan Co. WCID #2				
Revised TWDB High Case	1,777	182	362	0.32
Revised TWDB Low Case	1,481	135	224	0.20
Paul Price Associates Projection	1,481	182	302	0.27
Projected Demand for Lake Bosque	--	--	119	0.11
Meridian				
Revised TWDB High Case	3,303	175	647	0.58
Revised TWDB Low Case	2,604	117	341	0.30
Paul Price Associates Projection	2,604	175	510	0.46
Projected Demand for Lake Bosque	--	--	9	0.01
Waco				
Revised TWDB High Case	160,199	285	51,142	45.65
Revised TWDB Low Case	133,422	227	33,926	30.28
Paul Price Associates Projection	133,422	285	42,594	38.02
Projected Demand for Lake Bosque	--	--	-4,131	-3.69
Woodway				
Revised TWDB High Case	19,858	206	4,582	4.09
Revised TWDB Low Case	16,539	148	2,742	2.45
Paul Price Associates Projection	16,539	206	3,816	3.41
Projected Demand for Lake Bosque	--	--	3,816	3.41
Potential Customer Entities				
Municipal Demand				
Mart				
Revised TWDB High Case	3,758	252	1,061	0.95
Revised TWDB Low Case	3,128	194	680	0.61
Paul Price Associates Projection	3,128	252	883	0.79
Projected Demand for Lake Bosque	--	--	883	0.79
Moody				
Revised TWDB High Case	2,643	167	494	0.44
Revised TWDB Low Case	2,201	109	269	0.24
Paul Price Associates Projection	2,201	167	412	0.37
Projected Demand for Lake Bosque	--	--	412	0.37
Northcrest				
Revised TWDB High Case	5,169	165	955	0.85
Revised TWDB Low Case	4,305	107	516	0.46
Paul Price Associates Projection	4,305	165	796	0.71
Projected Demand for Lake Bosque	--	--	796	0.71
Bruceville-Eddy				
Revised TWDB High Case	1,851	168	348	0.31
Revised TWDB Low Case	1,545	110	190	0.17
Paul Price Associates Projection	1,545	168	291	0.26
Projected Demand for Lake Bosque	--	--	291	0.26

Table A.1-1a Summary of Municipal 1980 Water Use and 1990-2040 Demand Projections

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	1980 Population	Water Use: Per Capita GPD	Water Use: Acre-feet per year	Water Use: MGD	1990 Projected Population	Water Demand Projections: Per Capita GPD	Water Demand Projections: Acre-feet per year	Water Demand Projections: MGD	2000 Projected Population	Water Demand Projections: Per Capita GPD	Water Demand Projections: Acre-feet per year	Water Demand Projections: MGD
SUMMARY OF TOTAL DEMAND												
Project Participants												
(Excluding City of Waco)												
Revised TWDB High Case	28,352	162	5,149	4.60	39,211	184	8,070	7.20	44,318	188	9,310	8.31
Revised TWDB Low Case	28,352	162	5,149	4.60	37,538	126	5,307	4.74	41,624	130	6,039	5.39
Paul Price Associates Projection	28,352	162	5,149	4.60	37,538	184	7,732	6.90	41,624	187	8,729	7.79
Projected Demand for Lake Bosque	-	- -	0	0	-	- -	6,831	6	-	- -	7,777	7
Potential Customers												
Revised TWDB High Case	6,754	159	1,204	1.07	8,929	189	1,888	1.69	9,711	190	2,068	1.85
Revised TWDB Low Case	6,754	159	1,204	1.07	8,561	131	1,252	1.12	9,093	132	1,346	1.20
Paul Price Associates Projection	6,754	159	1,204	1.07	8,561	189	1,809	1.61	9,093	190	1,937	1.73
Projected Demand for Lake Bosque	- -	- -	0	0.00	- -	- -	1,809	1.61	- -	- -	1,937	1.73
Total Municipal Demand												
Revised TWDB High Case	35,106	162	6,353	5.67	48,140	185	9,958	8.89	54,029	188	11,379	10.16
Revised TWDB Low Case	35,106	162	6,353	5.67	46,099	127	6,559	5.86	50,717	130	7,386	6.59
Paul Price Associates Projection	35,106	162	6,353	5.67	46,099	185	9,541	8.52	50,717	188	10,666	9.52
Projected Demand for Lake Bosque	- -	- -	0	0.00	- -	- -	8,640	7.71	- -	- -	9,714	8.67
Total Municipal Demand												
(Includes the City of Waco)												
Revised TWDB High Case	136,367	235	35,971	32.11	162,695	252	45,887	40.97	169,938	254	48,382	43.19
Paul Price Associates Projection	136,367	235	35,971	32.11	155,155	252	43,745	39.05	159,235	254	45,309	40.45
Source: Texas Water Development Board Revisions 2/1987 Paul Price Associates												

Table A.1-1a

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	2010 Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD	2020 Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD	2030 Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD
SUMMARY OF TOTAL DEMAND												
Project Participants (Excluding City of Waco)												
Revised TWDB High Case	47,158	188	9,915	8.85	51,734	188	10,878	9.71	56,794	188	11,945	10.66
Revised TWDB Low Case	42,335	130	6,165	5.50	48,245	132	7,138	6.37	51,110	131	7,520	6.71
Paul Price Associates Projection	42,335	188	8,901	7.95	45,935	189	9,722	8.68	48,327	188	10,181	9.09
Projected Demand for Lake Bosque	-	--	7,907	7	-	--	8,680	8	-	--	9,138	8
Potential Customers												
Revised TWDB High Case	10,247	190	2,183	1.95	11,212	190	2,388	2.13	12,267	190	2,608	2.33
Revised TWDB Low Case	9,253	132	1,370	1.22	9,649	132	1,428	1.28	10,386	132	1,538	1.37
Paul Price Associates Projection	9,253	190	1,971	1.76	9,649	190	2,055	1.83	10,386	190	2,208	1.97
Projected Demand for Lake Bosque	--	--	1,971	1.76	--	--	2,055	1.83	--	--	2,208	1.97
Total Municipal Demand												
Revised TWDB High Case	57,405	188	12,097	10.80	62,946	188	13,267	11.84	69,061	188	14,553	12.99
Revised TWDB Low Case	51,588	130	7,535	6.73	57,894	132	8,566	7.65	61,496	131	9,057	8.09
Paul Price Associates Projection	51,588	188	10,872	9.70	57,894	188	11,778	10.51	61,496	188	12,389	11.06
Projected Demand for Lake Bosque	--	--	9,878	8.82	--	--	10,736	9.58	--	--	11,346	10.13
Total Municipal Demand (Includes the City of Waco)												
Revised TWDB High Case	179,702	254	51,140	45.65	196,759	254	55,985	49.98	215,474	254	61,294	54.72
Paul Price Associates Projection	161,996	254	46,118	41.17	173,065	250	48,545	43.34	185,457	250	51,962	46.39
Source: Texas Water Development Board Revisions 2/1987 Paul Price Associates												

Table A.1-1a

Municipal Water Use for 1980 and Revised 1990 - 2040 Demand Projections	2040** Projected Population	Water Demand Projections Per Capita GPD	Acre-feet per year	MGD
SUMMARY OF TOTAL DEMAND				
Project Participants (Excluding City of Waco)				
Revised TWDB High Case	62,359	188	13,120	11.71
Revised TWDB Low Case	52,341	131	7,655	6.83
Paul Price Associates Projection	52,341	188	11,037	9.85
Projected Demand for Lake Bosque	-	--	10,203	9.11
Potential Customers				
Revised TWDB High Case	13,421	190	2,859	2.55
Revised TWDB Low Case	11,179	132	1,655	1.48
Paul Price Associates Projection	11,179	190	2,381	2.13
Projected Demand for Lake Bosque	--	--	2,381	2.13
Total Municipal Demand				
Revised TWDB High Case	75,780	188	15,979	14.26
Revised TWDB Low Case	63,520	131	9,310	8.31
Paul Price Associates Projection	63,520	188	13,418	11.98
Projected Demand for Lake Bosque	--	--	12,584	11.23
Total Municipal Demand (Includes the City of Waco)				
Revised TWDB High Case	235,979	254	67,122	59.92
Paul Price Associates Projection	196,942	254	56,012	50.00
Source: Texas Water Development Board Revisions 2/1987 Paul Price Associates				

Table A.1-2 1980 Water Use and 1990-2040 Demand Projections for the User Category of Other

Bosque and McLennan County Other 1980 Water Use and Revised 1990-2040 Demand Projections	1980	Water Use			1990	Water Projections		
	Population	Per Capita *GPD*	*Acre-feet per year*	*MGD*	Projected Population	Per Capita *GPD*	*Acre-feet per year*	*MGD*
County Other Demand (Rural)								
McLennan County Other								
Revised TWDB High Series	24,925	125	3,501	3.13	24,432	180	4,929	4.40
Revised TWDB Low Series	24,925	125	3,501	3.13	23,259	133	3,467	3.10
Bosque County Other								
Revised TWDB High Series	7,782	108	941	0.84	8,739	161	1,577	1.41
Revised TWDB Low Series	7,782	108	941	0.84	8,483	113	1,075	0.96
Paul Price Associates Projected County Other Demand								
McLennan Co. High Demand	24,925	125	3,501	3.13	24,432	180	4,926	4.40
Low Demand	24,925	125	3,501	3.13	23,259	180	4,690	4.19
Bosque County High Demand	7,782	108	941	0.84	8,739	161	1,576	1.41
Low Demand	7,782	108	941	0.84	8,483	161	1,530	1.37
Total high Demand	32,707	- -	4,442	3.97	33,171	- -	6,502	5.80
Total Low Demand	32,707	- -	4,442	3.97	31,742	- -	6,220	5.55
Paul Price Associates Projected Other Demand for Lake Bosque Water								
McLennan County								
High	- -	- -	- -	- -	- -	- -	4,382	3.91
Low	- -	- -	- -	- -	- -	- -	4,146	3.70
Bosque County								
High	- -	- -	- -	- -	- -	- -	70	0.06
Low	- -	- -	- -	- -	- -	- -	24	0.02
Source: Texas Water Development Board; Paul Price Associates, Inc.; TWDB Population Revisions 2/1987								

Table A.1-2

Bosque and McLennan County Other 1980 Water Use and Revised 1990-2040 Demand Projections	2000	Water Projections			2010	Water Projections		
	Projected Population	Per Capita GPD	Acre-feet per year	MGD	Projected Population	Per Capita GPD	Acre-feet per year	MGD
County Other Demand (Rural)								
McLennan County Other								
Revised TWDB High Series	24,643	186	5,138	4.59	26,001	185	5,392	4.81
Revised TWDB Low Series	23,071	138	3,569	3.19	23,473	137	3,605	3.22
Bosque County Other								
Revised TWDB High Series	11,103	166	2,066	1.84	12,474	166	2,321	2.07
Revised TWDB Low Series	9,343	118	1,236	1.10	10,355	117	1,358	1.21
Paul Price Associates Projected County Other Demand								
McLennan Co. High Demand	24,643	186	5,134	4.58	26,001	185	5,388	4.81
Low Demand	23,071	186	4,807	4.29	23,473	185	4,864	4.34
Bosque County High Demand	11,103	166	2,065	1.84	12,474	166	2,319	2.07
Low Demand	9,343	166	1,737	1.55	10,355	166	1,925	1.72
Total high Demand	35,746	--	7,199	6.43	38,475	--	7,708	6.88
Total Low Demand	32,414	--	6,544	5.84	33,828	--	6,790	6.06
Paul Price Associates Projected Other Demand for Lake Bosque Water								
McLennan County								
High	--	--	4,590	4.10	--	--	4,844	4.32
Low	--	--	4,263	3.81	--	--	4,320	3.86
Bosque County								
High	--	--	436	0.39	--	--	750	0.67
Low	--	--	108	0.10	--	--	356	0.32
Source: Texas Water Development Board; Paul Price Associates, Inc.; TWDB Population Revisions 2/1987								

Table A.1-2

Bosque and McLennan County Other 1980 Water Use and Revised 1990-2040 Demand Projections	2020	Water Projections			2030	Water Projections		
	Projected Population	Per Capita GPD	*Acre-feet per year*	*MGD*	Projected Population	Per Capita GPD	*Acre-feet per year*	*MGD*
County Other Demand (Rural)								
McLennan County Other								
Revised TWDB High Series	28,447	183	5,835	5.21	31,126	181	6,315	5.64
Revised TWDB Low Series	24,483	136	3,732	3.33	26,353	135	3,988	3.56
Bosque County Other								
Revised TWDB High Series	13,944	166	2,595	2.32	15,655	166	2,913	2.60
Revised TWDB Low Series	11,407	117	1,496	1.34	12,570	117	1,649	1.47
Paul Price Associates Projected County Other Demand								
McLennan Co. High Demand	28,447	183	5,831	5.21	31,126	181	6,311	5.63
Low Demand	24,483	183	5,019	4.48	26,353	181	5,343	4.77
Bosque County High Demand	13,944	166	2,593	2.31	15,655	166	2,911	2.60
Low Demand	11,407	166	2,121	1.89	12,570	166	2,337	2.09
Total high Demand	42,391	--	8,424	7.52	46,780	--	9,222	8.23
Total Low Demand	35,890	--	7,140	6.37	38,923	--	7,680	6.86
Paul Price Associates Projected Other Demand for Lake Bosque Water								
McLennan County								
High	--	--	5,287	4.72	--	--	5,767	5.15
Low	--	--	4,475	3.99	--	--	4,799	4.28
Bosque County								
High	--	--	1,106	0.99	--	--	1,998	1.78
Low	--	--	634	0.57	--	--	1,424	1.27
Source: Texas Water Development Board; Paul Price Associates, Inc.; TWDB Population Revisions 2/1987								

Table A.1-2

Bosque and McLennan County Other 1980 Water Use and Revised 1990-2040 Demand Projections	2040	Water Projections by Paul Price Associates		
	Projected Population	Per Capita *GPD*	*Acre-feet per year*	*MGD*
County Other Demand (Rural)				
McLennan County Other				
Revised TWDB High Series	34,057	180	6,871	6.13
Revised TWDB Low Series	28,365	133	4,229	3.77
Bosque County Other				
Revised TWDB High Series	17,575	166	3,270	2.92
Revised TWDB Low Series	13,853	117	1,817	1.62
Paul Price Associates Projected County Other Demand				
McLennan Co. High Demand	34,057	180	6,867	6.13
Low Demand	28,365	180	5,719	5.11
Bosque County High Demand	17,575	166	3,268	2.92
Low Demand	13,853	166	2,576	2.30
Total high Demand	51,632	- -	10,135	9.05
Total Low Demand	42,218	- -	8,295	7.40
Paul Price Associates Projected Other Demand for Lake Bosque Water				
McLennan County				
High	- -	- -	6,323	5.64
Low	- -	- -	5,175	4.62
Bosque County				
High	- -	- -	2,355	2.10
Low	- -	- -	1,663	1.48
Source: Texas Water Development Board; Paul Price Associates, Inc.; TWDB Population Revisions 2/1987				

Table A.1-3. Manufacturing 1980 Water Use and 1990-2040 Demand Projections

Bosque and McLennan County Manufacturing Water Use for 1980 and Projections for 1990-2040	1980 USE		1990 Projection		2000 Projection		2010 Projection		2020 Projection		2030 Projection		2040 Paul Price Asso. Projection	
	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD
County Manufacturing Demand														
McLennan County														
TWDB High Series	3,982	3.55	6,320	5.64	9,181	8.20	12,296	10.98	16,206	14.47	20,618	18.41	26,231	23.42
TWDB Low Series	3,982	3.55	5,895	5.26	8,238	7.35	10,787	9.63	13,984	12.48	17,593	15.70	22,133	19.76
Bosque County														
TWDB High Series	87	0.08	112	0.10	148	0.13	186	0.17	233	0.21	288	0.26	356	0.32
TWDB Low Series	87	0.08	108	0.10	137	0.12	168	0.15	206	0.18	252	0.22	308	0.28
Paul Price Associates Projected Manufacturing Demand for Lake Bosque														
McLennan County														
High Series	–	–	5,825	5.20	8,744	7.81	11,921	10.64	6,259	5.59	0	0.00	5,613	5.01
Low Series	–	–	5,400	4.82	7,801	6.96	10,412	9.29	4,037	3.60	-3,025	-2.70	1,515	1.35
Bosque County														
High Series	–	–	0.00	0.00	148	0.13	186	0.17	233	0.21	288	0.26	356	0.32
Low Series	–	–	-4	0.004	137	0.12	168	0.15	206	0.18	252	0.22	308	0.28
Source: Paul Price Associates; Texas Water Development Board														

Table A.1 - 4 Municipal Water Supplies

Municipal Water Supply for 1980 and Projections for 1990-2040 (for High Series Demand Projections)	Supply 1980		Projection 1990		Projection 2000		Projection 2010		Projection 2020		Projection 2030		Projection 2040	
	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD
Bellmead														
Trinity Ground-Water	996	0.89	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	1,953	1.74	2,150	1.92	2,268	2.02	2,482	2.22	2,716	2.42	2,716	2.42
Total	996	0.89	1,953	1.74	2,150	1.92	2,268	2.02	2,482	2.22	2,716	2.42	2,716	2.42
Clifton														
Trinity Ground-Water	583	0.52	263	0.23	263	0.23	263	0.23	263	0.23	209	0.19	209	0.19
Local Supply	94	0.08	150	0.13	150	0.13	150	0.13	150	0.13	150	0.13	150	0.13
Waco Surface-Water	0	0.00	464	0.41	606	0.54	728	0.65	864	0.77	1,075	0.96	1,075	0.96
Total	677	0.60	877	0.78	1,019	0.91	1,141	1.02	1,277	1.14	1,434	1.28	1,434	1.28
Hewitt														
Trinity Ground-Water	844	0.75	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	1,144	1.02	1,203	1.07	1,269	1.13	1,389	1.24	1,520	1.36	1,520	1.36
Total	844	0.75	1,144	1.02	1,203	1.07	1,269	1.13	1,389	1.24	1,520	1.36	1,520	1.36
Lacy-Lakeview														
Trinity Ground-Water	639	0.57	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	698	0.62	751	0.67	792	0.71	867	0.77	949	0.85	949	0.85
Total	639	0.57	698	0.62	751	0.67	792	0.71	867	0.77	949	0.85	949	0.85
McLennan County WCID #2														
Trinity Ground-Water	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16
Waco Surface-Water	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16	183	0.16
Meridian														
Trinity Ground-Water	115	0.10	305	0.27	356	0.32	398	0.36	446	0.40	501	0.45	501	0.45
Waco Surface-Water	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	115	0.10	305	0.27	356	0.32	398	0.36	446	0.40	501	0.45	501	0.45
Waco														
Trinity Ground-Water	0	26.44	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	29,618	26.44	35,913	32.06	36,987	33.02	39,026	34.84	42,703	38.12	46,725	41.71	46,725	41.71
Total	29,618	26.44	35,913	32.06	36,987	33.02	39,026	34.84	42,703	38.12	46,725	41.71	46,725	41.71
Woodway														
Trinity Ground-Water	1,695	1.51	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	2,780	2.48	3,314	2.96	3,497	3.12	3,826	3.42	4,186	3.74	4,186	3.74
Total	1,695	1.51	2,780	2.48	3,314	2.96	3,497	3.12	3,826	3.42	4,186	3.74	4,186	3.74
Potential Customers														
Mart														
Trinity Ground-Water	669	0.60	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	744	0.66	767	0.68	809	0.72	886	0.79	969	0.87	969	0.87
Total	669	0.60	744	0.66	767	0.68	809	0.72	886	0.79	969	0.87	969	0.87
Moody														
Trinity Ground-Water	159	0.14	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	327	0.29	357	0.32	377	0.34	413	0.37	452	0.40	452	0.40
Total	159	0.14	327	0.29	357	0.32	377	0.34	413	0.37	452	0.40	452	0.40
Northcrest														
Trinity Ground-Water	173	0.15	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	588	0.52	691	0.62	729	0.65	798	0.71	873	0.78	873	0.78
Total	173	0.15	588	0.52	691	0.62	729	0.65	798	0.71	873	0.78	873	0.78
Bruceville-Eddy														
Trinity Ground-Water	203	0.18	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Waco Surface-Water	0	0.00	240	0.21	252	0.22	266	0.24	289	0.26	316	0.28	316	0.28
Total	203	0.18	240	0.21	252	0.22	266	0.24	289	0.26	316	0.28	316	0.28
Total Municipal Supply														
Trinity Ground-Water	6,259	32.03	751	0.67	802	0.72	844	0.75	892	0.80	893	0.80	893	0.80
Local Supply	94	0.08	150	0.13	150	0.13	150	0.13	150	0.13	150	0.13	150	0.13
Waco Surface-Water	29,618	26.44	44,851	40.04	47,078	42.03	49,761	44.42	54,517	48.67	59,781	53.37	59,781	53.37
Total	35,971	58.55	45,752	40.84	48,030	42.88	50,755	45.31	55,559	49.60	60,824	54.30	60,824	54.30
Source: Texas Water Development Board; Paul Price Associates											2040 supply figures were held constant with 2030 figures.			

Table A.1 - 5 Other 1980 Water Use and 1990-2040 Supplies

Bosque and McLennan County Other 1980 Water Use Supply and 1990 - 2040 Supply Projections	1980 Water Supply		1990 Water Supply		2000 Water Supply		2010 Water Supply		2020 Water Supply		2030 Water Supply		2040 Water Supply	
	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD
Supply Source for Other Demand (For High Series TWDB Projections)														
McLennan County														
Ground-Water Supply														
Trinity Group	0	0.00	544	0.49	544	0.49	544	0.49	544	0.49	544	0.49	544	0.49
Other	2,892	2.58	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Ground-Water Supply	2,892	2.58	544	0.49	544	0.49	544	0.49	544	0.49	544	0.49	544	0.49
Surface-Water Supply														
Lake Waco	609	0.54	4,374	3.90	4,578	4.09	4,829	4.31	5,281	4.71	3,506	3.13	3,506	3.13
Aquilla Creek	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Whitney WO Power	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Surface-Water Supply	609	0.54	4,374	3.90	4,578	4.09	4,829	4.31	5,281	4.71	3,506	3.13	3,506	3.13
Total Supply	3,501	3.13	4,918	4.39	5,122	4.57	5373	4.80	5,825	5.20	4,050	3.62	4,050	3.62
Bosque County														
Ground-Water Supply														
Trinity Group	0	0.00	1,506	1.34	1,629	1.45	1,569	1.40	1,487	1.33	913	0.82	913	0.82
Other	937	0.84	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Ground Water Supply	937	0.84	1,506	1.34	1,629	1.45	1,569	1.40	1,487	1.33	913	0.82	913	0.82
Surface-Water Supply														
Lake Waco	0	0.00	0	0.00	126	0.11	411	0.37	736	0.66	1,596	1.42	1,596	1.42
Local Supply	4	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Surface-Water Supply	4	0.00	0	0.00	126	0.11	411	0.37	736	0.66	1,596	1.42	1,596	1.42
Total Supply	941	0.84	1,506	1.34	1,755	1.57	1,980	1.77	2,223	1.98	2,509	2.24	2,509	2.24
Source: Texas Water Development Board; Paul Price Associates									Note: 2040 supply figures were kept constant with 2030 TWDB figures. Percent change from 2020 - 2030 was applied to 2030 base number to calculate total growth from 2030-2040.						

Table A.1-6 Manufacturing 1980 Water Use and 1990-2040 Supplies

Bosque and McLennan County Manufacturing Water Use for 1980 and Projections for 1990-2040	1980 USE		1990 Projection		2000 Projection		2010 Projection		2020 Projection		2030 Projection		2040 Paul Price Asso. Projection	
	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD	Acre-feet per year	MGD
Manufacturing Supply Source (For High Series Projections)														
McLennan County														
Ground-Water Supply														
Trinity Group	–	–	495	0.44	437	0.39	375	0.33	264	0.24	143	0.13	143	0.13
Brazos River Alluvium	–	–	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Ground-Water Supply	–	–	495	0.44	437	0.39	375	0.33	264	0.24	143	0.13	143	0.13
Surface-WaterSupply														
Lake Waco	–	–	5,825	5.20	8,744	7.81	11,921	10.64	6,259	5.59	0	0.00	0	0.00
Aquilla Creek	–	–	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Whitney WO Power	–	–	0	0.00	0	0.00	0	0.00	9,683	8.64	20,475	18.28	20,475	18.28
Total Surface-Water Supply			5,825	5.20	8,744	7.81	11,921	10.64	15,942	14.23	20,475	18.28	20,475	18.28
Total Supply	–	–	6,320	5.64	9,181	8.20	12,296	10.98	16,206	14.47	20,618	18.41	20,618	18.41
Bosque County														
Ground-Water Supply														
Trinity Group	–	–	112	0.10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Brazos River Alluvium	–	–	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Ground Water Supply	–	–	112	0.10	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Surface-Water Supply														
Lake Waco	–	–	0	0.00	0	0.00	186	0.17	233	0.21	288	0.26	288	0.26
Aquilla Creek	–	–	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Whitney WO Power	–	–	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total Surface-Water Supply			0	0.00	0	0.00	186	0.17	233	0.21	288	0.26	288	0.26
Total Supply	–	–	112	0.10	0	0.00	186	0.17	233	0.21	288	0.26	356	0.26
Source: Paul Price Associates Texas Water Development Board											2040 supply figures were kept constant with 2030 figures. Total demand was increased by the percent change from 2020-30.			

Manufacturing water demand projection figures used in the water demand projections were from the TWDB low series projections.

Demand for Lake Bosque was projected by subtracting the amount of total demand satisfied by supplies from Lake Waco as indicated in the TWDB supply summaries. The sum of demand satisfied by Lake Waco supplies and any excess demand was assumed to be demand for Lake Bosque water.

A.1.3 NOTES

** Mclennan County manufacturing water demand for Lake Waco, year 2030, is projected at 0 by the TWDB County Water Supply-Demand summary. This is because the TWDB projects Lake Whitney to supply over 99.3% of total water demand. Manufacturing water demand for Lake Waco, year 2040, is projected at 0. This is because to calculate 2040 demand the percent change from 2020-2030 was applied to 2030 base numbers.

** Table A.1 - 7 shows the proportion of manufacturing demand drawn from Lake Waco for 1990 - 2030 as indicated by the TWDB County Water Supply-Demand 1990-2030 summary.

Table A.1 - 7

Manufacturing Water Demand for Lake Waco

	1990	2000	2010	2020	2030
Mclennan County	92.17%	95.2%	96.9%	38.6%	0
Bosque County	0	100%	100%	100%	100%

** Projected 2040 supply data was not available. Therefore, in the supply projections, supply is assumed constant to 2030 supply levels and sources.

** The City of Robinson was not included in municipal water demand projections because the city withdrew from the project. The TWDB County Water Demand and Supply Summary indicates that Robinson will be drawing water from Lake Waco by 1990. However, it is the understanding of Paul Price Associates' that The City of Waco will not be selling water from Lake Waco.

** The definition of Other demand includes the rural county population and excludes the population of the communities listed in Table A.1 - 8.

Table A.1 - 8

Communities not Included in the Definition of Other (Rural) Demand

Robinson	Valley Mills	Waco	West	Woodway
Bruceville-Eddy	Hewitt	Bellmead	Beverly Hills	Clifton
Lacy-Lakeview	McGregor	Mart	Meridian	Moody
Northcrest				

Of the sixteen communities listed in Table A.1 - 8, seven are participating in the project and four were identified as potential participants. The four remaining communities, Beverly Hills, Valley Mills, Robinson, West and McGregor were not accounted for in the projections. Although the community of Robinson withdrew from the project, TWDB County Water Demand and Supply Summary reports that 100% of Robinson's water supply will come from Lake Waco surface water. Valley Mills and McGregor currently and in the future were projected (by TWDB County Water Demand and Supply Summary) to continue relying entirely on Trinity ground water, and the community of West is projected to continue relying on Aquilla Creek surface water for their water needs. Beverly Hill is currently contracting with the City of Waco for water is expects to continue doing so in the future.

** The population of Mclennan County WCID #2 (Elm Mott) was included in the "Other Demand" water projections.

Socioeconomic Baseline Report
For The
Lake Bosque Project
Bosque County, Texas Water Development Board
Contract No. 8-483-522

The following maps are not attached to this report. They are located in the official file and may be copied upon request.

Maps -Lake Bosque Project Area Land Use
Figure 7-1
Figure 7-2
Figure 7-3

Please contact Research and Planning Fund Grants Management Division at (512) 463-7926 for copies.

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ENVIRONMENTAL ASSESSMENT REPORT

for the

LAKE BOSQUE PROJECT

BOSQUE COUNTY, TEXAS

Prepared for

The Brazos River Authority

Prepared by

Paul Price Associates, Inc.
P.O. Box 23207
Austin, Texas 78736

September, 1987

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1.0 The Proposed Project

The following document is an Environmental Assessment Report that summarizes regional and site specific environmental data and examines the consequences of the construction and operation of the Lake Bosque Project by the Brazos River Authority (BRA). This report is based primarily on nine documents prepared specifically to address in detail the important aspects of the Lake Bosque Project. The documents listed below should be consulted when a more extended discussion, data presentation, or guide to the literature used to support assertions or opinions is desired:

* Baseline Ecology Report: the Lake Bosque Project, Technical Consulting Associates (now Paul Price Associates, Inc.), 1985;
* Baseline Ecology Report Supplement I: North Bosque River Regional Survey, Paul Price Associates, Inc., 1987;
* Baseline Ecology Report Supplement II: Important Species, Paul Price Associates, Inc., 1987;
* Socioeconomic Baseline Report for the Lake Bosque Project, Paul Price Associates, Inc., 1987;
* Water Supply Alternatives for Bosque County, HDR Infrastructure, Inc., 1982;
* Analysis of Project Alternatives for Proposed Lake Bosque Project, HDR Infrastructure, Inc., 1987;
* Reservoir Operation Studies for Proposed Lake Bosque Project and Lake Waco Enlargement, HDR Infrastructure, Inc., 1987;
* Geotechnical Investigation, Bosque Reservoir Site, Bosque County, Texas, NFS Services, Inc., 1983;
* An Archaeological and Historical Survey of the Proposed Lake Bosque Reservoir Site, Bosque County, Texas, Lone Star Archaeological Services, Georgetown, Texas, 1987.

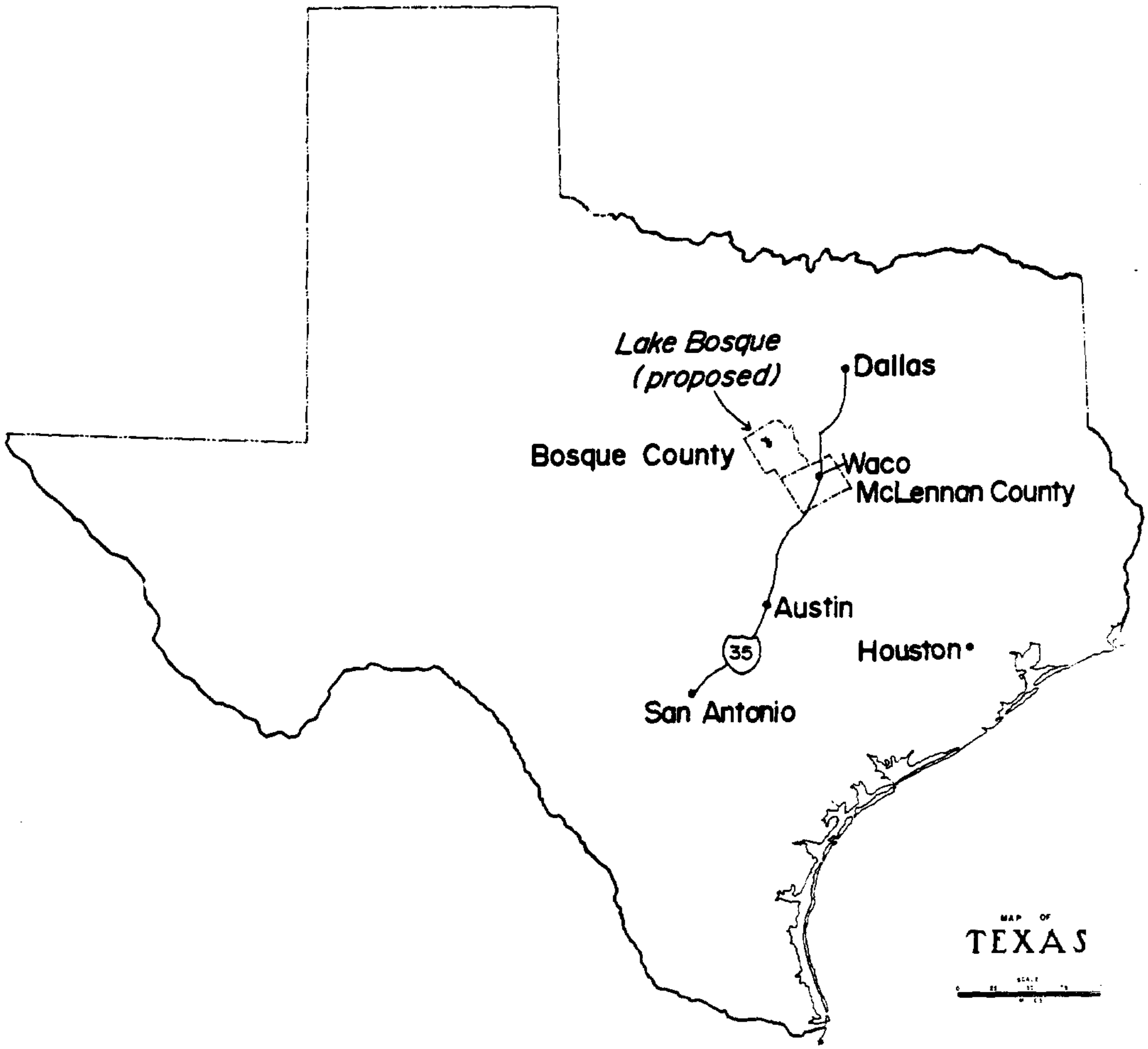
In addition, numerous publications, government agency reports and personal communications with qualified individuals are cited in support of the information and analyses presented here.

1.1 Scope of Project

The proposed project consists of the construction and operation of Lake Bosque, a municipal water supply reservoir at river mile 58.3 on the North Bosque River about four miles north of Meridian, in Bosque County, Texas (Figure 1-1). The new reservoir will be operated as a system with Lake Waco to maximize benefits in the Bosque River Basin. The conservation pool will cover 4564 acres at an elevation of 830 feet above mean sea level (MSL) and have an initial storage capacity of 102,909 acre-feet. As a result of dam construction and operation the existing 100 year floodplain in the reservoir reach will be raised to an approximate elevation of 841.3 feet MSL. The project will also include closure of four county road segments (tentatively), realignment of short portions of FM 927 and FM 144, and the rerouting of several electric transmission line segments each less than one mile in length (Figure 1-2).

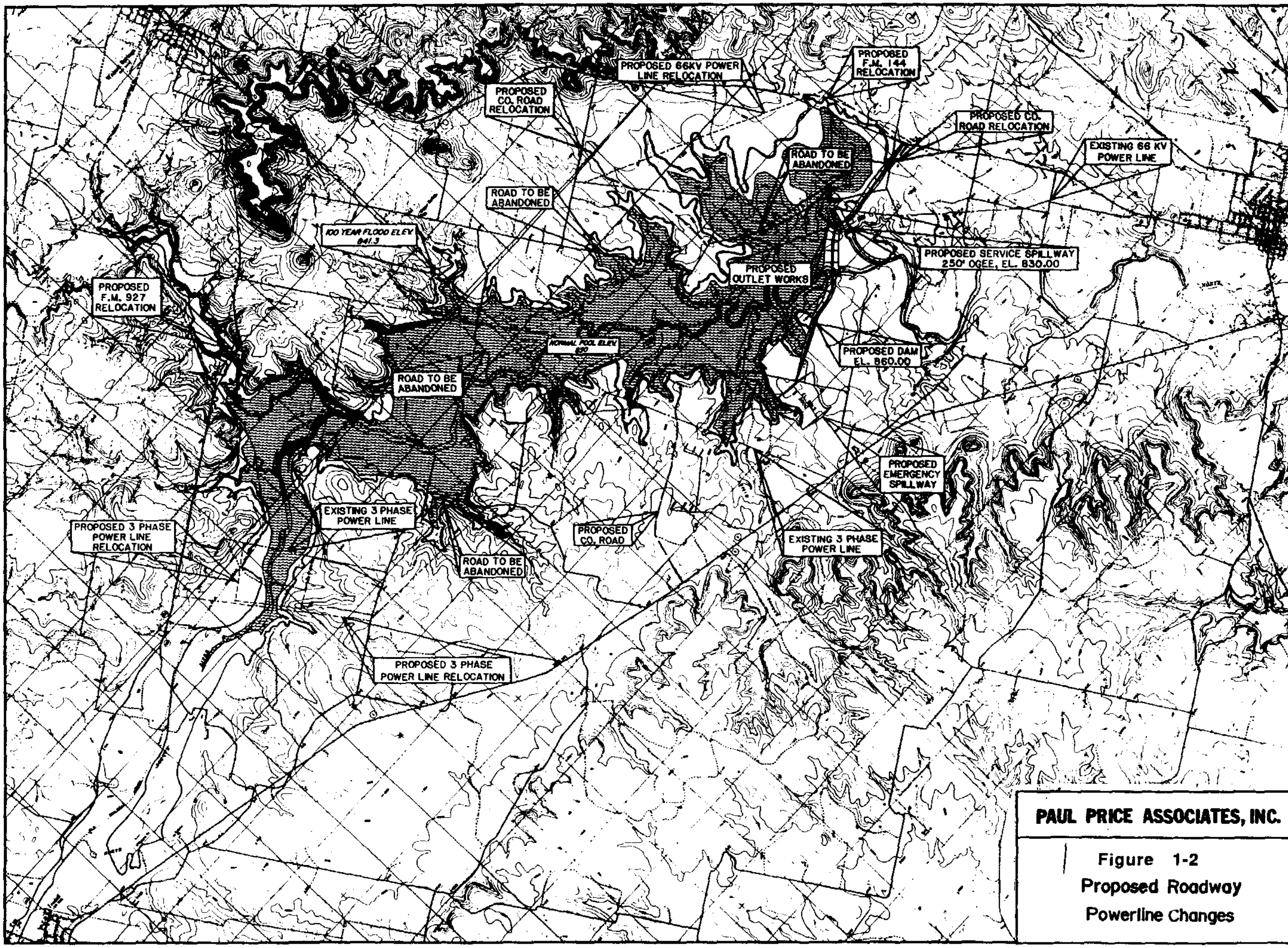
The capability to add a raw water diversion point will be included as part of the controlled outlet structure of the dam. This feature is intended for use by the Bosque County participants when they elect to take their 2.98 mgd share of the reservoir yield, projected to occur between 1990 and 2005. Since McLennan County users will receive Lake Bosque water via Lake Waco and the City of Waco's water treatment and distribution system, no new raw water delivery facilities will be neccessary for them.

The dam is to be an earthfill embankment with an impermeable core, approximately 14,000 feet in length with a crest



PAUL PRICE ASSOCIATES, INC.

Figure 1-1
Proposed Lake Bosque
Resevoir Site



PAUL PRICE ASSOCIATES, INC.

Figure 1-2
Proposed Roadway
Powerline Changes

elevation at 860 feet MSL. The primary spillway will be an uncontrolled concrete structure 250 feet wide with a crest at 830 feet MSL, the top of the conservation pool. The 2000 foot wide emergency spillway will be set at the 100 year flood elevation, 841.3 feet MSL, to allow passage of the Probable Maximum Flood without overtopping the embankment. Controlled release will be accomplished by use of a structure capable of selective, multilevel withdrawl and an outlet discharging into a stilling basin at the base of the primary spillway. The outlet will be constructed with a fixture to allow its eventual use as a raw water diversion point.

1.1.1 Construction Activities

Construction of the dam, spillways and associated structures is expected to take two years, with an additional one to six years required for the reservoir to fill. There is a 50% probablilty that it will fill within two years. Most of the materials to be used for dam construction are available on site from the spillway excavation and borrow areas. The borrow areas (about 230 acres) will be contained within the conservation pool area of the reservoir site. Clearing will be limited to that neccessary for construction activities and, if neccessary, to provide safe lanes for any boat launching facilities that may be constructed.

The proposed dam and spillways will cover 192 acres and the resulting conservation pool will inundate 4564 acres. An additional 1387 acres above the conservation elevation will be included in a new 100 year floodplain subject to periodic inundation.

1.1.2 Proposed Operation

It is anticipated that Lake Bosque and Lake Waco will be operated as a system. Water will be directly diverted from Lake Bosque for use in Bosque County, while releases of water from Lake Bosque to the North Bosque River will be made for delivery through Lake Waco for use in McLennan County. System operation can be structured to significantly increase the total water yield from lakes Bosque and Waco. Under maximum demand conditions, the greatest system yield will be obtained by maximizing storage in Lake Bosque and making releases only as neccessary to maintain the minimum useable pool in Lake Waco. However, until future water supply needs approach system yield, it will not be neccessary to make releases in accordance with this operating procedure, and it is planned that the system will be operated to stabilize the level of Lake Waco for enhanced recreation with releases from Lake Bosque.

The maximum yield of the two reservoir system will be 97,770 acre-feet per year (87.29 mgd), 17,900 acre-feet per year (15.98 mgd) of which will be attributable to Lake Bosque. Of the 15.98 mgd, 2.98 mgd will be used in Bosque County while the remaining 13.00 mgd will be delivered to Lake Waco for use in McLennan County.

1.2 Purpose and Need for the Project

The Lake Bosque Project is being proposed to enhance the quantity and quality of available water supplies in Bosque and McLennan Counties, particularly for those project participants which rely on ground water for present supplies and future growth. Except for Lake Waco which supplies the City of Waco, present water supplies for Bosque and McLennan Counties consist primarily of ground water from the Travis Peak formation of the Trinity Group. This aquifer is being mined at present rates of withdrawl and the region has been designated a Critical Ground Water Management Area by the Texas Water Commission. These are areas the Texas Water Commission believes are experiencing, or will experience within the next 20 years, serious problems with groundwater supply.

Studies were initiated in 1981 to examine the available alternatives and recommend solutions to the widely recognized coming water shortage in the region. Construction and operation of Lake Bosque will provide higher quality water to project participants, mitigate overpumping of ground water resources and assure the availability of a dependable water supply through the period 1990-2040 and beyond.

The reservoir's firm yield of 15.98 million gallons per day (mgd) is fully contracted for by the participating municipalities of Bosque and McLennan Counties (Meridian, Clifton, Bellmead, Hewett, Lacy-Lakeview, McLennan Co. WCID No. 2, Waco and Woodway) and financing is to be by sale of revenue bonds. Future water requirements are projected to begin exceeding the water supplies of some project participants by the year 2000, and is anticipated to continue increasing through the life of the project at an average rate of approximately 1.7% per year. Projections of future demand are discussed in the Baseline Socioeconomic Report (Paul Price Associates Inc., 1987), and in Section 3.8.3.5 of this document.

2.0 Water Supply Alternatives

HDR Infrastructure Inc. (1982; 1987) reviewed potential water supply alternatives and recommended Lake Bosque as the supply project that will best serve the needs of all eight project participants. Alternatives considered included: 1) additional groundwater development, 2) conservation, 3) new reservoir construction on the North Bosque (four sites) and Leon (one site) Rivers, 4) waste water reuse and 5) two methods of using uncommitted Brazos River water. All but two of the alternatives considered were judged to be technically feasible and environmentally sound to the extent that no unique or irretrievable resource losses would result from implementation. Therefore, unit cost for development, treatment and transmission of treated water was the main basis for comparison and selection of the preferred alternative.

2.1 Water Supply Alternatives considered

Four alternatives other than development of new surface water supply sources were examined and are summarized below in Section 2.1.1, Non Structural Alternatives. Structural Alternatives included examination of four reservoir sites on the North Bosque, one site on the Leon River, and development of diversion and off channel storage facilities on the Brazos River.

2.1.1 Non Structural Alternatives

2.1.1.1 Groundwater Use and Conservation

More extensive use of groundwater supplies and/or implementation of water conservation measures were evaluated and it was found that neither of these two procedures provided a sufficient and reliable supply to meet the demand of the project participants. Groundwater supplies are already being overdrafted and even in concert with reasonably achievable conservation levels cannot be expected to meet their projected demands.

2.1.1.2 Wastewater Reuse

The Brazos River Authority's Regional Wastewater Treatment Plant at Waco is currently discharging approximately 21 mgd. Therefore, increasing the firm yield of Lake Waco by pumped diversion of adequately treated wastewater effluent can develop the needed additional water supply. Although wastewater reuse has not yet been widely implemented, it appears technically feasible and may become a realistic water supply alternative in the future. Potential problems to be addressed include public concerns and perceptions, additional nutrient delivery to an already eutrophic reservoir, and transmission of water to the Bosque County users which are located as much as 60 miles from the Lake Waco diversion structure.

2.1.1.3 Lake Whitney Alternative

Lake Whitney is an existing Corps of Engineers multi-purpose project upstream of the City of Waco on the Brazos River astride the eastern boundary of Bosque County. A portion of the existing conservation storage has been purchased from the federal government by the Brazos River Authority and is presently contractually committed to entities other than the Lake Bosque project participants. The purchase of the remaining conservation storage space, with an appropriate water rights permit, could be used to develop a firm yield water supply for the two water systems serving the Bosque and McLennan County participants. The concurence of the U.S. Congress would be required to purchase the remaining storage space.

The McLennan County entities would receive their supply by releasing water down the Brazos River to an existing channel reservoir within the City of Waco. Released water would be diverted from the channel reservoir for treatment that would have to include demineralization and wholesale distribution. The demineralization step is necessary because dissolved solids concentrations in the Brazos River often exceeds the Secondary Constituent levels set for drinking water by the Texas Department of Health. The Bosque County entities would construct a raw water intake structure in Lake Whitney and divert their supply by pipeline to a similar demineralization and conventional treatment facility for wholesale distribution.

2.1.2 Structural Alternatives

2.1.2.1 North Bosque River Reservoir Sites

A previous study by HDR showed that a reservoir on the North Bosque River was the most economical water supply project for Bosque County (HDR Infrastructure, 1982). A review of USGS maps identified four sites on the North Bosque River as having the topographic characteristics that will allow development of reasonable storage capacity without incurring extensive relocation costs (HDR Infrastructure, 1987). All four North Bosque River alternative sites are located in Bosque County. Practical conservation storage volumes at these sites ranged from 29,200 acre-feet to 102,909 acre-feet. Estimated areal yields after 50 years of sediment accumulation ranged from 17,500 (15.6 mgd) to 35,000 (31.25 mgd) acre-feet per year.

Since all four potential reservoir sites are located in areas that are very similar in terms of soils, topography, vegetation and aquatic habitats, the primary predictors of environmental impact are conservation pool areas and position in the basin. Site 1 (3,083 surface acres) was located about six miles upstream of the proposed Lake Bosque, which is Site 2 and will cover 4564 acres. Site 3 (2,018 acres) was located just upstream of Clifton while Site 4 (4,938 acres) was about two miles upstream of Valley Mills. These four sites can be ranked in ascending order of probable fish and wildlife habitat impact as follows: Site 3 < Site 1 < Site 2 = Site 4.

2.1.2.2 Leon River Reservoir Site

The Leon River site selected for study is located approximately 4 river miles upstream of the town of Gatesville in Coryell County, Texas. The selection of this site is based on its ability to support a new reservoir, as well as its close proximity to the participating entities requiring water. The Gatesville location represents the most downstream site before inundation of either federal lands or population centers becomes significant.

The proposed Gatesville Reservoir would have an optimum conservation pool elevation of 864 feet MSL. At this elevation, the initial conservation storage pool would be about 500,000 acre-feet and surface area would be 14,400 acres. Since the site is environmentally very similar to the Bosque River sites, impacts here are also expected to be roughly proportional to inundated area. Construction of this reservoir would result in greater impacts than at any of the sites on the North Bosque. Delivery of water to both Bosque and McLennan Counties would also involve extensive pipeline construction.

2.1.2.3 Diversion and Off-Channel Storage, Brazos River

This alternative involves diversion of unappropriated Brazos River flows, when available, into an off-channel storage reservoir constructed in the floodplain adjacent to the Brazos River. The stored water would have to undergo conventional treatment and demineralization before distribution to the project participants. Delivery of the Bosque County demand of 2.98 mgd would require substantial pipeline construction from Waco to those participants.

2.2 Selection of the Proposed Project

Unit treated water costs were developed for each alternative and served as the basis for comparing the economic feasibility of each alternative, including treatment and delivery to the existing systems of the project participants. In alternatives requiring demineralization (Lake Whitney, Brazos River Diversion), the process requires conventional water treatment prior to the demineralization step. Part of the treated water must be discharged to carry off the removed minerals. Costs associated with treatment, storage, pumping, and transmission of this additional quantity of water were included in unit treated water cost estimates. Other costs, including avoidance or mitigation of environmental, social, or cultural impacts were considered to be reasonably similar for all five reservoir sites. The alternatives not involving construction of a new reservoir were all assumed to have lower costs in that category.

The proposed Lake Bosque site offers the lowest cost per unit of yield and is the most economical alternative. Its location is advantageous since all project participants are located downstream from the reservoir and water can be supplied with least capital investment and operating cost for diversion, treatment and transmission facilities. The site impounds water without exposure to unreasonable evaporation and seepage losses, and the construction requirements are not unusual.

3.0 The Affected Environment

The human and natural environments potentially affected by the proposed Lake Bosque are centered in portions of Bosque and McLennan Counties in central Texas. Of particular importance is the lower half of the North Bosque River basin which encompasses the reservoir site, the Bosque County project participants and the downstream river reach potentially affected by the presence of the dam.

The Bosque River is a major tributary of the Brazos River, which it joins at Waco, Texas. The Bosque is dammed a few miles upstream of its confluence, forming Lake Waco. Above this impoundment, the North, Middle and South Bosque Rivers drain a 1670 square mile basin extending about 90 miles to the northwest. The North Bosque River has the most extensive sub-basin of the three, draining an area of about 1290 square miles in portions of McLennan, Bosque, Coryell, Hamilton, Somervell, and Erath counties (Figure 3-1).

3.1 Climate and Air Quality

3.1.1 Climate

The basin of the North Bosque River is located near the dry margin of the subtropical humid belt 250 miles northwest of the Gulf of Mexico which exerts considerable influence on the climate of the region. Summers are typically hot and humid with prevailing southeasterly winds carrying Gulf moisture. The winters tend to be mild and to exhibit lower humidities characteristic of the prevalent northern and western air masses of that season. Rainfall tends to decrease from the eastern to the western extremities of the basin (Proctor, 1969; TDWR 1982; NFIC, 1987).

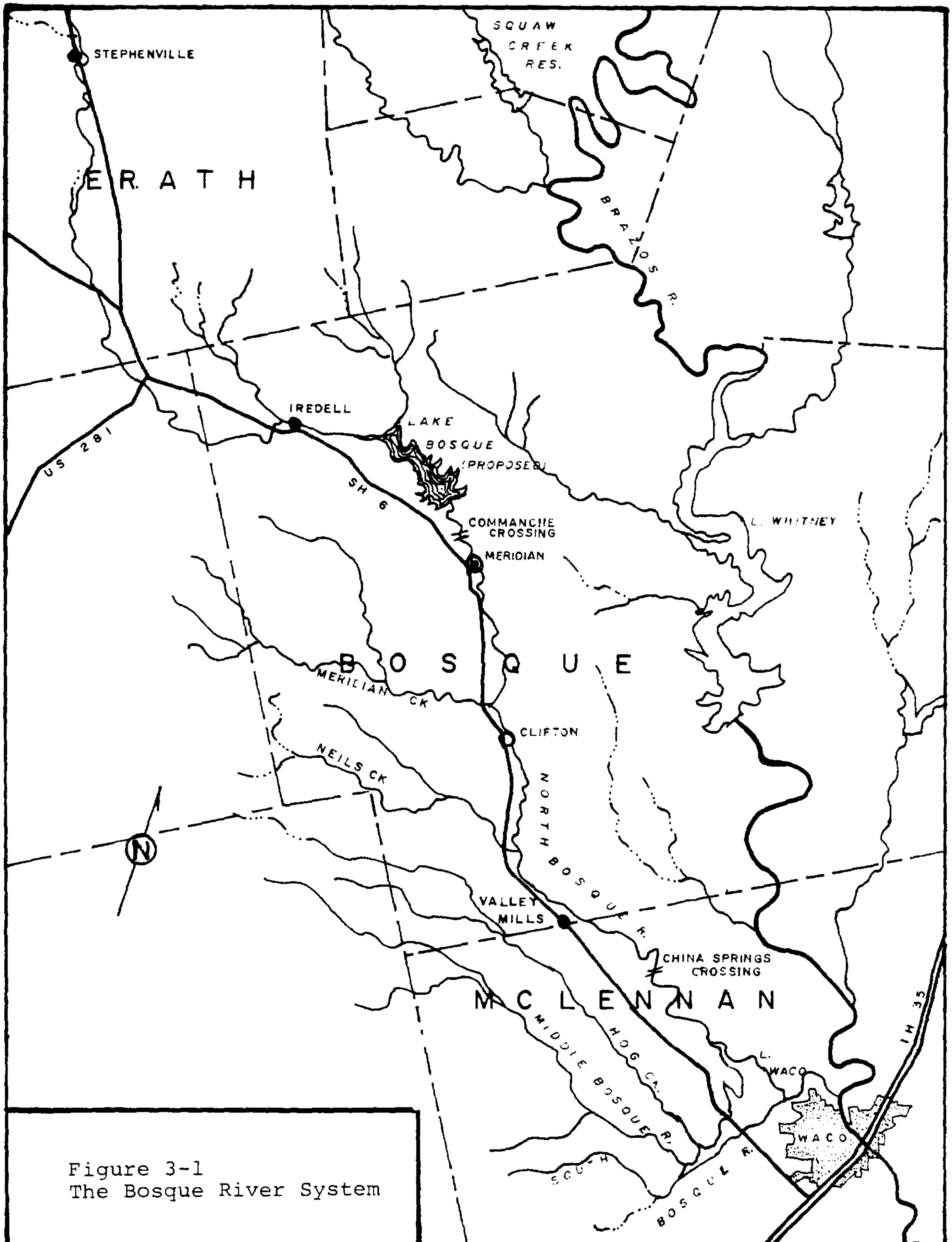


Figure 3-1
The Bosque River System

The climate of Bosque County is dominated by continental characteristics; large daily and annual temperature ranges and wide year to year fluctuations in seasonal rainfall patterns are the rule. Monthly average temperatures at Whitney Dam, 21 miles southeast of the project site, range from about 45 F in January to 85 F in July and August. The growing season averages 245 days, with average first and last frost dates of 21 November and 23 March, respectively.

Precipitation averages 30-35 inches per year in Bosque County (31.6 inches at Whitney Dam) and evapotranspiration averages 30-32 inches. Although rainfall exhibits a relatively even distribution throughout the year, weather extremes can be quite pronounced, particularly with respect to large spring thunderstorms and summer hurricane outliers that may be intensified by the orographic effect of the Balcones Escarpment. Months with highest average rainfall are April, May, June, September and October, but the range is only from an average of 1.75 inches in August to 4.59 inches in May. Annual snowfall averages less than 1 inch, and is generally confined to the months of January and February.

Local climate is variably affected by orientation and topography. Differential insolation on opposite valley walls can result in several degrees difference in both average surface temperatures and in diurnal range, with commensurate differences in consequent characteristics such as soil moisture, erosion rates and vegetative cover. In the vicinity of the proposed reservoir, topography can be very important in determining local climate where steeper slopes may be quite arid and seepage onto flat limestone ledge outcrops may create mesic microclimates in otherwise upland areas.

3.1.2 Air Quality

The Texas Air Control Board (TACB) classifies McLennan County as an attainment area for all pollutants of concern. Monitoring has shown levels of airborne pollutants to be less than the criteria of the national primary, national secondary and state of Texas air quality standards for ozone, carbon monoxide, sulfur dioxide, nitrogen oxides, lead and particulates. A similar determination has been made for Bosque County except that ozone monitoring has not been conducted. Because Bosque County is a rural area with no large sources of emissions, the TACB does not anticipate excess ozone levels to be present there.

3.2 Noise

The proposed project is located in a sparsely populated rural area without significant manufacturing or currently operating mining facilities. The only noise sources in the vicinity of the project are seasonally operated farming machinery, trucks and automobiles. The most significant of these sources appear to be traffic on State Highway 6, FM 144, and FM 927 which surround the proposed reservoir site on the west, east and north sides. Segments of Highways 6 and 144 lie within one mile of proposed construction areas.

3.3 Geology and Soils

3.3.1 Stratigraphy and Lithology

The North Bosque watershed is located on the structurally stable Texas craton (Proctor, 1969) in a zone of very low seismic activity. It is underlaid by Cretaceous aged marine sediments of the Washita, Fredricksburg, and Trinity groups, and Pennsylvanian rocks of the Atoka series. Figure 3-2 illustrates the distribution of exposed geologic

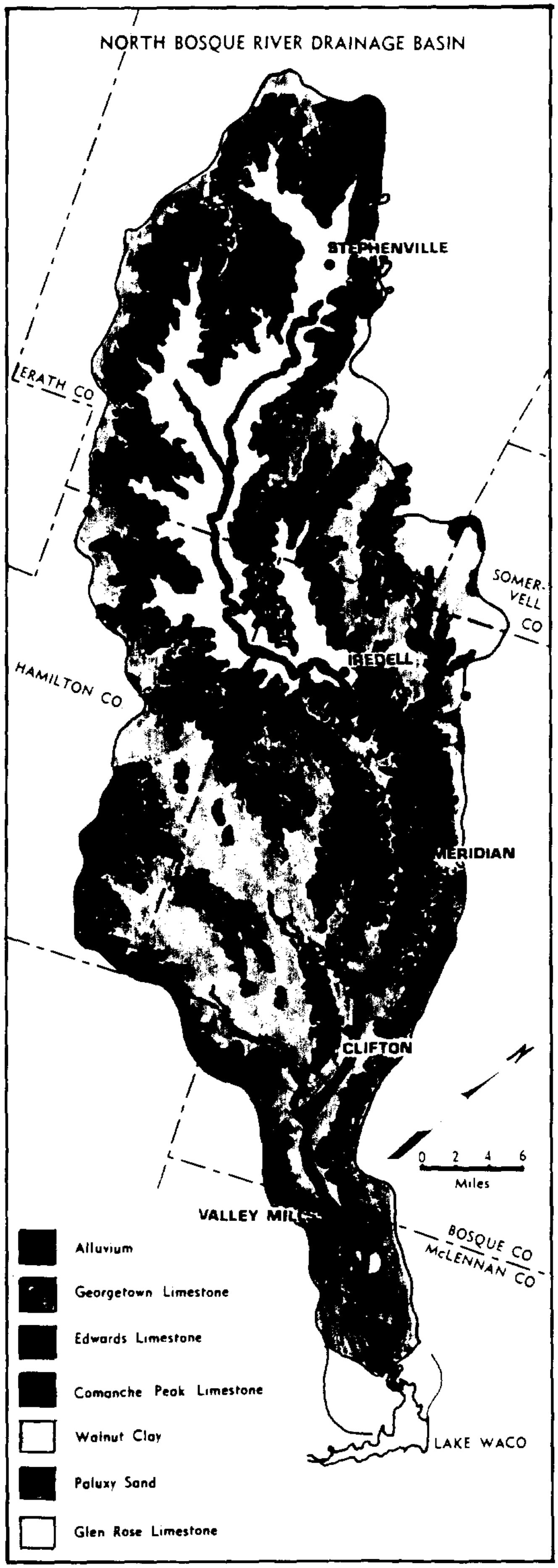


Figure 3-2 Geological Map of the North Bosque Watershed (from Proctor, 1969)

formations in the North Bosque River Basin. Except for recent alluvium filling the valley floors along major stream channels, all the outcrops in the basin are Lower Cretaceous aged marine limestones, shales and sandstones. The exposed strata strike north northeast and dip southeastward at 12 to 27 feet per mile. This structure strongly influences local gradient in the North Bosque River and affects the type and distribution of aquatic habitats (see Section 3.5.1, Aquatic Habitats and Biota).

Most of the reservoir site covers recent valley alluvium that is underlaid by the Paluxy formation. This formation consists of dense, light gray, fine sand interbedded with occasional strata of soft, gray shale and weakly cemented sandstone. Small areas within the upland portion of the reservoir site are occupied by outcrops of the Paluxy and Walnut formations. The Walnut consists of moderately hard tan to light gray limestone alternating with clay and shale and containing massive shell beds. The Glen Rose formation, consisting of hard, light gray limestone strata alternating with shale and marly limestone beds is exposed in the stream bed of the North Bosque at the extreme upper limit of inundation. Above Iredell, the upper half of the Bosque basin is underlaid primarily by the Glen Rose and Paluxy formations.

3.3.2 Physiography

The lowermost reach of the North Bosque River, below Valley Mills, is located in the Washita Prairie physiographic region. This is a rolling prairie developed on the Georgetown Limestone exhibiting little relief and a vegetational cover primarily of grasslands with scattered stands of oak. Although the soils of the Washita Prairie are considered reasonably fertile, they are used almost exclusively for grazing except along the North Bosque River where alluvial soils are used for crop and hayland.

From the vicinity of Valley Mills to Iredell and including the proposed Lake Bosque site, the North Bosque River flows through the Lampasas Cut Plain Physiographic Region, the highly dissected northern extension of the Edwards Plateau. It is characterized by broad, level to rolling valleys separated by steep sided, flat topped divides that are the remnant (cut) plain. Local relief is much greater than in the Washita Prairie, with elevation differences of 150 to 200 feet between valley floors and divides common. The distinct topography is largely the result of the physical resistance to weathering and hydraulic properties of the Edwards Limestone formation which forms a resistant cap on the tops of the divides. The less resistant Commanche Peak Limestone and Walnut Clay formations, which form (respectively) the steep, upper slopes below the Edwards cap and the lower slopes and valley floors, are eroded much more rapidly than the Edwards producing the characteristic mesa dominated landscape. The Edwards limestone here is a perennial aquifer, exhibiting a "spring line" of seeps and springs at its base that increases erosional activity on the underlying Commanche Peak and Trinity formations and contributes to area streamflow.

Above Iredell (and the proposed reservoir site) the remainder of the North Bosque basin lies in the Paluxy Cross Timbers and Glen Rose Prairie physiographic regions. These are regions of little relief and are underlaid by the Paluxy Sands and Glen Rose formations, respectively.

3.3.3 Soils

In the Lampasas Cut Plain, only soils developed on the Walnut formation, Paluxy Sands and Recent alluvium are utilized for agricultural activities other than grazing. Upland soils within the reservoir site range from very shallow to moderately deep, sloping clayey sands of the Denton-Purves and Tarrant-Denton units (SCS, 1980). These soils are developed on the limestones of the Walnut formation and account for about 22 and 8 percent, respectively, of Bosque county soils. More intensively farmed, the Krum-Sunev and Frio-Bosque soils of the bottomlands are easily cultivated since even adjacent to the river channel they are only occasionally flooded. These soils are calcareous clay- and silty-clay loams that are developed on recent alluvium and are the characteristic riparian soils of the North Bosque River. They exhibit high crop potentials and account for about 12 and 3 percent, respectively, of Bosque County soils.

The Soil Conservation Service classifies 205,458 acres (32%) of the 641,920 acres of Bosque County as prime farming soils, based on soil depth, moisture, slope, stoniness, erodibility, and presence of soil problems. Prime farmland soils occupy about two thirds of the proposed reservoir site, considering both the dam and conservation pool.

3.3.4 Paleontology

The Walnut Clay formation exhibits widespread occurances of marine fossils, primarily in the form of oyster reefs dominated by the Lamellibranch genus *Gryphaea*. These fossil reefs can be large structures that outcrop on the surface throughout the Lampasas Cut Plain as low, rounded hills or benches. The Glen Rose formation, which begins to outcrop in the river channel in the vicinity of Iredell, above all but the extreme upper reach of the reservoir, is known in particular for the dinosaur tracks that have been found at numerous outcrop locations from Glen Rose to Uvalde.

3.3.5 Economic Geology

Geological resources in the vicinity of the proposed reservoir appear limited to sand and gravel deposits that are widely distributed along the North Bosque River, and limestones suitable for construction purposes that are present in numerous areas in Bosque and McLennan Counties. Resource extractive industries (e.g., mining, oil and gas) do not constitute a significant portion of the economy of Bosque County at the present time. No operating oil or gas wells or mining facilities are located within the proposed reservoir site.

3.4 Water Resources

3.4.1 Ground Water

Groundwater resources in Bosque and McLennan Counties include aquifers of the Trinity Group, Edwards formation, Brazos valley alluvium, and Woodbine formation (TDWR, 1982). The Travis Peak formation of the Trinity group provides by far the largest fraction of groundwater supplies in these counties. The Hensel and Hosston members of the Travis Peak formation provide over 95% of the municipal and industrial water supply in Bosque County. In McLennan County all the project participants except the City of Waco use these aquifers for their primary water supply, as do nearly all other entities in the county.

The Hensel and Hosston members of the Trinity Group have freshwater sand thicknesses ranging from 50 to 120 feet. Aquifer depths range from several hundred feet in western Bosque County to nearly 2000 feet in eastern McLennan County. Pumping capacity of wells developed in these formations range up to 300 gallons per minute. Originally artesian, development of the resource has resulted in declining water levels throughout the study area. At present rates of withdrawal, the aquifer is being mined, and has been included in a Critical Groundwater Management Area by the Texas Water Commission. These have been defined as areas that are experiencing, or will experience within the next 20 years, serious problems with groundwater supply.

The recharge zone of the Trinity aquifer outcrops in a north-south bearing band that touches the western edge of Bosque County and extends westward to cover most of Erath, Hamilton and Comanche Counties. This aquifer does not compact when drawn down and the outcrop is located in an area having sufficient rainfall that recharge can occur within a reasonable period if overdrafting is halted. Information on sustainable withdrawal rates is not currently available for this area.

While the Edwards formation in Bosque county supports a number of perennial springs and seeps, it does not make any substantial contribution to municipal or industrial water supplies. The Paluxy Sand, which outcrops in the vicinity of the proposed Lake Bosque, is another minor aquifer providing small to moderate supplies of freshwater (10-20 gallons per minute) for agricultural purposes in Bosque County. This aquifer has a high mineral content and relatively low permeability that restricts its potential for water supply development. At the reservoir site the valley of the North Bosque River is a discharge area for the Paluxy formation. A low gradient groundwater flow from west to east is present in this aquifer at the proposed dam site. (NFS Services, Inc., 1983).

In Mclennan County, the Woodbine occurs only in a small area in the northern part of the county, while the Brazos

Alluvium constitutes a relatively limited ground water resource within the confines of the Brazos River valley.

3.4.2 Surface Water

Surface water resources in the study area are limited to the Brazos and Bosque Rivers, their tributaries and impoundments, and the many smaller impoundments constructed for agricultural purposes. Several reservoirs have been constructed on the Brazos River, including Lake Whitney which is on the northeastern county line about 15 miles east of the proposed Lake Bosque site. Brazos River reservoirs have seen only limited use as municipal water supply sources because the dissolved solids concentration of Brazos River water commonly exceeds state and federal drinking water standards. Much of this material originates from brine springs located on the Salt Fork of the Brazos River. The federal government has considered addressing this problem by building a system of large reservoirs in the Salt Fork basin to contain and evaporate the salt spring discharges. However, salinity reduction in the Brazos River and its impoundments by these federal salt control projects appears unlikely because of construction costs and potential environmental effects.

Lake Waco, on the Bosque River, is the water supply for the City of Waco. The existing conservation storage volume of this reservoir is contractually committed to the City of Waco so water from this source is unavailable to the other communities of McLennan and Bosque Counties. Lake Waco as presently permitted can supply 58,200 acre feet (51.96 mgd) per year. An enlargement has been proposed by the City of Waco (possibly occurring by year 2000) to increase Lake Waco's yield by 20,100 acre feet (17.9 mgd) under 2040 sediment conditions.

3.4.2.1 Hydrology and Water Quality

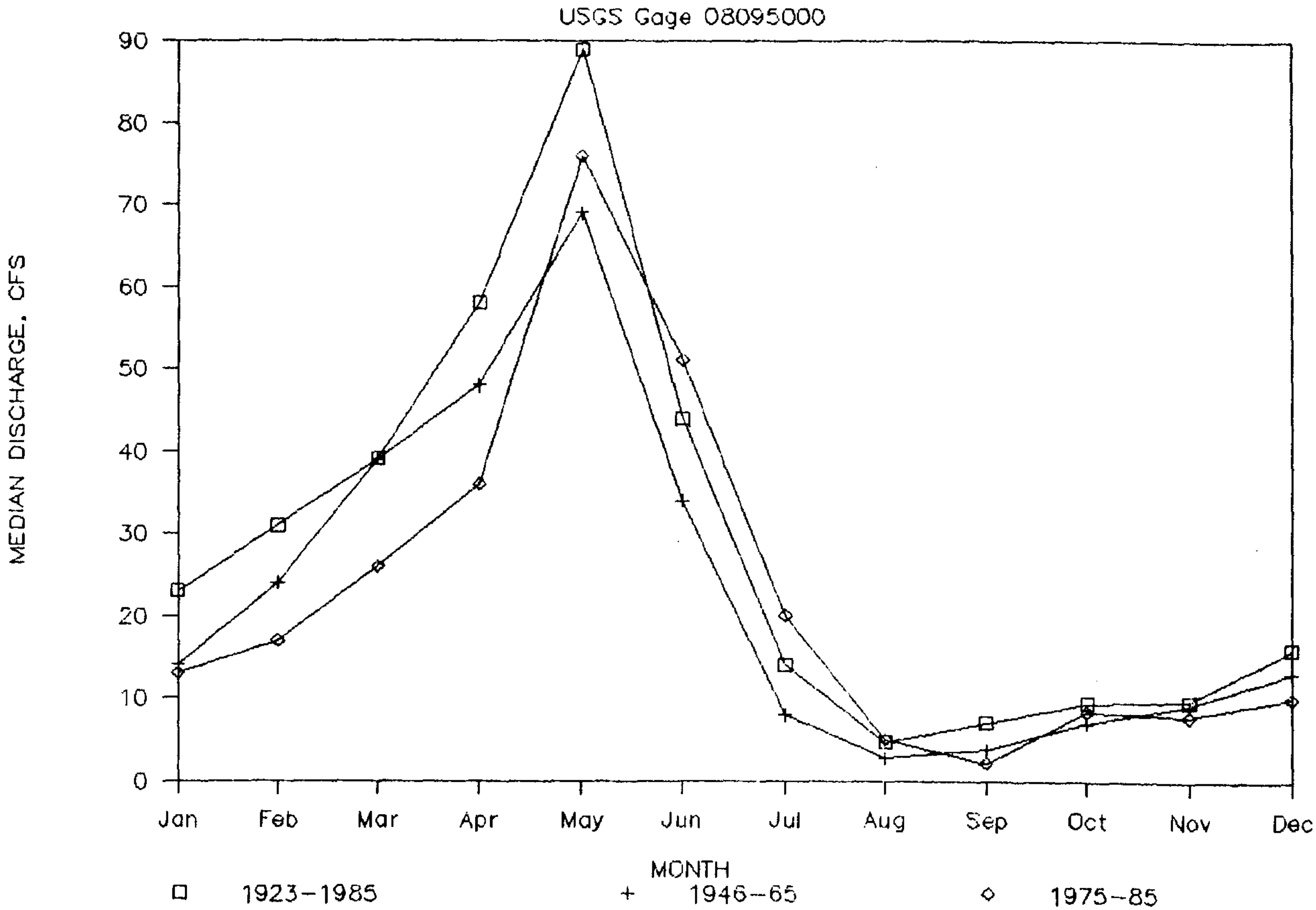
The stream gages nearest the location of the proposed Lake Bosque are U.S. Geological Survey (USGS) stations at Hico, about 28 miles upstream, and at Clifton, about 20 miles downstream of the dam site. Drainage area at the proposed dam is 707.6 square miles, which encompasses 73% of the area above the Clifton gage. Average discharge of the North Bosque River at Clifton is approximately 187 cubic feet per second (cfs) when calculated over the entire 1923-1985 period of record (USGS, 1987). At the Clifton gage the median annual discharge, that flow at which one half the daily average flows are greater and one half are less is 20 cfs, 10.7% of the average. The large difference between the average and median discharges reflects the statistical effect of occasional large flood flows and indicates the great variation in discharge experienced at a given location. Median discharge calculated on a monthly basis shows a spring (March-June) maximum in which median monthly discharges are roughly 2 to 4 times the annual median. The July-October low flow period exhibits medians of one half to one forth the annual value while the remaining months tend to approximate it (Figure 3-3).

Yield and reservoir operation studies (HDR Infrastructure, Inc., 1987a) were performed using the period of record 1946-1965 in order to include the critical drought period. This procedure is used in order to ascertain the reliable, or firm, yield of the system, on which the water users can depend. Median annual discharge during this latter period is about 14 cfs, or 30% less than that for the entire Clifton period of record.

In order to evaluate the effect of possible trends in the rainfall-runoff relationship on discharge characteristics at the proposed dam site and at the Clifton gage, additional

Figure 3-3

Median Flow by Month at Clifton, Texas



analyses were performed. Because of watershed changes, particularly the construction of flood retarding and sediment retention structures in the East and upper North Bosque basins during the period 1955-1975, records indicate that the rainfall-runoff ratio has declined, resulting in a real decrease in discharge. The period since completion of the SCS structures (1975-1985) has annual and median monthly flows at Clifton that are similar to those calculated for the 1946-1965 period. Median annual discharge for 1975-1985 is about 15 cfs at the Clifton gage. Plots of the median monthly discharges calculated for all three periods of record are included in Figure 3-3.

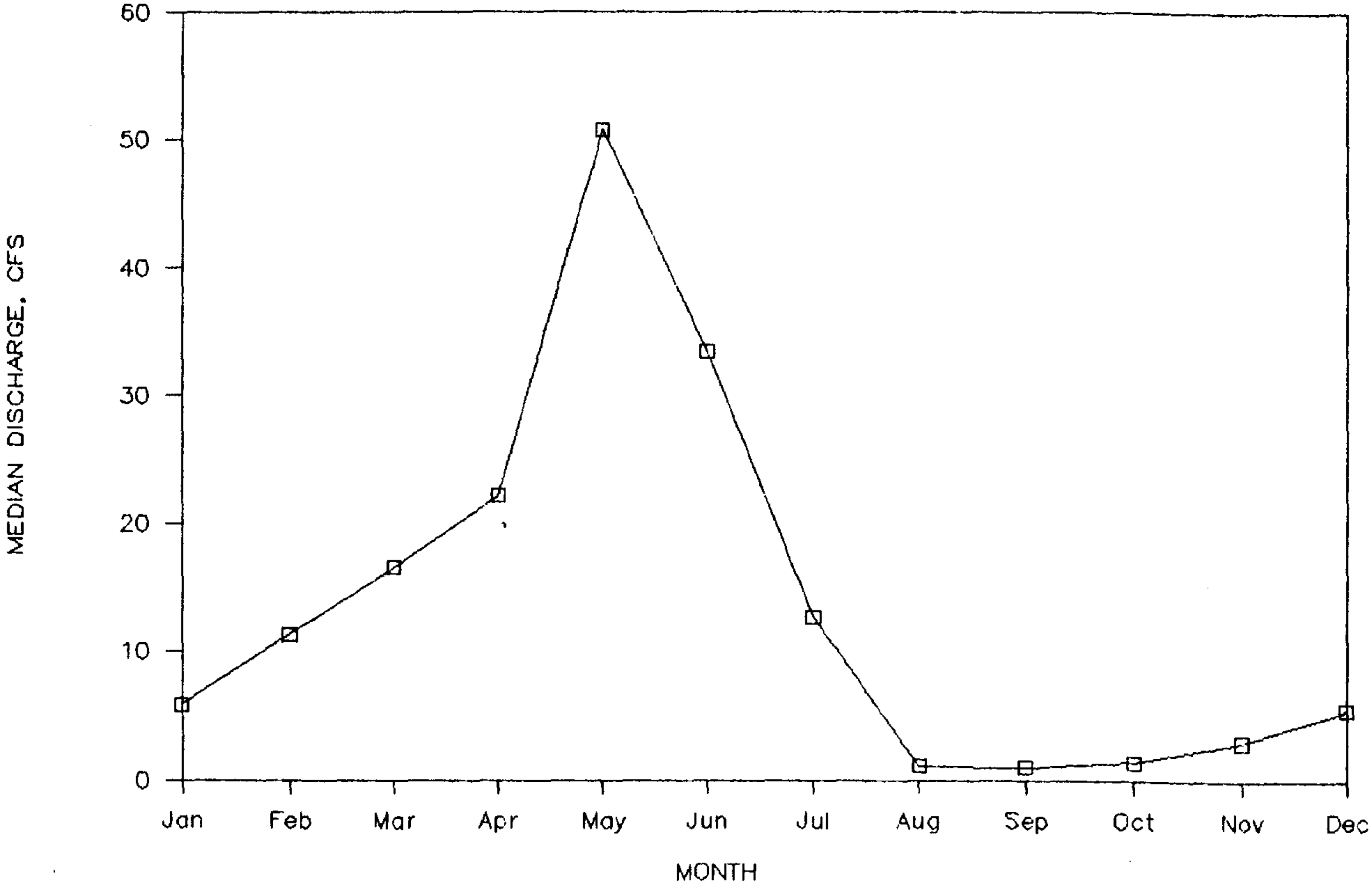
To allow discharges at the proposed dam site to be accurately estimated using available gage records, synoptic discharge measurements at Hico, Clifton and at Comanche Crossing (between Meridian and the dam site) were used to delineate the relation between discharge at the three locations. Figure 3-4 shows monthly median discharges at the proposed dam site calculated over the 1975-1985 period of record, and Table 3-1 presents the range of flow frequencies from which the figure was derived. The 1975-1985 period was chosen to determine discharge at the dam site to reflect the present and most probable future flow regime.

Water quality information is available for the North Bosque River in the Texas Parks and Wildlife Department fishery survey reports for Lake Waco (TPWD, 1974; 1975; 1976), from Statewide Monitoring Network stations maintained by the Texas Water Commission (TWC, 1987), from an intensive survey report (TDWR, 1980) and from data collected during the baseline studies (TCA, 1985; Paul Price Associates Inc., 1987a).

Figure 3-4

Median Flow by Month at Bosque Dam Site

Period of Record: 1975-85



□ Without Dam

Table 3-1 Monthly Flow Frequency Distribution at the proposed Dam Site

Percent of Days with Less Than Tabulated Flows	January	February	March	April	May	June	July	August	September	October	November	December
98%	132.00	485.00	776.00	1426.00	1749.00	653.00	231.00	54.20	73.00	187.00	42.60	82.20
95%	69.80	218.00	338.00	565.00	1071.00	391.00	101.00	25.80	23.10	82.10	24.00	49.30
90%	53.00	138.00	148.00	308.00	581.00	203.00	47.00	19.60	4.53	27.20	16.40	27.90
80%	32.80	41.50	81.80	131.00	275.00	106.00	28.20	11.10	2.76	4.53	9.59	11.30
70%	16.60	19.60	46.20	69.80	153.00	69.20	22.70	4.34	2.37	2.56	5.52	8.62
50%	5.91	11.40	17.70	22.20	50.70	33.50	5.91	1.10	0.97	1.36	2.96	5.52
30%	4.14	5.72	10.50	5.32	12.90	9.90	0.39	0.00	0.00	0.49	1.79	2.76
20%	3.75	4.73	5.12	3.75	5.52	4.14	0.00	0.00	0.00	0.00	0.95	1.95
10%	3.15	3.15	2.76	2.56	2.96	1.38	0.00	0.00	0.00	0.00	0.00	0.87
5%	2.96	2.76	1.81	1.95	0.14	0.34	0.00	0.00	0.00	0.00	0.00	0.14

Note: Tabulated values are average daily flows in cubic feet per second.
Source: HDR Infrastructure, 1987

Designated uses for Segment 1226 are Contact Recreation and High Quality Aquatic Life (Texas Water Code, 26.023.333.21.A). This Segment is not designated for Public Water Supply use, but Segment 1225, Lake Waco, is so designated and is used for that purpose.

Numerical criteria for Segment 1226 are:

Chloride	75	milligrams per liter (mg/l)
Sulfate	60	mg/l
TDS	540	mg/l
D.O.	5.0	mg/l
pH	6.5-9.0	units
Fecal Coliform	200/100	ml
Temperature	91	F

North Bosque River water is typically of slightly alkaline pH (7.0-9.0), moderate conductivity (300-600 micromhos per centimeter, umho/cm) and moderate to high alkalinity and hardness (100-300 mg/l). Bicarbonate is the dominant anion, chloride and sulfate concentrations are usually moderate, generally in the ranges 15-30 mg/l, and 20-50 mg/l, respectively.

Nutrient levels tend to be moderate to high. For example, about half of all total phosphorus samples collected between Meridian and Clifton since 1983 have exceeded 0.05 mg/l. During the 1980 through 1983 period most values from that location fell in the range 0.02-0.05 mg/l. Inorganic nitrogen levels also tend to be moderate to occasionally high, but ammonia is generally not present at problem levels. Chlorophyll *a* measurements from North Bosque stations do not indicate excessive amounts of suspended algae in response to these nutrients. However, all solid surfaces in shallow water typically exhibit massive growths of filamentous green algae, which apparantly constitutes a mainstay of the river food webs.

While dissolved oxygen (DO) levels are only rarely observed to fall below 5.0 mg/l, diurnal ranges are often quite large, presumably reflecting the metabolism of the large algal biomass. Data collected in April 1978 showed a zone from Stephenville to Hico affected by wastewater discharge (TDWR, 1980). This impact was not evident in diurnal DO measurements made in October 1983 (TWC, 1987). Unlike the North Bosque River, Lake Waco periodically exhibits serious DO depletion in the hypolimnion. The City of Waco operates a system of compressed air bubblers in the North Bosque arm of the lake to suppress stratification and assist in reaeration to help minimize water treatment costs.

3.4.2.2 Wetlands and Floodplains

Wetlands in the proposed reservoir site are mapped and discussed in the Baseline Ecology Survey (TCA, 1985). These consist, for the most part, of the channel of the North Bosque, its tributaries and artificial stock watering ponds. There are also a few small seep areas that are sufficiently persistant to allow development of wetland vegetation. This situation appears typical of the remainder of the North Bosque Valley all the way to Lake Waco.

Generalized flood potential and floodplain studies that include the North Bosque River have been conducted by the U.S. Army Corps of Engineers but the only FEMA floodplain study available is for Valley Mills. HDR Infrastructure, Inc. has estimated the present 100, 50 and 10 year floods to have peaks of 94,500, 80,360 and 47,660 cfs, respectively, at the proposed dam site. In the reach below the dam site to Meridian, the 100 year flood inundates an average of about 145 acres per stream mile, giving an average stream width at maximum stage of approximately 1200 feet.

3.5 Aquatic Biology

3.5.1 Aquatic Habitats and Biota

Aquatic habitats are defined by the same factors that shape terrestrial ones; the interaction of regional climate, geology and soils together with the biological responses of resident species and human activities. As a result of regional geology and climate, the North Bosque River exhibits the same channel morphology from the proposed reservoir headwaters below Iredell all the way to Lake Waco, a distance of about 60 river miles. These same factors have also influenced human settlement patterns and land uses, resulting in relatively uniform cultural impacts throughout this reach.

3.5.1.1 Channel Characteristics

The North Bosque River channel is typically 75 to 150 feet wide, incised into an alluvial floodplain in which it is free to meander. The channel is bordered with steep to vertical banks up to about 30 feet in height. Unless vertical, the banks support a narrow strip of brush or woodland. Except for these wooded strips, which rarely exceed 50 feet in width, land adjacent to the river is almost exclusively cultivated (SCS, 1980).

The river exhibits a characteristic pool-riffle sequence throughout the survey reach that consists of elongated pools, commonly 200 to 1000 yards, or more, in length, often occupying the full width of the bed, that terminate in short boulder/cobble/gravel riffles. At intervals, the common pool/ short riffle sequence gives way to reaches in which bed elevation appears to drop sharply in a series of short pools, boulder/cobble riffles and deeper runs over gravel/cobble substrates. The wetted area in these reaches typically does not occupy the entire channel bottom, but is a narrower channel meandering among an extended series of gravel bars.

The gradient of the North Bosque River ranges from a maximum of 27 feet per mile to a minimum of less than 5 feet per mile. The reach from the reservoir headwaters to Commanche Crossing (Figure 3-1) and most of the way to Lake Waco exhibits an average gradient of about 5.5 feet per mile. Between the proposed dam site and Lake Waco, high gradient reaches occur between Meridian and Clifton (14 feet per mile) and below China Springs Crossing (27 feet per mile) . The higher gradient portion of the Meridian-Clifton reach is about 6 miles in length, while the highest gradient reach, just above Lake Waco is only 3-4 miles long. The average gradient for the entire length of the North Bosque River is 9.9 feet per mile. Changes in gradient are controlled by the lithology and structure (dip) of the formations traversed by the river channel. This relation is illustrated in Figure 3-5.

The East Bosque River is a smaller, intermittent stream with a narrow, but well developed channel which in many places is heavily shaded by surrounding vegetation. Substrates are typically gravel (often *Gryphaea* fossils) with occasional outcropping slabs and loose boulders in the reach to be inundated. This stream usually exhibits clearer water than the North Bosque, a greater variety of rooted vegetation and substantially greater accumulations of terrestrial plant debris from riparian vegetation. The food webs of the East Bosque River, in common with most lower order streams, are probably based primarily on the consumption of detritus.

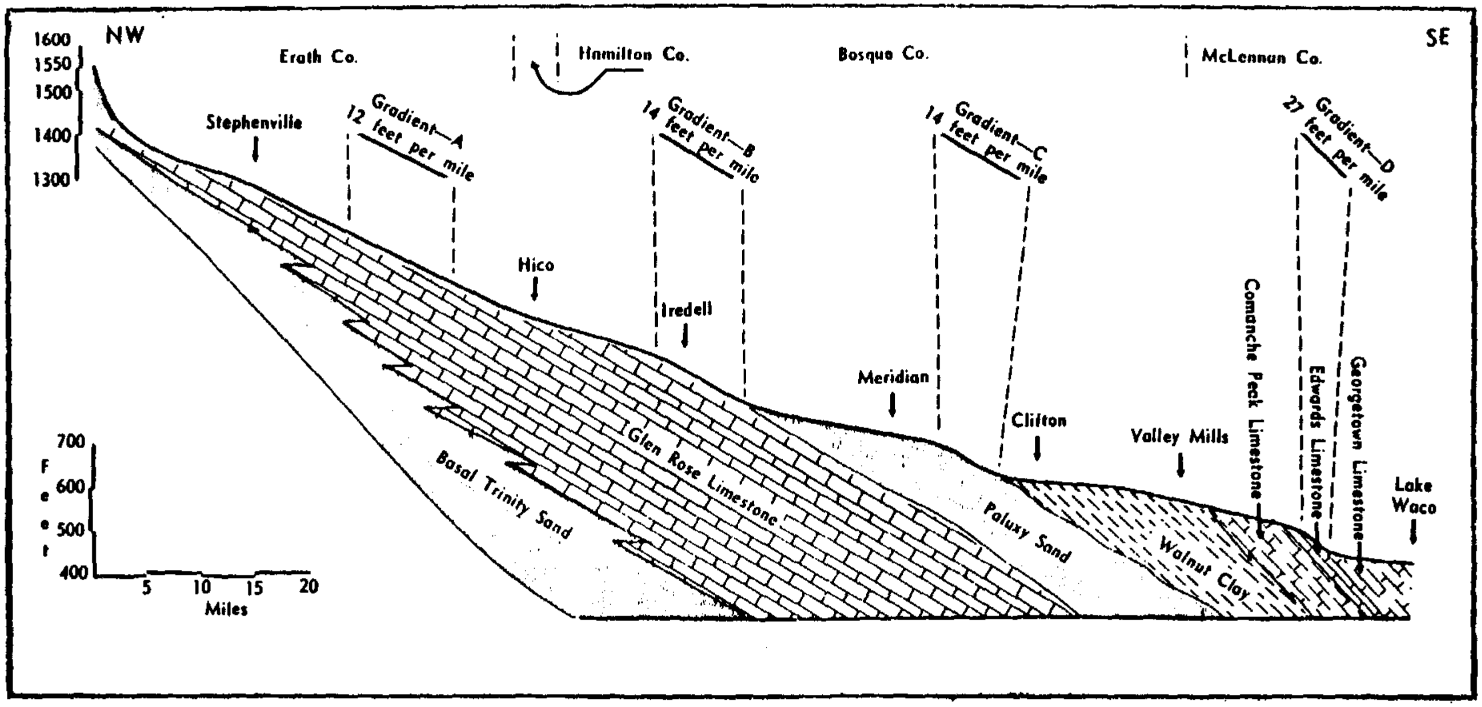


Figure 3-5
The Influence of Underlying Geological Structure on the Longitudinal Gradient of the North Bosque River (from Proctor, 1969)

3.5.1.2 Pool Habitats

Pool habitats with muddy sand and gravel substrates dominate the river environment both within the reservoir site and in the reach downstream to Lake Waco. The extreme upper portion of Lake Bosque (Station 5, TCA, 1985) will inundate a portion of the streambed floored with slabs of Glen Rose limestone overlaid by sheets and bars of gravel and finer sediments. Habitats here are comprised almost entirely of shallow, rock bottomed pools.

Rooted aquatic vegetation is largely absent from the pools, as they tend to have steeply sloping littoral margins that, together with the characteristically turbid water, periodic scouring during high flows and marginal shading from riparian vegetation, limits the development of these species. Pool depths, even at zero flow when intervening segments are dry, appear to commonly exceed six feet. Pools tend to become gradually shallower in an upstream direction, with the uppermost segment often consisting of a very flat stream bed completely inundated by a few inches of water even at relatively low flow. Silty sands and gravel dominate the physical habitat in the river. Rocky areas, stands of aquatic vegetation, accumulations of plant debris and masses of tree roots exposed in cut banks all occur occassionally and contribute to habitat diversity but cannot be considered common.

Given this general lack of cover in the North Bosque River, it is probable that shallow areas in the main stem and in the tributaries are important as spawning areas and as refuges for forage species and the juveniles of larger forms.

Pools are also the dominant habitat component in the East Bosque River. Small, relatively clear pools formed where the extensive gravel substrate has been scoured out at the base of a bluff or channel bend are typical of this stream. These pools often contain substantial stands of aquatic vegetation and accumulations of plant debris. During extended dry periods only a small proportion (10% or less) of the stream bed of the East Bosque River contains surface water.

3.5.1.3 Riffle Habitats

Pools terminate in riffles that are usually quite short (less than 50 yards) regardless of their composition. Ledge outcrops occur occasionally, but riffles with gravel/cobble/boulder substrates are most common.

The riffle at Comanche Crossing (Station 1 in the Baseline Ecology Survey and the location of IFIM studies by the U.S. Fish and Wildlife Service) is reasonably typical of the North Bosque River. This riffle drops nearly two feet in bed elevation in 50 yards. If we assume all changes in stream bed elevation occur in riffles, and that all riffles have the same gradient, we will expect about 150 yards/mile (8.5% of channel length) of riffle habitat in the low gradient (5.5 feet per mile) reaches that account for 83% of the channel from the reservoir headwaters to Lake Waco.

Compared to lower gradient reaches, pools in the Meridian-Clifton high gradient segment were shorter, generally less than 200 yards in length, but riffles were also shorter, ranging from single falls over ledges through cobble/gravel runs up to 30 yards in length. Riffles accounted for about 20% of channel length in the reach examined.

Riffle habitat is very restricted in the reach of the East Bosque River to be inundated by construction of Lake Bosque. Like the uppermost North Bosque River reach of the proposed reservoir, substrates are either gravel bars or limestone slabs and the riffle habitats typical of most of the North Bosque River tend to be absent.

3.5.1.4 Aquatic Biota

For the reasons noted above, aquatic macrophytes are restricted in distribution in the North Bosque River. The only species observed in significant amounts there has been American water willow (*Justicia americana*), although bladderwort (*Utricularia* sp.) and South American elodea (*Elodea densa*) were present in the East Bosque. River productivity appears to be based primarily on algal growth. The large pools that dominate the river environment support planktonic algae, while solid surfaces in shallow areas usually exhibit substantial stands of filamentous green algae, predominantly *Cladophora* sp., but *Hydrodictyon* sp. has also been observed and others are undoubtedly present. Both are common in nutrient rich waters in Central Texas. The paucity of terrestrial plant debris in the river is further indication of the autotrophic character of this stream.

Invertebrate assemblages reflect the substrates, the flow regiemes and the food supplies available at the times of collection. Pool habitats tend to exhibit a diverse and abundant assemblage of organisms that live within and sprawl upon sandy and silty sediments. This community is dominated by chironomids, oligochaetes and the asiatic clam, *Corbicula fluviatilis*. Other groups tend to be more restricted in diversity and abundance by the low substrate diversity characteristic of this river, but includes typically lentic taxa of Crustacea, Ephemeroptera, Odonata, Coleoptera, Gastropoda and others, rather than species of definitely riverine association.

Riffle areas are heavily dominated by filter feeders, including the caddisfly *Cheumatopsyche* sp. and blackflies (Simulidae), and by Mayflies that cling to stones and graze on epilithic algae (*e.g.*, *Heptagenia* sp., *Stenonmema* sp.). The large megalopteran predators (e.g., *Corydalus* spp.) are conspicuous by their absence from these habitats. The kinds and numbers of riffle invertebrates common in the proposed reservoir site appear to dominate downstream riffle habitats as well, at least to China Springs Crossing.

The general lack of substantial stands of rooted vegetation or accumulations of organic detritus (e.g., leaf pack, etc.), the extensive development of attached algae on submerged surfaces and the planktonic algae of the large, unshaded pools is reflected in the preponderance of surface inhabiting collectors and scrapers and the rarity of shredders in the invertebrate assemblage. This community structure indicates that the food webs in the North Bosque River are primarily based on direct consumption of instream (autochthonus) production rather than being detrital based, as is generally the case in smaller streams such as the East Bosque River.

Table 3-2 lists fish species collected in the Bosque River during the ecological baseline survey (1984-1985) and by Texas Parks and Wildlife Department in 1953 and fish reported from Lake Waco (TCA, 1985; TPWD, 1954; 1974; 1975; 1976). The assemblage is not atypical for the Texan Biotic Provence, which is an ecotonal region between the eastern woodland and western grassland faunas. Most of the species collected are widely distributed, but one, the chub shiner (*Notropis potteri*), is restricted to the Texan Biotic Provence. Others, including the blackstripe topminnow (*Zygonectes notatus*), blacktail shiner (*Notropis venustus*) and spotted bass (*Micropterus punctulatus*) are primarily eastern and coastal plain species.

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
Spotted Gar	*Lepisosteus oculatus*			+
Longnose Gar	*L. osseus*	+		+
Threadfirm Shad (v)	*Dorosoma petenense*			+
Gizzard Shad	*D. cepedianum*	+	+	+
Carp	*Cyprinus carpio*	+		+
Golden Shiner	*Notemigonus crysoleucas*	+		+
Pugnose Minnow	*Opsopoeodus emiliae*	+		
Suckermouth Minnow	*Phenacobius mirabilis*	+		
Chub Shiner	*Notropis potteri*		+	
Blacktail Shiner	*N. venustus*	+	+	+
Red Shiner	*N. lutrensis*	+	+	+
Ghost Shiner	*N. buchanani*	+		
Blackspot Shiner	*N. atrocaudalis*			+
Bullhead Minnow	*Pimephales vigilax*			+
Fathead Minnow	*P. promelas*	+		
Stoneroller	*Campstoma anomalum*			+
Small Mouth Buffalo	*Ictiobus bubalus*			+
River Carpsucker	*Carpiodes carpio*	+	+	+
Gray Redhorse	*Moxostoma congestum*			+
Creek Chubsucker	*Erimyzon oblongus*		+	

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
Channel Catfish (V)	*Ictalurus punctatus*	+	+	+
Black Bullhead	*Ictalurus melas*			+
Yellow Bullhead	*I. natalis*			+
Flathead Catfish	*Pylodictis olivaris*			+
Freckled Madtom	*Noturus nocturnus*			+
Blackstripe Top-minnow	*Fundulus notatus*	+	+	+
Black spotted Top-minnow	*Fundulus olivaceus*			+
Mosquitofish	*Gambusia affinis*	+	+	+
Mississippi Silverside	*Menedia andens*			+
Brook Silverside	*Labidesthes sicculus*			+
Spotted Bass	*Micropterus punctulatus*	+	+	+
Largemouth Bass (V)	*M. salmoides*	+	+	+
Warmouth	*Lepomis gulosus*	+		+
Green Sunfish	*L. cyanellus*	+	+	+
Redear Sunfish	*L. microlophus*			+
Bluegill	*L. Macrochirus*	+	+	+
Orange Spotted Sunfish	*L. humilis*			+
Longear Sunfish	*L. megalotis*	+	+	+
White Crappie	*Pomoxis annularis*	+		+
Black Crappie	*Pomoxis nigromaculatus*			+
Striped Bass (V)	*Roccus saxatilis*			+

Table 3-2 Fish Species Occuring in the North Bosque River and Lake Waco

Common Name	Scientific Name	Collected Oct. 1984 or May 1985	Reported 1953 by TPWD**	Reported from Lake Waco *
White Bass	*Roccus chrysops*			+
Walleye (V)	*Stizostedion vitreum*			+
Logperch	*P. caprodes*	+		+
Freshwater Drum	*Aplodinotus grunniens*			+

Notes: * Texas Parks and Wildlife Department, 1974,1976.
** Texas Parks and Wildlife Department, 1954. (V) = stocked by TPWD into Lake Waco.

The species known to inhabit the North Bosque River tend to be characteristic of pool or backwater habitats and most are capable of survival and reproduction in a reservoir. For example, the only darter collected from the reservoir site has been the logperch (*Percina caprodes*). This fish was more widely distributed and abundant in samples collected during a zero flow period (fall 1984) than in the following spring when riffles were present. The species is also reported to be present in Lake Waco.

Of the forage fish, the most abundant species were mosquitofish (*Gambusia affinis*) and blackstripe topminnow, but the cyprinids (minnows) constituted the most diverse group of small fishes collected in the reservoir site. So called rough fish, primarily longnose gar (*Lepisosteous osseus*), river carpsucker (*Carpiodes carpio*) and gizzard shad (*Dorosoma cepedianum*), were common in collections from the proposed reservoir site. Gamefish tended to be present in lower numbers, and were represented by channel catfish (*Ictalurus punctatus*) and several centrarchid species including spotted bass (*Micropterus punctulatus*), crappie (*Pomoxis annularis*), warmouth (*Lepomis gulosus*), bluegill (*L. macrochirus*), and longear sunfish (*L. megalotis*). Most of these species are also present in Lake Waco, although in different proportions, and the Lake appears to have a somewhat more diverse assemblage than the river.

All groups, but particularly large multivoltine forms, are affected by the periodic low flow periods that reduce the river to a series of isolated pools. During these periods primary production can decrease dramatically due to the lack of nutrient input and inadequate recycling, while the paucity of cover may expose invertebrates, small fish species, and juveniles, to catastrophic levels of predation. Periods of zero summer flow at the proposed dam site presently recur at an average rate of once in three years (Table 3-1).

3.5.2 Important Species

Important species are defined as those which (a) are commercially or recreationally valuable, (b) are threatened or endangered, (c) affect the well-being of some important species within criteria (a) or (b); or, (d) are critical to the structure and function of the ecological system.

3.5.2.1 Commercially or Recreationally Important Species

Local fishermen and Texas Parks and Wildlife Department personnel report that channel and yellow catfish (*Ictalurus natalis*) constitute the most important recreational resource in the North Bosque River. Bass and crappie are also sought, often incidentally to catfishing, and rough fish such as buffalo, carp and gar, are sometimes fished for. These species are all reported by Texas Parks and Wildlife Department to be present in Lake Waco, although the assemblage reported from that lake appears to be substantially more diverse than is present in the North Bosque River.

While Lake Waco supports a substantial fishery for white bass (*Roccus chrysops*), this species is not believed to run upstream even as far as China Springs Crossing, and no other important, strongly migratory fish is known from the Bosque River.

3.5.2.2 Threatened and Endangered Species

With one exception, no threatened or endangered aquatic species, listed either by the Texas Parks and Wildlife Department or by U.S. Fish and Wildlife Service, is known to occur or is considered likely to occur in Bosque County. Harter's water snake (*Nerodia harteri*) is listed as endangered by the TPWD, and is considered "confirmed" in Bosque County. The upper Brazos River drainage subspecies (*N. h. harteri*) is not currently believed to be in danger of extinction by USFWS, and intensive surveys in its range indicate that it is highly unlikely to be found in the Bosque River system (Maxwell, 1982; Scott and Fitzgerald, 1985).

3.5.2.3 Other Important Species

No single species is known to be critical to the survival of any important species, or to the functioning of the community as a whole. The most abundant species, or groups of species, present in the river are considered important in that they define the character of the biological community. A variety of algal producers and both invertebrate and vertebrate consumers constitute a complex food web based largely on in situ photosynthesis. But no particular species, either among the algal producers or among the consumer links, appears likely to be critical to this trophic structure as none of the consumers is known to be strictly dependant on one or a few species for its nutrition.

The stands of water willow present in the channel may be important in providing habitat for some invertebrate taxa that might otherwise be excluded and they probably serve as cover for forage fish and juveniles of larger species. However, the extent of the habitat created by this species is not great, and it is unlikely, given the taxa collected in the North Bosque River, that it can be considered critical to the functioning of the aquatic community or to a particular important species.

3.6 Vegetation

The Lake Bosque site lies in the southeast region of the Cross Timbers and Prairies Vegetational Area (Gould, 1975). Although the climax vegetation type of the Cross Timbers is typically upland woodland dominated by post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) little of this is present in the vicinity of the reservoir site. Due to the proximity of the project area to other vegetational areas (i.e., Blackland Prairies to the east, Rolling Plains to the west, and Edwards Plateau to the south), the native vegetation of the project area contains species characteristic of these adjacent areas. Project area upland woodlands, for example, are dominated by many species characteristic of the Edwards Plateau.

Over 200 plant species were identified in the project area during the original baseline studies. These species were grouped into eight major plant communities consisting of upland and bottomland woodlands, native grasslands, improved pastures, stream beds, aquatic habitats, wetlands, and croplands. A vegetation map of the Lake Bosque project area is presented in the Baseline Ecology Report (TCA 1985). Table 3-3, reproduced from TCA, 1985, lists the acreages of each community type affected by the proposed project.

3.6.1 Plant Communities And Characteristic Species

3.6.1.1 Upland Woodland

Upland woodlands, which encompass only 182.5 acres within the 4756 acre reservoir site (the area occupied by the conservation pool, dam and spillway), occur primarily as narrow bands along ridge tops at the periphery of the project area. These woodlands are dominated by ash juniper

Table 3-3 Areas (acres) and Percentages of Vegetation Map Units, Bosque Lake Project Area, May 1985

	Normal Pool (1)	100 year Flood Pool (2)	Dam & Spillways (3)	Total	Percentage of Total
U Upland Woodland	106.29	92.74	3.44	202.47	3.30%
Uj Upland, Juniper dominated	72.78	4.82	0.00	77.60	1.26%
Up Upland, Post Oak dominated	0.00	0.00	0.00	0.00	0.00%
N Native Pasture	1,466.71	765.84	44.08	2,276.63	37.06%
Nm Native Pasture > 50% Mesquite cover	14.46	2.30	0	16.76	0.27%
I Improved Pasture	927.00	239.44	80.35	1,246.79	20.30%
C Cropland	1,000.00	130.16	49.36	1,179.52	19.20%
Cp Pecan Orchard	6.89	0.00	0.00	6.89	0.11%
B Bottomland Woodland	780.53	105.83	12.40	898.76	14.63%
W Wetland	12.86	13.55	0.00	26.41	0.43%
A Aquatic (ponds)	18.13	12.41	0.00	30.54	0.50%
S Streambed	158.86	20.20	1.83	180.89	2.94%
TOTALS	4,564.51	1,387.29	191.46	6,143.26	1.00

Note: (1) Acres inundated at normal operating pool, 830 ft. MSL.
(2) Area of intermittant inundation, between elevations 830 and 841.3 MSL.
(3) Area covered by dam and spillways.
Source: Technical Consulting Associates, 1985

(*Juniperus ashei*), plateau live oak (*Quercus fusiformis*), Texas red oak (*Q. texana*), and cedar elm (*Ulmus crassifolia*). Texas ash (*Fraxinus texensis*), post oak, coma (*Bumelia lanuginosa*), and netleaf hackberry (*Celtis reticulata*) are also common overstory species.

3.6.1.2 Bottomland Forest

The bottomland forests of the project area represent the western most outliers of the extensive bottomland forests of the eastern United States. Within the reservoir site this community occupies 792.9 acres of broad, first and second bottomland terraces along the North Bosque River, narrow riparian areas along secondary drainages, and mesic slopes immediately adjacent to the river. Although this habitat type is referred to as "bottomland forest" (and "decidous forested wetland" by the U.S. Fish and Wildlife Service), it does not generally fit the U.S. Army Corps of Engineers definition of a wetland and is not dependant on annual inundation by the North Bosque River for maintenence. The Bosque County Soil Survey (SCS, 1980) shows the forests adjacent to the Bosque River channel are developed on occasionally flooded (2-5 years) Bosque Loam and Frio Silty Clay Loam soils. Those on mesic slopes along tributary channels and in other areas away from the main river channel have developed on a variety of soils.

Due to the distribution of this community, substantial variation in floral composition of the overstory, understory, shrub, and ground cover layers amongst the stands sampled were evident. Cedar elm was the single most dominant species present, while bur oak (*Quercus macrocarpa*), pecan (*Carya illinoiensis*), and Texas sugarberry (*Celtis laevigata*) were the most common co-dominants on the bottomland terraces. Boxelder (*Acer negundo*) was most important on the mesic slopes along the river in association with pecan, Texas sugarberry, cedar elm, and American elm (*Ulmus americana*).

3.6.1.3 Native Grassland

Native grasslands account for 1525.2 acres of the reservoir site. A small portion (14.5 acres) has greater than fifty percent honey mesquite (*Prosopis glandulosa*) cover. The majority of this community consists of overgrazed upland pastures, but also includes well-managed or lightly grazed pastures, roadsides, and a few small remnants of native prairies. The dominants of the original tallgrass prairie have decreased in importance over most of the site, primarily due to overgrazing, fire control, and mowing (roadsides). Such decreasers include little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), and Indian grass (*Sorghastrum nutans*). Texas wintergrass (*Stipa leucotricha*) is most common in overgrazed pastures, usually in association with Texas grama (*Bouteloua rigidiseta*), silver beardgrass (*Bothriochloa saccharoides*), buffalo grass (*Buchloe dactyloides*), and side-oats grama (*Bouteloua curtipendula*). As a result of mowing pressure, roadsides are dominated by increasers such as King Ranch bluestem (*Bothriochloa ischaemum* var. *songaricus*), silver beardgrass, jointed goat-grass (*Triticum cylindricum*), three-awn (*Aristida* spp.), and Texas wintergrass.

Well-managed native pastures occur at scattered locations in the project area, but are most prominent in the northeast portion. Native grasses are prevalent in many of these pastures because of active reseeding efforts. Climax grasses present include little bluestem, side-oats grama, Indian grass, muhly (*Muhlenbergia* spp.) and dropseed (*Sporobolus* spp.).

3.6.1.4 Improved Pasture

Improved pastures cover 1007.4 acres of the reservoir site. These were formerly native grasslands which have given way, through planting efforts, to exotic grasses such as King Ranch bluestem, kleingrass (*Paspalum coloratum*), and both common and coastal bermudagrass (*Cynodon dactylon*). Increasers which may also be found on improved grasslands include Texas wintergrass, windmill fingergrass (*Chloris verticillata*), silver beardgrass, and broomweed (*Xanthocephalum dracunculoides*). In addition, numerous dicot herbs of importance to this community may be found at different times of the year.

3.6.1.5 Stream Beds

This 160.7 acre plant community is limited to the stream beds and immediately adjacent, nonforested banks along the North and East Bosque rivers. Most of the stream bed consists of linear pools and exposed bars of rock and gravel which are scoured and rearranged during flood events. Aquatic vegetation is almost entirely limited to stands of American water willow (*Justicia americana*) and mats of filamentous green algae including *Cladophora* sp. and *Hydrodictyon* sp., except during extended dry periods when species characteristic of marginal lentic habitats (see Aquatic Habitats, below) invade the channel.

Where terrestrial vegetation has become established, the stream banks may become densely vegetated with species such as sumac (*Rhus* spp.), eastern prickly pear (*Opuntia compressa*), Mexican devil-weed (*Aster spinosus*), mist-flower (*Eupatorium coelestinum*), little bluestem, buffalo-gourd (*Cucurbita foetidissima*), side-oats grama, Johnson grass (*Sorghum halepense*), and cat-brier (*Smilax bona-nox*). More elevated, protected areas may have Arizona walnut (*Juglans* *major*), buttonbush (*Cephalanthus occidentialis*), bastard indigo (*Amorpha fruticosa*), Roosevelt weed (*Baccharis neglecta*), and rough-leaf dogwood (*Cornus drummondii*). Numerous herbs and vines specific to this community include cardinal flower (*Lobelia cardinalis*), hierba del marrano (*Aster subulatus* var. *ligulatus*), horse-weed (*Conyza canadensis*), late eupatorium (*Eupatorium serotinum*), hairy grama (*Bouteloua hirsuta*), morning glory (*Ipomoea trichocarpa*), noseburn (*Tragia brevispica*), and others. Substantial development of terrestrial vegetation is presently uncommon within the channel. However, stands of cocklebur (*Xanthium strumarium*), Johnsongrass, buttonbush, and other weedy species develop on the gravel bars during extended low flow periods.

3.6.1.6 Aquatic Habitats

The aquatic habitats of the reservoir site account for about 18.1 acres, which only includes scattered farm and stock ponds. Emergent species which dominate the periphery of these ponds include buttonbush, pink smartweed (*Persicaria bicornis*), Texas frog fruit (*Phyla incisa*), spikerush (*Eleocharis* spp.), sedges (*Carex* spp.), common bermudagrass, American water willow, wild petunia (*Ruellia nudiflora*), black willow (*Salix nigra*), and Roosevelt weed.

3.6.1.7 Wetlands

Wetlands occupy 12.9 acres of the reservoir site. The majority of the wetland habitats are areas immediately along the edges of streams and ponds, old river meander depressions in the floodplain, and beaver impoundments. In these areas, emergent marsh vegetation occurs as small, scattered patches. With the exception of black willow and Roosevelt weed, dominant species in this community include those listed for aquatic habitats.

3.6.1.8 Cropland

Croplands account for 1056.2 acres, plus 6.9 acres of pecan groves. Row crops of sorghum (*Sorghum bicolor*), wheat (*Tritiicum aestivum*), and oats (*Avena fatua*) occupy the majority of this largely bottomland acreage. Oats are widely planted, especially in the bottomland pastures, during the fall. Common ruderal species which invade cultivated and fallow fields include Johnsongrass, cat-brier, cocklebur, bull nettle (*Cnidoscolus texanus*), ragweed (*Ambrosia* spp.), common sunflower (*Helianthus annuus*), and broomweed.

3.6.2 Important Plant Species and Communities

Important species are defined above, in Section 3.4.2. Important communities are considered to be those that have unusual ecological value.

3.6.2.1 Recreationally and Commercially Valuable Species

Commercially important tree species in the project area include ash juniper and hardwoods (cedar elm, green ash, pecan, Shumard red oak, plateau live oak, and others) which may be used for fence posts or firewood. In addition, pecans may be sold for profit or used for personal consumption. The regional diversity in soils and range sites leads to wide variations in the density and relative importance of tree species.

Both native and improved forage grasses and row crops are of commercial importance both as on site livestock feed and as cash crops. Common and coastal bermuda grass, King Ranch bluestem, and Kleingrass are most important in the area's extensive improved pastures. Common and coastal bermuda grass and Johnsongrass are important cultivated species in the hayfields, and the row crops of greatest commercial importance oat, sorghum, and wheat.

Numerous plant species on the site are ecologically important as browse and forage materials for important wildlife species. Examples include various grape species (*Vitis* spp.), cat-brier, common elder-berry (*Sambucus canadensis*), numerous oak species, possum-haw (*Ilex decidua*), yaupon (*Ilex vomitoria*), rough-leaf dogwood, common buttonbush, American beautyberry (*Callicarpa americana*), pecan, black hickory (*Carya texana*), black willow, cedar elm, Texas sugarberry, southern dewberry (*Rubus trivialis*), poison ivy (*Rhus toxicodendron*), Texas persimmon (*Diospyros texana*), red ash (*Fraxinus pennsylvanica*), and various sedges and grasses. Oak mast is of particular importance to deer.

3.6.2.2 Endangered and Threatened Plant Species

No threatened or endangered plant species, either listed by the U. S. Fish and Wildlife Service or the Texas Parks and Wildlife Department or Texas Organization for Endangered Species (TOES) are known from these counties.

3.6.2.3 Important Communities

Bottomland forest and riparian habitats are of particular ecological importance in the project area, as well as in the general region. These habitats, while relatively small in areal extent, are responsible for much of the diversity in plant and wildlife in the project area. Many important species are limited to or prefer these types of habitats. Because of the trend of reduction in bottomland forest throughout Texas, primarily as a result of agricultural activities, this lowland habitat type is of particular concern.

3.7 Wildlife

The Lake Bosque project area occurs on the western edge of the Texan Biotic Province near the northeastern edge of the Balconian Biotic Province as delineated By Blair (1950). The Texan Province extends south as a broad strip to the Gulf Coast between Calhoun and Brazoria counties, and it extends north through central Oklahoma to the Kansas border. The region is considered to be an ecotone between the eastern forests and western grassland. This ecotonal nature of the region is further indicated by its placement in the Cross Timbers and Prairies Vegetational Area.

Results of the site-specific surveys revealed a diverse fauna in the Lake Bosque project area, with faunal elements exhibiting a variety of biotic affinities. Fourteen species of mammals, 61 species of birds and 27 species of reptiles and amphibians were detected during the fall reconnaissance and spring baseline surveys (1984-85). Common and other characteristic species are discussed in the following paragraphs.

Although the majority of the project area wildlife habitats and species were typical of the Texan Province, the wildlife species assemblage in the project area was distinctly marked by Balconian Province characteristics. The Cretaceous-age limestone uplands in the project area provided habitat for some Edwards Plateau forms that are not typical of, or at least are not as common in the rest of the Texan Province. For example, the white-ankled mouse (*Peromyscus pectoralis*), a typical Balconian Province species was common in the woodlands. Some other observed species that are more typical of the Balconian than the

Texan Province included the Texas greater earless lizard (*Cophosaurus texana*), Texas spotted whiptail (*Cnemidophorus gularis*), ladder-backed woodpecker (*Picoides scalaris*), and rufous-crowned sparrow (*Aimophila ruficeps*).

Like most areas in the region, clearing of bottomland forest for agriculture has resulted in its conversion to open habitats of improved pasture and cropland.

3.7.1 Wildlife Communities and Species

3.7.1.1 Bottomland/Riparian Woodland

Typical bottomland/riparian woodland associated wildlife species were present in the project area, but their preferred habitat was limited to relatively small interspersions of woodland, mostly in the form of narrow riparian strips.

Transect counts of birds in one of these bottomland/riparian strips indicated that the most common breeding species included the northern cardinal (*Cardinalis cardinalis*), Carolina chickadee (*Parus carolinensis*), tufted titmouse (*P. bicolor*), Louisiana waterthrush (*Seirus motacilla*), and Carolina wren (*Thryothorus ludovicianus*).

The white-ankled mouse was the only common small mammal captured in the bottomland habitat sampled by live-trapping. The white-tailed deer (*Odocoileus virginianus*), northern raccoon (*Procyon lotor*), and fox squirrel (*Sciurus niger*) were also commonly observed in this habitat. The gray treefrog (*Hyla versicolor* or *H. chrysoscelis*) was a common amphibian in the bottomlands.

Other less common, but equally characteristic species of the bottomland included the nine-banded armadillo (*Dasypus *novemcinctus*), Virginia opossum (*Didelphis virginiana*), red-bellied woodpecker (*Melanerpes carolinus*), downy woodpecker (*Picoides pubescens*), eastern wood pewee (*Cotopus virens*), yellow-billed cuckoo (*Coccyzus americanus*), red-eyed vireo (*Vireo olivaceus*), wild turkey (*Meleagris gallopavo*), and Texas rat snake (*Elaphe obsoleta*).

3.7.1.2 Upland Woodlands

Wildlife habitats of the upland woodlands in the project area have also been affected by clearing, primarily for conversion to native rangeland. As with the bottomlands, there are no large contiguous acreages of upland woodland, and strips of woodland on ridges at the periphery of the reservoir site are the most typical woodland situations. In some places these strips border the narrow riparian habitats of the intermittent drainages. In these locations, wildlife usage of the two habitat types overlaps to a considerable extent.

Based on transect counts, the most common breeding season birds in the upland woodland habitat type included the Carolina chickadee, brown-headed cowbird (*Molothrus ater*), northern cardinal, tufted titmouse, painted bunting (*Passerina ciris*), and lark sparrow (*Chondestes grammacus*). Mourning dove (*Zenaida macroura*) nest in the woody vegetation of the uplands as evidenced by a nest with two eggs found along the sampling transect. The red-tailed hawk (*Buteo jamaicencis*) was the common summer raptor in this habitat, but this wide-ranging species uses a variety of terrestrial habitats.

As in the bottomland woodland, the only commonly captured small mammal was the white-ankled mouse. Eastern cottontails (*Sylvilagus floridianus*) were commonly seen at the woodland/grassland edges and in openings of the upland woodlands.

The rocky slopes in the uplands harbored a number of reptilian species including the Texas greater earless lizard, Texas spotted whiptail, great plains ground snake (*Sonora episcopa*), and Texas lined snake (*Tropidoclonion lineatum*). The Texas spiny lizard (*Sceloporus olivaceus*), southern fence lizard (*S. undulatus*), Texas rat snake and gulf coast toad (*Bufo valliceps*) were also common species.

3.7.1.3 Open Habitat

Terrestrial wildlife habitats in the project area were predominantly open pastureland, rangeland, and croplands (3588.9 acres or 75.5% of the reservoir site).

Dominant breeding season birds detected in the native grassland transect included the eastern meadowlark (*Sturnella magna*), scissor-tailed flycatcher (*Tyrannus forficatus*), brown-headed cowbird, grasshopper sparrow (*Ammordramus sayannarum*), northern mockingbird (*Mimus polyglottus*), northern bobwhite (*Colinus virginianus*), and dickcissel (*Spiza americana*). Other characteristic birds of the open habitats included the western kingbird (*Tyrannus verticalis*), eastern kingbird (*T. tyrannus*), killdeer (*Charadrius vociferus*), common nighthawk (*Chordeilus minor*), Cassin's sparrow (*Aimophila cassinii*), mourning dove, and loggerhead shrike (*Lanius ludovicianus*). The red-tailed hawk was the only common summer raptor of the open habitats; however, the American kestrel (*Falco sparverius*) became conspicuous in the fall. The turkey vulture was an abundant resident, and a nest with young of this species was photographed in the attic of an abandoned house in a grassland area.

The white-footed mouse (*Peromyscus leucopus*) and plains harvest mouse (*Reithrodontomys montanus*) were the small mammals captured in grasslands. Both the black-tailed jackrabbit (*Lepus californicus*) and the eastern cottontail were common, with the jackrabbits occurring most often at the more heavily grazed sites. At night, white-tailed deer can be seen in the open habitats.

Several species of reptiles and amphibians were found in the open habitats of the Lake Bosque project area, including the gulf coast toad, ornate box turtle (*Terrapene ornata*), prairie racerunner (*Cnemidophorus sexlineatus*), prairie kingsnake (*Lampropeltis calligaster*), western coachwhip (*Masticophis flagellum*), and bullsnake (*Pituophis melanoleucus*).

3.7.1.4 Aquatic and Other Wetlands

Aquatic and other wetland habitats of the project area were mostly associated with the North Bosque River, its tributaries, and farm ponds. These areas provide water sources for wildlife species in surrounding habitats, as well as habitat for a number of directly wetland dependent species.

Amphibians and reptiles typical of these areas included Blanchard's cricket frog (*Acris crepitans*), gray treefrog, spotted chorus frog (*Pseudacris clarki*), Strecker's chorus frog (*P. streckeri*), upland chorus frog (*P. triseriata*), bullfrog (*Rana catesbiana*), southern leopard frog (*R. utricularia*), Texas slider (*Chrysemys concinna*), red-eared slider (*C. scripta*), spiny softshell (*Trionyx spiniferus*), blotched water snake (*Nerodia erythrogaster*), and red-striped ribbon snake (*Thamnophis proximus*).

Birds that were typically associated with wetlands included the little blue heron (*Egretta caerulea*), green-backed heron (*Butorides striatus*), belted kingfisher (*Ceryle alcyon*), Louisiana waterthrush, and red-winged blackbird (*Agelaius phoeniceus*), Many other wildlife species, including mammals, use wetlands extensively, even though their primary habitat type may be of another category. Some mammals, such as the beaver (*Castor canadensis*) and northern raccoon make major use of such areas as foraging habitat.

3.7.2 Important Wildlife Species and Habitats

Important species are defined above, in section 3.4.2. Important habitats are considered to be those that have unusual ecological value.

3.7.2.1 Recreationally or Commercially Important Species

Several species of game mammals and birds have geographic ranges that encompass Bosque County. The fact that such species are hunted and/or trapped indicates that they are an economic and recreational resource to the area. A more detailed discussion of the biology and status of each of these species is presented in "Baseline Ecology Report Supplement II: Important Species" (Paul Price Associates, Inc. 1987b).

As defined by the Texas Parks and Wildlife Department for reporting purposes, the Cross Timbers and Prairies Ecological Region (Cross Timbers), which encompasses the project area, ranks fourth among the ten ecological regions in Texas with respect to mourning dove spring population size. Mourning dove population counts in the project area in May, 1985 indicated levels typical for the region.

The Cross Timbers ranks second out of eight ecological areas in Texas which support populations of bobwhite quail. The results of the May, 1985 survey of the project area showed bobwhite populations to be typical of the region.

In 1985 the Texas Parks and Wildlife Department reported a post hunting season wild turkey population in Bosque County that ranked 15th of the 25 counties in the Cross Timbers, only 21.8% of the high county (Brown) count.

Many species of waterfowl winter in or migrate through the Cross Timbers. Although goose populations are minimal, approximately 19.9% of the total 1984-85 Texas duck harvest was within the north central reporting zone which includes the project area. The most commonly harvested species there are the wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), gadwall, and green-winged teal (*A. crecca*). The project area provides little habitat for these species, since the only wetlands are farm ponds and portions of the North Bosque River.

The Cross Timbers supported approximately 7.8% (287,308) of the state's white-tailed deer population in 1985, ranking fifth among ten ecological regions. Many general observations of deer in the project area were in the bottomland woodlands but the species was widespread at various upland sites as well.

The Cross Timbers was first of all ecological regions in Texas in eastern cottontail rabbit and third in blacktail jackrabbit population sizes. Good habitat for both species existed in the Lake Bosque project area at the time of the baseline studies.

In addition to the game species discussed above, the range of several furbearers includes Bosque County, including northern raccoon, skunks (species combined), Virginia opossum, ringtail (*Bassariscus astutus*), gray fox (*Urocyon cinereargenteus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and bobcat. Habitat for all of these species is present in the project area, and most were observed during the surveys, together with signs of beaver.

3.7.2.2 Endangered and Threatened Wildlife Species

Twelve species of endangered, threatened or protected nongame wildlife species (USFWS 1986; TPWD 1987) have been reported from Bosque County or are assumed to have some probability of occurrence. The biology of these species and their status as determined by each organization are discussed in detail in "Baseline Ecology Report Supplement II: Important Species" (Paul Price Associates Inc. 1987b). While the geographic range of these species encompasses the project area, the actual likelihood that they occur on the site or that suitable habitat is even present, varies depending on the biological requirements of each individual species. The following paragraphs give a brief statement of the expected status of each species in the project area.

Five federally listed endangered or threatened species potentially occur in Bosque County. These are the bald eagle (*Haliaeetus leucocephalus*), arctic peregrine falcon (*Falco peregrinus tundrius*), whooping crane (*Grus americana*), (interior) least tern (*Sterna albifrons athalassos*), and the black-capped vireo (*Vireo atricapilla*) which is currently proposed by USFWS for listing as endangered, and is, as such, protected.

The USFWS lists Bosque County and bordering McLennan County as having wintering areas for the bald eagle, presumably around reservoirs. It is therefore possible that bald eagles can occasionally pass through the project area and might find some feeding habitat along the Bosque River during periods when the river has low turbidity. However, no sightings have been reported for nearby Meridian State Park which has a small lake and surrounding woodlands that could be potential habitat. It is highly improbable that the bald eagle would nest in the project area even if suitable habitat were present.

Peregrine falcons, including the arctic subspecies, occur only as migrants in North Texas. Although no records are reported for Bosque County (including Meridian State Park), there is at least one sight record for McLennan County which borders Bosque County to the southeast. The project area does contain some areas of habitat that could be occupied briefly by migrating peregrine falcons.

Portions of North Texas, including Bosque County, lie within the migratory corridor that whooping cranes follow enroute to and from their nesting grounds in Wood Buffalo National Park, Canada. However, in Texas, there are no known regular migration stopover points such as are found in certain areas in Nebraska; in fact, there are only a few scattered confirmed ground sightings of whooping cranes anywhere in Texas other than on the wintering grounds on the coast. None of these are for Bosque County, and the likelihood of the whooping crane using the project area habitats is slim.

A summer specimen record of the interior least tern from Palo Pinto County and unconfirmed summer and breeding records for McLennan County have been reported. No sight or specimen records are reported for Bosque County or other bordering counties. Inasmuch as there appears to be little, if any, preferred habitat for the least tern in the project area, it is unlikely that the species will occur there, except perhaps as an extremely rare migrant.

The black-capped vireo is an inhabitant of well-drained, bushy or thicket covered hills typical of many parts of the Edwards Plateau. Specimen and/or sight records for three counties bordering Bosque County are known. The species has been reported for Meridian State Park, but despite having what appeared to be potential habitat, the project area did not harbor the species during 1984 and 1985 surveys.

Seven species in addition to the first five discussed above are listed as either endangered or protected nongame species (equivalent to threatened) by the TPWD. The following paragraphs present a brief statement of the expected status of each species, except the Brazos water snake (discussed above in Section 3.5.2.2), in the project area.

The white-faced ibis (*Plegadis chihi*) and the wood stork (*Mycteria americana*) are threatened avian species that do not breed in or near Bosque County. In the United States the latter nests only in Florida. Both species often exhibit a postnesting wandering period during which they may occur very irregularly at inland locations. Based on past records of occurrence in North Texas, their presumed ranges include Bosque County. The wood stork is considered "probable" and the white-face ibis is "confirmed" for the county by TPWD.

The American swallow-tailed kite (*Elanoides forficatus*) is currently considered threatened by TPWD, and is under review by USFWS as a "Category 2" species (further biological research needed to evaluate its status). The species is associated with wetland woodlands and associated native prairie type habitats and is not expected to nest in Bosque County, nor are there any sight or specimen records for Bosque County. Based on the presumed potential migration range, TPWD lists the kite as "possible" for Bosque County.

The golden-cheeked warbler (*Dendroica chrysoparia*) is a state listed threatened species that is endemic to central Texas where it nests in very old juniper (*Juniperus* spp.) woodlands. This warbler species is also under review as a "Category 2" species by USFWS. With regard to Bosque County, a population in Meridian State Park was reported and it is probable that suitable habitat occurs in other mature upland cedar brake areas in Bosque County. Surveys of the project area, including the 73 acres of juniper woodland in the reservoir site, did not reveal nesting habitat for the golden-cheeked warbler. TPWD lists the bird as being "confirmed" for Bosque County due to its known occurrence in Meridian State Park.

The Texas horned lizard (*Phrynosoma cornutum*) has been recorded from Bosque County and is listed as "confirmed" for the county by TPWD. Individuals of this species have been observed in the northeastern portion of the project area on the arid upland terraces overlooking the alluvial valley floor. These sites are located at or above the conservation pool elevation (830 feet MSL), but individuals of this species may occur within the reservoir site, although none were collected with the 19 species of reptiles identified during the 1984-85 baseline ecology survey.

The Timber Rattlesnake (*Crotalus horridus*) is listed by TPWD as "confirmed" for Bosque County. A southeastern species typically inhabiting heavy cover, it has been reported from riparian environments on the Trinity and Brazos Rivers as far west as Bosque and McLennan Counties. None were observed on the reservoir site during either the Ecology or the Cultural Resources surveys.

3.7.2.3 Important Habitats

Bottomland forest and riparian habitats are of particular ecological importance in the project area, as well as in the general region. These habitats, while relatively small in areal extent, are responsible for much of the diversity in plants and wildlife in the project area. Many important species, as previously discussed, are limited to or prefer these types of habitats. Because of clearing of bottomland forest for agricultural purposes throughout the region, this lowland habitat type is of particular concern.

3.8 Socioeconomics and Land Use

The following sections are based primarily on a comprehensive study of Bosque and McLennan counties reported in detail in "Baseline Socioeconomic Report for the Lake Bosque Project, Bosque County, Texas" (Paul Price Associates Inc., 1987).

3.8.1 Population

Population characteristics were examined in Bosque and McLennan Counties which include the proposed reservoir site and the communities participating in the project.

Bosque and McClennan Counties experienced relatively slow growth during the 1960s, The 1970s brought unprecedented growth to Texas as well as to Bosque County, and on a somewhat lesser scale, to McClennan County. Bosque County's 1980 population of 13,401 represents a 22% increase over 1970. McLennan County's 1980 population of 170,755 increased by 16% during the same decade. Table 3-4 displays 1970 and 1980 population figures and growth rates for the two counties and eight project participants.

Table 3-4 Population Growth in the Study Area 1970 and 1980			
Jurisdiction	1970 Population	1980 Population	% Change 1970-1980
Bosque County	10,966	13,401	22.2%
Meridian	1,162	1,330	14.5%
Clifton	2,578	3,063	18.8%
McLennan County	147,553	170,755	15.7%
Bellmead	7,698	7,569	-1.7%
Hewitt	569	5,247	822.1%
Lacy-Lakeview	2,558	2,752	7.6%
McLennan Co. WCID #2 (Elm Mott)	NA	1,300	----
Waco	95,326	101,261	6.2%
Woodway	4,819	7,091	47.1%

Source:
U. S. Bureau of the Census. General Population Characteristics, 1970-1980.
Note: NA = not available

3.8.1.1 Age Distribution

The age distribution of the study area's 1980 population was characterized by a higher proportion of elderly than the state average. In McLennan County, the proportion of elderly age 75 years and older was only slightly higher than the states' average. However, in Bosque County, the proportion of people 75 years and older was almost three times as high as the state average, and the proportion of those aged 70-75 was twice as high as the state average. The Texas Department of Health expects this trend to continue through 2000.

3.8.1.2 Population Projections

Five population projection models were examined in detail and evaluated on the basis of the assumptions and methodologies employed. The Texas Water Development Board (TWDB) Low Series Population Projections were jugded to provide the most probable scenario for future population growth. However, in planning for critical infrastructure and community resources, particularly where long lead times for development are involved, use of a "most probable" projection may result in significant deficits in needed facilities and resources. Therefore, we believe that for critical planning purposes the low series projections represent the minimum future population sizes to be accomodated. The upper limit of reasonably probable future population growth was assumed to be represented by the TWDB High Series Population Projections.

TWDB low series population projections for the study area show Bosque County's population increasing to 24,045 by 2040, a 79% increase from 1980. The high series population projection shows the population increasing by 128% to 30,505 in 2040. The range of projections for the 2040 population in McLennan County is 239,559 (a 40% increase over 1980) for the low series, to 287,645 (68% increase) for the high series. Population projections for the study area continue the historical trend of communities in the City of Waco's ETJ growing at a much faster rate than the City of Waco. Table 3-5 displays the TWDB Low and High population projections for McLennan and Bosque Counties and the participating municipalities.

3.8.2 Local Economy

Since the 1960's, the major employment sectors by Standard Industrial Classification (SIC) Code in McLennan County have been Manufacturing, Trade, Service and Government. The total labor force for 1986 was 71,446, an increase of 11% over 1980. The fastest growing industries since 1980 have been Agriculture and Finance, Insurance, Real Estate (FIRE) and Service. Manufacturing and Mining employment declined slightly.

During the 1960's and 1970's, major employment sectors in Bosque County were Agriculture, Trade and Service. Since the 1960s, the proportion of the labor force employed in Agriculture and Service Industries has steadily declined while the number of workers employed in Manufacturing, Construction and the category of Other industries has increased. In 1980, the three largest employment sectors were Manufacturing, Trade, and Government. The Texas Employment Commission (TEC) estimates a total work force of 3,040 in 1980 and 3,168 in 1986, an increase of 4%. Because TEC employment statistics do not include the self-employed and unpaid family workers in their estimated labor force figures it is likely that these estimates are lower than the actual work force in Bosque County. United States Bureau of the Census estimated the total 1980 work force at

Table 3-5 Study Area Population Projections								
Jurisdiction	1980 Population	1990 Projection	2000 Projection	2010 Projection	2020 Projection	2030 Projection	2040 Projection	% Change 1980-2040
BOSQUE COUNTY								
TWDB High Case	13,401	15,633	19,790	22,015	24,489	27,332	30,505	128%
TWDB Low Case	13,401	15,175	16,653	18,275	20,032	21,947	24,045	79%
Clifton								
High Case	3,063	3,737	4,793	5,332	5,932	6,620	7,388	141%
Low Case	3,063	3,738	4,244	4,750	5,316	5,971	6,707	119%
Meridian								
High Case	1,330	1,662	2,142	2,383	2,650	2,958	3,303	148%
Low Case	1,330	1,613	1,802	1,978	2,168	2,376	2,604	96%
MCLENNAN COUNTY								
TWDB High Case	170,755	200,412	208,117	219,587	240,264	262,889	287,645	68%
TWDB Low Case	170,755	190,790	194,846	198,243	206,793	222,574	239,559	40%
Bellmead								
High Case	7,569	10,766	11,708	12,353	13,517	14,790	16,183	114%
Low Case	7,569	10,249	10,961	11,152	11,634	12,522	13,478	78%
Hewitt								
High Case	5,247	6,158	6,395	6,747	7,383	8,078	8,838	68%
Low Case	5,247	5,862	5,987	6,091	6,355	6,839	7,359	40%
Lacy-Lakeview								
High Case	2,752	3,443	3,626	3,826	4,187	4,581	5,012	82%
Low Case	2,752	3,277	3,394	3,454	3,604	3,878	4,173	52%
McLennab County WCID #2 (Elm Mott)* **								
High Case	1,300	1,275	1,286	1,357	1,484	1,624	1,777	37%
Low Case	1,300	1,213	1,203	1,224	1,277	1,375	1,481	14%
Waco								
High Case	101,261	114,555	115,909	122,297	133,813	146,413	160,199	58%
Low Case	101,261	109,056	108,518	110,408	115,171	123,961	133,422	32%
Woodway								
High Case	7,091	12,170	14,368	15,160	16,587	18,149	19,858	180%
Low Case	7,091	11,586	13,452	13,686	14,277	15,366	16,539	133%

Source: County1980-2030 projections are revisions by the Texas Water Development Board as of 2/1987.
2040 projections were extended by Paul Price Associates.
NOTE: *** Elm Mott (McLennan County WCID #2) projections are by Paul Price Associates, Inc.
Municipal estimates were derived by disagregating the the TWDB county population figures.

5,378. Their estimates include self employed and family workers.

3.8.2.1 Income Analysis

To compare local family income with state family income, all family households in Texas were separated into five equal groups (quintiles) by annual income level for 1970 and 1980. In comparison to the state average, both counties are characterized by a high proportion of low income families and a low proportion of medium to high income families. In McLennan County those proportions were only 4-6% higher or lower than the state average, but in Bosque County the difference was much greater. In 1980, 28% of all families were in the lowest income bracket, compared to the state average of 20%. Fifty-six percent of all Bosque County families were in the two lowest income brackets, compared to the state average of 40%. Only 14% of the county's families were in the top two income brackets, compared to the state average of 40%. The proportion of families qualifying for middle to upper income brackets, while still considerably lower than the state average, increased over the decade.

3.8.3 Community Facilities and Services

3.8.3.1 Education

There are 26 independent School Districts (ISDs) in the study area, 18 in McLennan County and eight in Bosque County. Of the total 1985-86 student enrollment of 37,791, 93% attended McLennan County schools and 7% attended Bosque County schools. The ratio in McLennan County averaged 18.2 students per teacher while in Bosque County the average was 15.7. Average expenditure per student in McLennan County was $2,790; in Bosque County, average expenditure per student was $3,125.

3.8.3.2 Public Safety

None of the participating municipalities satisfy the public safety standards of 2.1 police officers per 1,000 population. The police officer to population ratio ranges from a low of .75 for Meridian to a high of 1.97 for Woodway. The community of Elm Mott does not employ a police officer.

Fire protection in the study area is provided by volunteer and full-time paid firemen. Only Bellmead and the City of Waco employ full-time firemen; however, the ratio of firemen to 1,000 population for both communities is below the accepted safety standard of two full-time firemen per 1,000 population. The remaining project communities rely on volunteer firemen for fire protection.

3.8.3.3 Health Service and Facilities

The study area contains eight hospitals and 1,995 beds, of which 95% are located in McLennan County. Both McLennan and Bosque County's ratios of 10.37 and 6.8 beds per 1,000 population is higher than the recommended minimum of five beds per 1,000 population. Of the 318 physicians in the two counties, 95% practice in McLennan County. The public health standard ratio of 0.7 physicians per 1,000 population is exceeded in both counties.

3.8.3.4 Existing Water and Wastewater Treatment Facilities

Each of the project participants maintains a water system and provides wastewater treatment services. Except the City of Waco, all the participants rely on Trinity ground water for water supplies. These communities do not have developed facilities for treating surface water.

3.8.3.5 Future Water Requirements

Water demand projections were prepared through 2040 for communities currently participating in the Lake Bosque project, as well as for probable customer entities, rural county areas and manufacturing in the two county study area (Paul Price Associates Inc., 1987). Initial water demand projections incorporated Texas Water Development Board (TWDB) low series population projections and high series per capita water demand projections. The high demand per capita estimates were employed because these levels are already being exceeded in McLennan County, and because they include drought period demands which must be planned for to protect public health, welfare and safety. Per capita water demand includes the adjustments for future conservation projected by TWDB.

To prevent a situation of unmet demand requiring additional capital investment, and possibly more serious consequences, water demand projections should allow for the highest reasonable population growth and per capita water demand. Reservoir firm yield supplies should accommodate an upper limit as well as satisfying the minimum projected demand. For the Lake Bosque Project, this range begins with the initial water demand projection mentioned above and is capped by a projection using the TWDB's High Series population projection, high per capita demand and high manufacturing demand.

Municipal per capita demand ratios for project participants, potential customer cities, the City of Waco and other (rural) portions of McLennan County and Bosque County are shown in Table 3-6. Generally, per capita consumption rates

Table 3-6 Per Capita Water Demand Projections							
Demand Categories	1980	1990	2000	2010	2020	2030	2040
Municipal Per Capita Demand (GPD)							
Project Participants (excludes City of Waco)	162	184	187	187	187	187	187
Potential Customers	159	189	190	190	190	190	190
City of Waco	261	280	285	285	285	285	285
All Municipalites	235	252	254	254	254	254	254
Other Per Capita Demand (GPD)							
McLennan Co.	125	180	186	185	183	181	180
Bosque Co.	108	161	166	166	166	166	166

Source:
Texas Water Development Board, High Series Water Demand Projections.

peak in year 2000 and are assumed by the TWDB to remain stable thereafter due to conservation measures. Potential project customers are defined as communities currently relying on ground water but identified by the TWDB as relying on Lake Waco water as a future supply source.

The projected 2040 water demand range for each user category is shown in Table 3-7. Municipal water use in 1980 by project participants (excluding the City of Waco) was 4.60 mgd and is projected to increase through 2040 to a range of 9.85 to 11.71 million gallons per day (mgd), a 114% to 154% increase. The City of Waco is the largest water consumer in the area, with 1980 water use at 26.44 mgd and projected 2040 low and high water demands of 38.02 to 45.66 mgd. Water use in 1980 by potential customers amounted to 1.07 mgd and is projected to increase by 99% to 138% (see Table 3-7).

The category of Other demand includes demand from rural county areas and demand from communities with populations smaller than 1,000. In 1980, Other demand was 3.81 mgd for the two county study area; 2040 demand was projected to be between 7.14 and 8.73 mgd, an increase of 87% to 129% (see Table 3-7). Total municipal demand, including project participants, the City of Waco, potential customers, and Other demand in 1980, was 35.92 mgd. Projected low and high 2040 demand ranges from 57.14 to 68.65 mgd, increases of 59% and 91%, respectively.

Manufacturing demand in the two county study area during 1980 was 3.63 mgd. The TWDB provides two demand projections

Table 3-7 Reported 1980 Water Use and Projected Low and High Range 2040 Water Demand						
User Category	Reported 1980 Water Use		Low Range 2040 Demand Projection		High Range 2040 Demand Projection	
	mgd	Acre-feet	mgd	Acre-feet	mgd	Acre-feet
Municipal Demand						
Project Participants (excludes City of Waco)	4.60	5,153	9.85	11,033	11.71	13,117
Potential Customers	1.07	1,199	2.13	2,386	2.55	2,865
Total Municipal Demand	5.67	6,352	11.98	13,419	14.26	15,973
City of Waco	26.44	29,617	38.02	42,588	45.66	51,146
Total Municipal Demand including the City of Waco	32.11	35,968	50.00	56,008	59.92	67,119
Other Demand (rural)						
McLennan County	2.97	3,323	4.84	5,422	5.81	6,505
Bosque County	0.84	941	2.30	2,576	2.92	3,271
Total	3.81	4,264	7.14	7,998	8.73	9,776
Total Municipal and Other Demand	35.92	40,232	57.14	64,006	68.65	76,895
Manufacturing Demand						
McLennan County	3.55	3,977	19.76	22,134	23.42	26,234
Bosque County	0.08	90	0.28	314	0.32	358
Total	3.63	4,066	20.04	22,448	23.74	26,592
Total Muncipal, Other and Manufacturing Demand						
Including the City of Waco	39.55	44,298	77.18	86,454	92.39	103,488
Excluding the City of Waco	13.11	14,681	39.16	43,866	46.73	52,342

Source: Paul Price Associates, Inc. Socioeconomic Baseline Report for the Lake Bosque Project, 1987. Texas Water Development Board.
Note: Demand for Elm Mott was originally included in the category of Other Demand. In this table Elm Mott is not included in the Other Demand category because its demand is already included in the project participant category.

(high and low series) to use for planning purposes and both are shown in Table 3-7. We believe the low series manufacturing demand projection represents the most probable scenario under present conditions, but an aggressive regional economic development program coupled with an assured water supply could result in accelerated manufacturing demand. Projected low and high 2040 demand ranged from 20.04 to 23.74 mgd, increases of 452% and 554%, respectively.

3.8.3.6 Transportation

The proposed Lake Bosque lies in northwest Bosque County within the tract of land bordered by Highway 6, FM 144 and FM 927. Gravel surfaced county roads provide access from the site to major roadways. Traffic volume, in 1985 along State Highway 6 near the project site averaged 1,350 vehicles per day. Along FM 144 the average was 890 vehicles per day, while FM 927 carried an average of 420 vehicles per day. Traffic volume, in 1984, on area county roads ranged from 35 to 100 vehicles per day. There are no major road improvements planned for Bosque County by the State Department of Highways and Public Transportation.

Air strips are available in Clifton and Waco, 24 and 50 miles, respectively, from the proposed site. Complete air services and commercial flights are available only in Waco.

Commercial rail service is available in Clifton. Amtrak passenger rail service is available in the Dallas Fort Worth area approximately 70-100 miles from the proposed Lake Bosque.

3.8.3.7 Housing

Vacancy rates for owner occupied housing units in Bosque and McLennan Counties indicate a shortage of available housing. Rental vacancy rates point to a slightly larger but still limited supply of available rental units. In McLennan County, there were about 61,554 occupied housing units with 2.65 persons per housing unit in 1980. Median value of owner-occupied homes was $29,100. In Bosque County there were approximately 5,513 occupied housing units with 2.36 persons per occupied unit in 1980. Median value of owner-occupied homes was $23,000. There are 11 homes currently located within the the 100 year flood elevation (841.3 MSL) at the proposed Lake Bosque site.

3.8.4 Public Finance

Total bi-county governmental revenue for fiscal year ended September 1985 was $24,081,188. McLennan County revenues of $22,051,851 accounted for 92% of total revenues and Bosque County revenues of $2,029,337 accounted for 8%. Property taxes contributed 42% and 30%, respectively, of total county revenues. Intergovernmental transfers, a significant source of revenue for McLennan County, contributed 16% of total revenue, but accounted for only 4% of total revenues in Bosque County. Licenses and Permits accounted for 24% of revenues in Bosque County, and were a major revenue source. Principal county expenditures in Bosque County were for Public Safety. In McLennan County, principal county expenditures were for General Government Services. Per capita expenditure in McLennan County was $121; in Bosque County per capita expenditure was $110. McLennan County had excess revenues of $1,023,527 (5.5% of total revenues). Bosque County had excess revenues of $323,961 (18% of total revenues).

The financial position of Bosque and McLennan Counties is good. Both have strong credit ratings and, if needed, have ample tax margins allowing major increases in property tax revenues. The project participants are also in good financial condition, with relatively low property tax rates, ample tax margins and low per capita debt ratios.

In McLennan County, assessed 1985 property valuations of $3.4 billion represent an increase of 6.84% from the preceding year. The County can raise $20.3 million in additional tax revenue before reaching the legal property tax limit. Assessed 1985 property valuations in Bosque County stood at $385.6 million. The County can raise $2.4 million in additional tax revenue before reaching the legal property tax limit.

Measures for calculating bond and credit rating strength reveal that both counties are secure, as per capita debt is low, as well as the ratio of debt to assessed value. In addition, McLennan County was assigned an A-1 rating by Moody's investors in 1985, further indicating the financial strength of the County.

Property tax rates for each of the seven project participating municipalities are much lower than the legal limit of $2.50 per $100 valuation. Present property tax rates range from $0.22 per $100 (Clifton) to $0.56 per $100 (Waco).

Based on three different methods of analyzing municipal credit soundness, all participants, except Hewitt, Waco and Lacy-Lakeview, satisfied each criteria. Hewitt and Waco had a slightly higher than desirable debt service to revenue ratio and Hewitt and Lacy-Lakeview had a slightly higher than recommended net debt per capita.

picnic tables, soccer fields, softball fields, swimming areas, walking and hiking trails.

An aesthetic survey of the proposed Lake Bosque site was conducted in February of 1987. Five viewsheds were photographed and evaluated for aesthetic values including topographical features, coloration, vegetational diversity and vividness, unique geological formations, man-made structures and uniqueness of view with respect to the region. The survey emphasized views presently available to the public from area roads.

The surveyed area is located in a transitional zone and includes rolling pastures and farmland with interspersed woodlands and grasslands. The Bosque River valley is characterized by river-bottom land of 800 feet mean sea elevation (MSL), is dotted with 900-1,050 foot high hills and encompassed by an 800-1,000 foot high ridge. Panoramic views of the valley and the proposed lake site are available almost anywhere at elevations above 850 feet. Natural vegetation and animal life includes grasses, trees, flowers and animals typical of Central Texas.

From each vantage viewshed, visual landscape elements of the proposed Lake Bosque site include pastureland, cropland, some wooded areas, farm machinery, an occasional farm house, livestock, natural vegetation (scrub oak, brush, cactus, etc.), and barbed wire fences. See Paul Price Associates Inc., 1987, for photographs.

3.8.6 Land Use

Land uses identified in the evaluation of the proposed Lake Bosque site include cropland, pastureland, woodland, residential, wetland and stockponds. Of the total 641,337 acreas in Bosque County, 595,172 acres (92.8%) consist of cropland, pastureland, hayland and rangeland.

The most significant changes in land use in Bosque County since 1958 have been a 127% increase in pasture and hayland, a 33% decrease in cropland and an 18% increase in land designated as Other land (includes water, urban, roads, railroads, and recreation land uses).

Since 1970, the majority of Bosque County's total market cash receipts were from livestock and livestock products. When compared to market cash receipts for the other 25 counties in the Blackland Agriculture District, the County was above average overall for livestock and livestock products market cash receipts, and slightly below average for crop cash receipts and total crops and livestock cash receipts.

3.9 Cultural Resources

3.9.1 Regional Setting

Bosque County lies near the northern margin of the Central Texas Archaeological Region in which the terms Paleoindian, Archaic, Neoarchaic and Historic have been used to describe major periods of cultural history (Howard, 1983). Prehistoric cultural associations and chronologies are based primarily on projectile point assemblages supplemented with radiocarbon dates.

Paleoindian people are believed to have been migratory with a hunting economy, but most of our knowledge of them has come from excavations remote from Central Texas. Radiocarbon studies from a relatively few sites in Central Texas date Paleoindian occupation of the region as being prior to about 8500 years before the present (B.P.). These early sites tend to be difficult to recognize, perhaps because of an overreliance by American archaeologists on the use of chronologies linked to the presence of projectile points. Accordingly, there are probably sites in the vicinity of Lake Bosque which are older than the one located during this survey. However, this Paleoindian site is an indicator, along with other work in Central Texas, that human occupation of the North Bosque River Valley has continued (perhaps intermittently) for the last 14,000 to 15,000 years. Previous surveys have located Paleoindian sites in the vicinity of Lake Waco, Lake Whitney, Squaw Creek Reservoir and several locations on the Brazos River. Several sites on the Brazos River are of such depth and density of projectile points as to indicate either sedentary occupation or numerous short-term occupations over a very long period.

Archaic peoples, distinguished on the basis of tool forms, are believed to have also been primarily migratory with a hunting and gathering economy. The Archaic, occuring roughly between 8500 and 1250 B.P., has been extensively studied in Central Texas where early, middle and late periods are distinguished on the basis of apparantly differing subsistence strategies. While early Archaic sites are relatively rare, middle Archaic (beginning about 5,000 B.P.) sites are more common and those of the late Archaic (3,000 B.P.) are fairly abundant. As population densities presumably increased throughout the Archaic, evidence indicates that both the variety of food sources and the technological developments neccessary to exploit them increased. Several Archaic sites are known from the North Bosque River including one at Comanche Crossing, between the proposed reservoir site and Meridian.

During the Neoarchaic period (1250 to 250 B.P.) the subsistance economy did not appear to differ substantially from that of the Archaic. These people engaged in hunting, gathering, fishing and some agriculture. River terrace and shelter sites in Central Texas, and in the vicinity of the proposed project, often contain indications of a riverine subsistence orientation. Some of these sites contain Caddoan artifacts, or exotic materials such as obsidian that do not occur naturally in Texas, implyimg considerable movement or contacts with other, remote cultural groups.

The Historic period dates from the advent of Europeans into the Central Texas area during the early eighteenth century. Aboriginal tribes resident in the area at the begining of the nineteenth century include Tawakoni, Tonkawa and Hainai. The town of Waco was surveyed in 1849, settlement of the Bosque County area by whites became significant during the 1850's, and Meridian was established in 1854. The earliest settlers from Norway, the descendants of whom still maintain a distinct community in Bosque County, also established themselves during that year.

Conflicts with the aboriginal inhabitants continued throughout the mid-century and was particularly intense during and after the War Between the States. The "Indians of the Brazos" were transferred to the Wichita Agency in Oklahoma in 1869 but the threat of hostilities did not cease completely until the Comanche were finally expelled from Central Texas in the mid 1870's.

The railroad was important in helping establish local communities, including Walnut Springs and Morgan, and linking them with existing towns like Iredell. A section of roadbed and artifacts believed to belong to the Texas Central Railroad and dating from the last quarter of the nineteenth century is present on the reservoir site. The decline and eventual abandonment of the railroad in the 1940's adversely affected the local economy, as did the decrease in economic importance of farming in Bosque County. During the twentieth century, and continuing to the present, ranching has become a more important part of the county economy as farm yields and profits have declined. At present, less than a dozen families are now living in or adjacent to the reservoir site, probably the smallest number of people since Paleoindian times.

3.9.2 Lake Bosque Site Survey

Prior to the archaeological survey performed in response to the permitting requirements of the proposed Lake Bosque project, no sites, either prehistoric or historic, had been recorded from the vicinity of the project area in the Texas Archaeological Research Laboratory files (Howard, 1983). A total of 145 sites were located and recorded during the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987). Of these, 77 were prehistoric, 49 were historic and the remainder contained material from both periods. The sites recorded in the project area reflect human use from the Paleoindian period to the present century, including the Great Depression of the 1930's. In addition to a 100% pedestrian survey and probing, selected sites were subjected to additional testing appropriate to the location and resource, including large-scale excavation using power equipment. The latter technique was useful primarily in locating, defining and evaluating buried terrace deposits.

In the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), each recorded site is mapped, fully described, and evaluated in terms of its potential value for additional study and with respect to its eligibility for inclusion either in the National Register of

Historic Places or as a State Archaeological Landmark. Table 3-8 summarizes the primary characteristics of these sites. Of the 63 sites located that are eligible for nomination to the National Register of Historic Places, 34 were prehistoric, 20 were occupied during historic times and the remaining nine exhibited multiple periods of occupation. The 36 sites consisting of those National Register sites to be encompassed by the conservation pool of Lake Bosque will be State Archaeological Landmarks by the Provisions of the Antiquities Code of Texas (Title 9, Section 191.092).

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project 76 affected

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ219	846-851	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ220	840-852	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	-
41BQ221	828-832	historic	-	-	disturbed	road	unknown	damage	dam	dam	loss	none	-	-	-
41BQ222	836-848	historic	-	-	disturbed	house	unknown	damage	none	-	-	inundation	lake	flood	-
41BQ223	820-830	prehistoric	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ224	860-862	historic	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ225	828-840	prehistoric	-	-	erosion	road	seasonal	damage	none	-	-	inundation	lake	pool	-
41BQ226	834-842	historic	-	-	construction	pens	once	loss	none	-	-	inundation	lake	flood	-
41BQ227	820-850	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	-
41BQ228	860+	historic	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ229	900-920	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ230	845-848	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ231	860+	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ232	860-870	prehistoric	-	-	erosion	road	on-going	loss	none	-	-	none	-	-	-
41BQ233	850-860	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ234	834-838	historic	-	-	cleared	highway	once	loss	none	-	-	none	-	-	-
41BQ235	820-842	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ236	822-832	historic	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ201	856-862	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ202	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ203	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	flood	-
41BQ204	821-830	multiple	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ205	835-845	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ206	838-850	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ207	835-842	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ208	842-849	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ209	841-846	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ210	843-845	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ211	832-836	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ212	830-835	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	flood	-
41BQ213	842-846	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ214	846-849	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	unknown	-	-	-
41BQ215	848-858	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ216	839-845	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ217	830-840	prehistoric	-	-	redeposit	wash	on-going	loss	none	-	-	none	-	-	-
41BQ218	846-854	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ183	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ184	850-853	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ185	800-802	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	
41BQ186	829-834	historic	☒	☒	displaced	machine	unknown	damage	none	-	-	inundation	lake	pool	loss
41BQ187	840-844	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ188	802-806	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ189	825-828	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ190	828-830	historic	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ191	839-842	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ192	830-832	prehistoric	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	flood	-
41BQ193	826-829	historic	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ194	825-828	prehistoric	-	-	eroded	road	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ195	810-818	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ196	822-829	multiple	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ197	900-905	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ198	853-857	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ199	846-850	historic	-	☒	none	-	-	-	none	-	-	unknown	-	-	-
41BQ200	860	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ165	835-838	historic	-	-	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ166	842-845	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ167	832-835	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ168	774-788	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundaton	lake	pool	loss
41BQ169	763-766	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ170	800-820	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	pool	-
41BQ171	830-840	historic	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ172	830-835	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ173	788-790	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ174	835-841	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	damage
41BQ175	812-814	geological	-	-	-	-	-	-	-	-	-	-	-	-	-
41BQ176	859-861	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ177	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ178	840-843	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ179	845	multiple	-	-	cleared	machine	once	loss	none	-	-	none	-	-	-
41BQ180	813-823	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ181	820-826	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ182	833-836	historic	-	-	displaced	machine	once	loss	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ147	820-830	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ148	800-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ149	810-823	multiple	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ150	848-850	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	none	-	-	-
41BQ151	840-851	prehistoric	-	☒	clearing	highline	once	damage	dam	spillway	loss	none	-	-	-
41BQ152	815-828	historic	☒	☒	erosion	wash	seasonal	damage	dam	dam	loss	none	-	-	-
41BQ153	785-805	historic	☒	☒	filling	wash	seasonal	positive	spillway	haul road	loss	none	-	-	-
41BQ154	800-838	prehistoric	-	-	erosion	wash	seasonal	damage	spillway	haul road	loss	none	-	-	-
41BQ155	790-830	prehistoric	-	-	clearing	highline	once	damage	none	-	-	none	-	-	-
41BQ156	775-780	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ157	820-825	historic	-	-	altered	building	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ158	774-779	prehistoric	☒	☒	sloughing	river	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ159	833-843	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	damage
41BQ160	810-811	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ161	812-824	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ162	800-810	historic	☒	☒	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ163	815-817	prehistoric	-	-	eroded	wash	on-going	loss	dam	dam	-	none	-	-	-
41BQ164	869	historic	-	-	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ129	820-828	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	normal	loss
41BQ130	845-846	historic	-	☒	clearing	owner	unknown	damage	none	-	-	none	-	-	-
41BQ131	826-836	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	pool	none
41BQ132	870	historic	-	-	cleared	owner	unknown	loss	none	-	-	none	-	-	-
41BQ133	856-860	historic	-	-	cleared	owner	once	loss	none	-	-	none	-	-	
41BQ134	850-854	historic	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ135	858-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ136	830-850	historic	-	-	cleared	dozer	once	loss	none	-	-	none	-	-	-
41BQ137	810-822	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ138	808-812	multiple	☒	☒	cleared	owner	once	disturbed	none	-	-	inundation	lake	pool	loss
41BQ139	796-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ140	802-804	historic	-	-	razed	owner	once	loss	none	-	-	inundation	lake	pool	-
41BQ141	780-793	historic	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ142	810-820	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	inundation	lake	pool	-
41BQ143	800-810	prehistoric	☒	☒	erosion	rill	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ144	805	historic	-	-	erosion	drain	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ145	856-862	prehistoric	-	☒	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-
41BQ146	860-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ111	805-808	prehistoric	☒	☒	turned	tillage	annual	damage	none	-	-	inundation	lake	pool	loss
41BQ112	828-830	historic	☒	☒	altered	building	on-going	damage	removal	clearing	damage	inundation	lake	pool	loss
41BQ113	845-860	prehistoric	-	-	eroded	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ114	820-850	historic	-	-	eroded	slope	on-going	damage	none	-	-	none	-	-	-
41BQ115	842-848	prehistoric	-	-	eroded	wash	on-going	-	none	-	-	none	-	-	-
41BQ116	815-820	prehistoric	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ117	840-855	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ118	840-850	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ119	860-868	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	none	-	-	-
41BQ120	853-856	multiple	-	-	altered	building	once	loss	none	-	-	none	-	-	-
41BQ121	838-850	prehistoric	-	-	cleared	dozer	once	damage	none	-	-	inundation	lake	flood	loss
41BQ122	820-828	multiple	☒	☒	buried	alluvial	flooding	preserved	none	-	-	inundation	lake	normal	loss
41BQ123	842-845	historic	-	☒	none	-	-	-	F.M. 927	relocation	unknown	none	-	-	-
41BQ124	818-822	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ125	818-819	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ126	818-820	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	normal	none
41BQ127	819-824	historic	-	-	razed	owner	unknown	loss	none	-	-	inundation	lake	normal	none
41BQ128	810-816	historic	-	-	none	-	-	-	none	-	-	inundation	lake	normal	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ93	840-842	prehistoric	-	-	erosion	cattle	seasonal	damage	none	-	-	erosion	waves	once	damage
41BQ94	832-835	multiple	-	-	scouring	creek	seasonal	damage	none	-	-	erosion	waves	-	-
41BQ95	850-860	prehistoric	-	☒	erosion	cattle	seasonal	damage	none	-	-	looting			
41BQ96	833-835	historic	-	-	mixing	vehicles	on-going	damage	mixing	dam	loss	none	-	-	-
41BQ97	820-842	prehistoric	-	-	erosion	cattle	seasonal	damage	mixing	clearing	loss	none	-	-	
41BQ98	812-820	historic	-	-	scouring	creek	seasonal	damage	none	-	-	siltation	lake	seasonal	-
41BQ99	802-806	historic	-	-	mixing	human	on-going	damage	none	-	-	siltation	lake	seasonal	damage
41BQ100	809-812	prehistoric	-	-	erosion	cattle	seasonal	neutral	none	-	-	none	-	-	-
41BQ101	820-830	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ102	828-840	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ103	832-836	historic	-	-	none	-	-	-	mixing	clearing	loss	none	-	-	-
41BQ104	820-870	historic	-	-	erosion	wash	seasonal	damage	-	-	-	none	-	-	-
41BQ105	834-839	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ106	805-806	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ107	820-824	multiple	☒	☒	erosion	wash	seasonal	damage	none	-	-	erosion	lake	on-going	loss
41BQ108	805	historic	-	-	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ109	837-840	prehistoric	-	☒	erosion	wash	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ110	820-825	multiple	☒	☒	erosion	cattle	on-going	damage	none	-	-	erosion	lake	on-going	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ237	778-780	prehistoric	☒	☒	sloughing	creek	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ238	789-791	prehistoric	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	unknown

4.0 Environmental Effects of the Proposed Project

4.1 Climatology and Air Quality

4.1.1 Effects of no action

In the absence of the proposed project regional climate and air quality will continue to be influenced by the factors outlined in Section 3.1. Air quality is not anticipated to undergo substantial change as a result of local influences for the forseeable future.

4.1.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any substantial effect on regional climate. However, localized effects, including some amelioration of diurnal temperature ranges and the creation of more mesic microclimates can be expected to occur in the immediate vicinity of the reservoir.

Some local and temporary increases in airborne particulates (dust) may result from disturbance of the vegetative cover in construction sites, borrow areas, and haul roads. Significant increases in areas other than the immediate vicinity of the work areas appears unlikely. Particulates are not presently a problem in Bosque County even though extensive soil disturbance now occurs as a result of agricultural practices. More than one thousand acres of seasonally plowed cropland and a considerable extent of unpaved road is present in the reservoir site.

With respect to near field effects, less than 10 residences are located within one mile of the proposed dam site and borrow area, and the nearest community, Meridian, is about four miles away. Two residences are located within the main embankment and borrow areas and may be vacated before construction begins. The other residences are in locations not expected to experience significantly increased dust levels. Construction machinery exhaust is not a large enough source to significantly affect air quality in the area.

4.1.3 Operation Effects

Reservoir operation is not expected to have any significant effect on climate or air quality, either locally or regionally.

4.2 Noise

4.2.1 Effects of No Action

In the absence of the proposed Lake Bosque, local and regional noise sources and levels will continued to be affected by ongoing economic and technological forces.

4.2.2 Construction Effects

Some localized increases in noise levels will accompany construction activities in the vicinity of the proposed dam. However, there is a paucity of receptors in the area, and less than seven residences within one mile of the dam and borrow areas will be occupied during the construction period. Wildlife in the immediate vicinity of work areas might experience some noise related disturbance, but most species accommodate rather rapidly to mechanical noise that is not accompanied by other threat stimuli.

4.2.3 Operation Effects

Operation of the proposed reservoir is not expected to have any direct effect on local or regional noise levels. Increase in residential land use and recreational activities in the vicinity of the reservoir can result in some local increases in noise, including that resulting from higher traffic volumes on surrounding roads and operation of power boats (see Section 4.5, Socioeconomics and Land Use).

4.3 Geology and Soils

4.3.1 Effects of No Action

Geological resources and soils in Bosque and McLennan Counties will continue to be affected by ongoing population, economic and technological forces in the absence of the proposed reservoir.

4.3.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any significant effects on the geological resources of the region. Within the reservoir site, various soil and rock materials will be utilized in dam construction. Sand and gravel deposits to be inundated by Lake Bosque do not appear to have much potential for economic recovery and off site sale.

Area palaeontological resources are centered in the Walnut and Glen Rose formations. Outcrops of these formations will be affected only slightly on the reservoir margins and in the river channel at the extreme upstream limit of inundation.

Roughly 3,000 acres of prime farming soils will be affected by dam construction and by inundation as a result of the construction of Lake Bosque. This is about 1.5% of the prime soils in Bosque County and is not anticipated to constitute a significant effect on a limited resource.

4.3.3 Operation Effects

Operation of the proposed Lake Bosque is not expected to have any substantial effect on either the geological or soil resources of Bosque and McLennan Counties. Effects upstream of the dam have been addressed in the preceeding sections, while downstream effects are expected to be negligible. Although Lake Bosque will not have a designated flood control function, flood peaks will be substantially attenuated by the presence of the dam and reservoir. As a result, the 100 year floodplain in the 6.3 mile reach from the proposed dam site to Meridian will be narrowed by about 58% from the present average width at maximum stage of 1200 feet to about 500 feet with the dam in place. Mean area inundated during the 100 year flood will be decreased from 145 acres per mile to 60 acres per mile. Neither direct effects nor resultant land use changes are expected to exert significant adverse effects on soils or geologic resources.

4.4 Water Resources

4.4.1 Effects of No Action

Unless another comparable alternative was selected, failure to construct Lake Bosque will result in continued overdrafting of groundwater resources. Declining water levels will result in increased pumping costs in the short term, a continuing decrease in groundwater quality and contribute to the continuing decline in water availability.

Existing surface water resources will have to be more intensively utilized, possibly to the detriment of other uses. Development of alternative surface water sources will impose financial burdens on project participants substantially greater than that required for the Lake Bosque alternative.

North Bosque River discharge may remain relatively unchanged in the absence of Lake Bosque. However, other projects may be constructed that will affect river flow. For example, additional flood and sediment retention structures might be built in the basin, or water from a project in the Paluxy River Basin may be discharged into the North Bosque from the City of Stephenville's wastewater treatment facilities.

Municipal wastewater discharges and agricultural runoff will continue to contribute sediment, oxygen demanding material, nutrients and toxic compounds to the river, and biotic responses to nutrient loading will continue to be evident. It is to be hoped that improved wastewater treatment and changes in agricultural practices, such as reduced dependence on pesticides or better soil retention of fertilizers, will result in improvements in water quality. However, population increases, or other changes in agricultural land uses and practices might result in adverse changes in surface water quality.

Based on recent past and present trends, it is likely that wastewater effluent quality will improve but that quantities will increase. Because of technological change and economic forces, future agricultural activity is not very predictable. However, it appears probable that the use of more specifially targeted pest and weed control practices will increase, resulting in fewer adverse environmental impacts, while the present pesticide burden in river sediments will continue to decline slowly through deep burial, degradation, and transport downriver to Lake Waco. On balance, it is unlikely that any great improvement in water quality can be expected in the North Bosque River or Lake Waco, considering present trends.

4.4.2 Construction Effects

Construction of the proposed Lake Bosque dam and reservoir will result in a decrease in pumping from presently used ground water resources. This can result in the eventual recharge of the important Trinity Group aquifers which will decrease pumping costs, improve quality and allow time for development of mechanisms to regulate withdrawl to long term sustainable levels.

Although some enhanced recharge of the Paluxy Sands was originally expected, geotechnical investigations indicated very low transmissivity in this formation, and consequently only small seepage losses from the reservoir. The reservoir site does not coincide with the recharge area of any important aquifer, so neither enhanced recharge nor potential contamination of a source can be expected to result from project construction.

As a result of the presence of Lake Bosque and planned conservation programs, regional surface waters can be managed to allow beneficial uses in addition to municipal water supply to be simultaneously realized.

Water quality in the proposed reservoir is expected to be similar to that now seen in Lake Waco since water chemistry is essentially the same throughout the lower North Bosque River. Based on experience at Lake Waco the proposed reservoir will likely be somewhat enriched and may exhibit DO depletion in the hypolimnion during stratification. Most reservoirs in the region have oxygen depleted bottom water during the summer and it is not considered a major problem. No substantial water quality problems are anticipated for Lake Bosque, standards for TWC Segment 1226 are not expected to be violated and no water quality conditions are indicated either by available data or by experience in Lake Waco that will prevent the use of Lake Bosque for public water supply or recreation.

4.4.3 Operation Effects

Operation of Lake Bosque is not expected to have any substantial effect on ground water resources beyond those items discussed above. Lake operation will decrease streamflow downstream of the dam. Table 4-1 presents flow frequencies at the proposed dam site derived from simulated reservoir operations under maximum demand (2040) conditions, using the 1946-1965 period of record. This table reflects maintenence of a minimum release of 0.5 cfs and release of up to a total of 2.0 cfs during April-August periods when inflows are available (see Section 5.0 Mitigation Plans). Comparison of Tables 3-1 and 4-1 shows that the lower flows, those equal to or less than the median for any given month are substantially reduced during the winter and spring but are augmented during the summer and fall months.

Under less than maximum demand conditions, Lake Bosque can be operated to maintain Lake Waco at a relatively stable elevation to enhance recreational benefits there. In that case more frequent releases will result in annual flows intermediate between the extremes exhibited in Tables 3-1 and 4-1, although the seasonal pattern of flows may be altered.

In order to assess the downstream extent of potential hydrologic changes, the reduction in stream discharge at Clifton due to the presence of the dam and reservoir was

Table 4-1 Monthly Flow Frequency Distribution at the proposed Dam Site, Lake Bosque operation under Maximum (2040) Conditions												
Percent of Days with Less Than Tabulated Flows	January	February	March	April	May	June	July	August	September	October	November	December
50%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
30%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
20%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
10%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
5%	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Note: Tabulated values are average daily flows in cubic feet per second.
Source: HDR Infrastructure, 1987

examined for the lower flow ranges. The large base flows available from the perennial tributaries (e.g., Meridian Creek) whose drainage basins include significant areas of Edwards Limestone, and the broad, deep valley alluvium and Paluxy Sands that begin to be present below Iredell are important contributors to flow in the North Bosque River below the proposed dam site.

Table 4-2 shows the percent change in tabulated values for the low flow percentiles at the Clifton gage resulting from the flow reduction due to the proposed project (cell by cell subtraction of the contents of Table 3-1 from Table 4-1, divided by the corresponding cell contents of the Clifton gage flow frequency table without the project). Table 4-2 shows that lower flows at Clifton will usually be reduced by substantially less than 50% and will often, particularly during the summer and fall, be increased. With regard to somewhat higher flows, analysis of reservoir inflow-outflow relationships were utilized to estimate the probable return interval for flows in the 1,000-2,000 cfs range at the proposed dam site. These flows are expected to recur at intervals of one to two years under 2040 operating conditions.

Drainage area runoff relationships were used to estimate the magnitudes of the two- and five-year flood peaks originating solely from storm runoff below the proposed dam site. These results are presented in Table 4-3.

Table 4-2 Percent Decrease, or Increase (+), in flows of Constant Frequency at Clifton, Texas due to the Operation of Lake Bosque under Maximum Demand (2040) Conditions

Flow Percentiles	January	February	March	April	May	June	July	August	September	October	November	December
0.50	41.50%	64.10%	61.90%	56.10%	64.10%	61.80%	19.50%	12.00%	22.70%	10.70%	32.00%	50.00%
0.30	36.00%	43.30%	62.70%	18.30%	54.50%	54.30%	(+85.10%)	(+52.10%)	(+82.00%)	0.00%	43.30%	32.80%
0.20	36.00%	42.00%	38.30%	15.00%	25.00%	24.40%	(+52.10%)	(+66.70%)	(+200.00%)	(+45.00%)	25.00%	32.60%
0.10	72.20%	29.50%	27.70%	18.10%	28.60%	(+30.00%)	(+250.00%)	(+416.70%)	(+833.30%)	(+72.00%)	(+55.60%)	26.70%
0.05	89.30%	33.30%	19.90%	63.60%	169.10%	(+43.20%)	(+333.30%)	*	*	(+208.30%)	(+80.60%)	(+47.00%)

Note: Percent change = (flow at dam with Project - flow at dam without Project) + (flow at Clifton without Project)
*= Zero flows augmented by the 0.5 cfs release from Lake Bosque.
Source: HDR Infrastructure, 1987

Table 4-3

Two and Five Year Flood Flows Originating in Drainage Areas below the Proposed Lake Bosque Dam

Stream miles below dam:	5	12	18*
2 year flood (cfs)	1,000	2,300	7,000
5 year flood (cfs)	2,000	4,300	15,000

*Meridian Creek

Considering highest flow regimes, although the proposed dam and reservoir will not have flood control as a specific purpose, its presence will result in the attenuation of flood peaks. Discharge of storm water will take place over a longer period of time and maximum flows reached will be less compared to the present conditions. For example, the 100 year flood peak will be reduced about 59%, from 94,500 to 39,100 cfs. Lesser floods will be attenuated to a proportionately greater degree; the 50 and 10 year flood peaks will be reduced by 62 and 68%, respectively, over present conditions. Maximum water surface elevations downstream of the reservoir will be reduced along with peak flows. Flooding in the reach between the proposed dam site and Meridian by the 100 year flood will be reduced by about 58%, from an average of 145 acres per mile to 60 acres per mile. This corresponds to a reduction of average inundated surface width from 1200 feet to 500 feet at the 100 year flood peak.

Potential effects on water quality in the tailwater reach include reductions in suspended solids, nutrients and coliform bacteria, discharge of oxygen depleted water with elevated hydrogen sulfide levels and alteration of water temperature patterns. By providing additional assimilatory capacity for the load of nutrients and other materials transported down the North Bosque River, the proposed reservoir is anticipated to result in improved water quality in the downstream portion of the river and in Lake Waco. Storage in Lake Bosque will result in enhanced oxidation of organic material, uptake of nutrients and sedimentation of algae, bacteria and non living material. The adverse effects, those involving low D.O. and temperature change, can be avoided with established operational techniques while retaining the beneficial effects.

4.5 Ecology

The following sections contain discussions of the potential effects of reservoir construction and operation on the biotic communities of the proposed Lake Bosque Site and downstream areas. Although the U.S. Fish and Wildlife Service has conducted Instream Flow (IFIM) studies on this reach of the North Bosque River, that has not been made avaliable at this time. Therefore, the discussion in Section 4.5.1, Aquatic Biology, and the mitigation plan proposed for aquatic environments in Section 5.1 does not make use of the formal IFIM methodology.

Terrestrial habitat values were also examined by the U.S. Fish and Wildlife Service using the Habitat Evaluation Procedure (HEP). These results are discussed in Section 4.5.2, Vegetation, and were used in formulating the mitigation plan proposed for terrestrial vegetation and wildlife in Section 5.2.

4.5.1 Aquatic Biology

4.5.1.1 Effects of No Action

In the absence of the proposed Lake Bosque, the North Bosque River will continue to be affected by the natural and cultural conditions prevailing in the basin. The river will still be subject to the regional climatic patterns and basin characteristics that produce its typical discharge levels, water quality and habitats. Biotic communities will continue to reflect the prevalence of pool habitats and sandy gravel/cobble substrates, the dependence of aquatic food webs on in situ production by algal species, the intense colonization of solid surfaces by these same algal species and the wide range and low predictability of river discharges.

Improvements in water quality will have to be substantial to result in appreciable changes to the biological community. Reduction of epilithic algal growth might result in some change in macroinvertebrate relative abundance, but other habitat factors, including the dominant character of the food webs, lack of structural diversity and periodic low flow episodes will continue to strongly influence the fish community.

4.5.1.2 Construction Effects

Construction of the proposed Lake Bosque will convert about 160 acres of stream bed to permanently inundated, deep water habitat, and about 4400 acres of dry land to aquatic habitats experiencing varying frequencies of inundation and depths. While some groups, including the filter feeding invertebrates and forage fish, may experience changes in species composition, most of the remainder of the community is capable of survival and reproduction in a reservoir habitat. None of the species reportedly fished for in the North Bosque River, nor the fish assemblage reported in TCA, 1985, will experience substantial adverse impacts as a result of construction of Lake Bosque. Table 3-2 lists fish species collected in the North Bosque River and notes those also reported from Lake Waco. Because of its size and potential habitat diversity it is expected that the 4564 acre conservation pool will support a significantly larger biomass, and probably a more diverse community than now occurs in the 160 acres of stream bed to be inundated, or even the approximately 350 acres of stream bed in the reach from the proposed reservoir to Clifton.

Water quality in the proposed reservoir is not expected to exert any substantial adverse influence on the resident biological community. Low D.O. levels in reservoir bottom waters during stratification may make that volume seasonally unavailable to fish and other aerobic organisms. This condition is very common in Texas reservoirs and although it might be supposed that it will result in reduced carrying capacity, it is in fact generally reflective of a more productive system, which supports higher growth rates and biomasses than more oligotrophic waters. Available water quality data and experience in Lake Waco indicates a lack of any other water quality problems that will adversely affect the biotic community of the reservoir.

4.5.1.3 Operation Effects

Effects on aquatic populations resulting from Lake Bosque operation can occur through three major routes. These are (1) the consequences of fluctuations in water surface elevation in the reservoir, (2) changes in the amount and timing of flows in the tailwater and (3) alteration of downstream water quality as a result of discharge of impounded water.

Fluctuations in reservoir elevation can have direct adverse effects on the reproductive success of fish species that spawn in shallow water, particularly those such as the centrarchids (sunfish) that construct nests. However, fluctuating reservoir surface elevation are not always problems. Precise effects are highly site specific and depend on a large number of factors including the nature of the drawdowns (seasonality, frequency, amount, rapidity), reservoir bathymetry, water quality and substrate distribution, and biotic community characteristics. The frequency and duration of water surface elevation changes will also affect development of littoral vegetation and, consequently, influence aquatic habitats. Too frequent fluctuation will result in suppression of vegetational development in the band between high and low water, while a constant level can lead to undesirably dense and extensive stands of aquatic macrophytes. The former situation is undesirable because it results in reduced aquatic habitat diversity, while the latter condition is a nuisance to human use.

Reservoir simulation studies for maximum demand (2040) conditions showed water surface elevations below 826 MSL occurred only infrequently (during the critical drought period). Considering April-July spawning periods, water surface elevations were stable within 2 feet in 15 of 20 years simulated, and changes of more than 3 feet occured only twice. Under 2040 conditions this route of impact is unlikely to be significant.

More frequent releases to Lake Waco during less than maximum demand conditions will result in somewhat more frequent and extensive drawdowns. However, extensive spring drawdowns are not expected under this operating condition either, because of the large water availability at that season. Consequently, we do not expect significant adverse impacts to biotic communities during less than maximum demand operation.

Changes in tailwater discharge patterns (see Section 4.4.3) will result in a reduction in the total inundated channel area, with most of this loss occuring in riffles, runs and shallow water habitats at the upper ends of pools. Substantial effects to the lotic environment will not extend below Clifton because of inflow from tributaries and aquifer outcrops. Downstream effects due to low flows will be most pronounced under maximum demand conditions. While Lake Bosque is operated to stabilize Lake Waco, large releases (about 1,000 cfs) will be made periodically in response to requests from the City of Waco. To ameliorate the potential effects of sudden changes in flow, particularly stranding during cessation of the release, a stepped discharge protocol will be employed (see Section 5.1).

Riffles occupy about 10% of the channel length (and a smaller proportion of channel area) between the dam site and Clifton. Aerial photography flown in September, 1984, after several months of zero discharge shows about half the stream bed occupied by permanent pools in the lower half of the reservoir reach and downstream to Meridian. Observations at Comanche Crossing (Station 1 in the Ecology Baseline Survey), between the proposed dam site and Meridian, indicate that substantial inundation of shallow channel reaches occurs when pools are filled. Flows of 2 cfs, or less, will inundate significantly more of these shallow areas, covering about 70-80% of the area wetted at median discharge.

In a pool dominated system such as this, inhabited by species that typically do not require flowing water for survival, it does not appear that reduced riffle habitat will be a substantial adverse effect. Obligate riffle species are largely absent from the North Bosque River, probably because of a combination of stress from low flow episodes and water quality conditions. While riffles have been identified as a source of prey items for fish, food limitation seems an unlikely circumstance for a river showing as much evidence of enrichment as this one.

It is most likely that long term carrying capacity for fish populations in the present North Bosque system is determined by the periodic occurence of low flow episodes. During very low flow summer conditions juveniles and all stages of forage fish can be exposed to intense predation if they are confined to the permanent pools where there is little cover and the water becomes clear as suspended materials settle out and nutrients are depleted and not replenished by inflows. Constant maintenence of some some shallow water non-riffle habitat, particularly during the summer, is probably far more important for resident fish populations than is the provision of flows high enough to inundate substantial riffle areas.

The attenuation of flood peaks resulting from the presence of the dam and reservoir has potential adverse consequences in that periodic flood flows are necessary to remove sands and silts deposited by minor runoff events, or sloughed from the banks, and to prevent invasion of the channel by terrestrial vegetation. Flows sufficient to scour the channel appear to be those in excess of 1,000 cfs which presently recurr more often than once per year. This flow will result in average current velocities of 3-5 feet per second and general mobilization of particles of one to three inches in size into the bed load. Flows of this magnitude are expected to occur at an interval of once in one to two years at the dam site under maximum demand conditions. Flows originating below the impounded part of the basin will substantially augment this scour regime.

Under less than maximum demand conditions, total annual flows will be similar to the present condition but low flow episodes will be periodically interuppted by large (ca. 1,000 cfs) releases to Lake Waco. No adverse impacts from lack of scouring events is expected to result from the proposed project.

Water quality changes as a result of impoundment include those that can be beneficial to downstream environments (reduction of suspended solids, nutrients and fecal coliforms), and those that tend to have adverse effects (release of hypolimnitic water depleted in dissolved oxygen and changes in seasonal temperature regimes). Discharge of relatively clear, low nutrient water will tend to reduce filamentous algal growth and substrate siltation in the tailwater reach possibly extending downstream as far as Clifton. This would tend to have the beneficial effect of altering shallow habitat areas to be more like those characteristic of the tributary streams, such as the East Bosque, and providing somne additional habitat diversity.

Discharge of water low in dissolved oxygen and, even more importantly, disruption of seasonal temperature patterns are widely recognized as having potentially adverse effects on macroinvertebrate and warm water fish assemblages. Avoidance of such impacts can be accomplished with appropriate operational protocols utilizing a multilevel withdrawl and outlet structure (Section 5.1).

4.5.1.4 Effects on Important Species and Habitats

No aquatic species, listed as endangered or threatened by either the State of Texas or the U.S. Fish and Wildlife Service, is known or is likely to occur in either the Lake Bosque site or in the downstream reach. No other important species (Section 3.5.2) are known that will suffer substantial adverse impact as a result of construction and operation of the Lake Bosque Project.

Habitats in the North Bosque River appear to be similar and widely distributed throughout the reach studied. Adverse impacts to unique habitats or communities is considered unlikely to occur as a result of reservoir construction or operation.

4.5.2 Vegetation

4.5.2.1 Effects of No Action

The no action alternative will eliminate both adverse and beneficial effects of construction and operation related to the proposed Lake Bosque project. The future status of the terrestrial flora of the project site will continue to be strongly affected by regional agricultural economics and management practices. Changes in these practices are not presently predictable. For example, during the interval 1958-1987 pasture and haylands increased from 396 to 50,855 acres in Bosque County, primarily at the expense of cropland. At the same time the "Otherland" use category (including public, recreation, wildlife, water, urban, and transportation route lands) increased from 30,450 to 46,165 acres.

Maintenance of current agricultural practices in the vicinity of the proposed reservoir site will probably result in the continued loss of species and habitat diversity through additional clearing of brush and woodland, planting and management for hybrid pasture grasses, and overgrazing in areas dominated by native vegetation. Substantial loss in habitat value can occur in the bottomland woodland map unit (TCA, 1985) as a result of continued conversion to cropland and improved pasture. Woodland areas amounting to at least half the 799.8 acres contained within the proposed conservation pool are probably at risk. These areas are scattered throughout the reservoir site along the North Bosque and its tributaries where the woodlands are more than just narrow, riparian strips.

The U.S. Fish and Wildlife Service has estimated the value of habitats in the project area using their Habitat Evaluation Procedure (HEP). The following is a simplified outline of the procedure, for a complete explanation of the HEP, see USFWS, 1980.

1) Select important, representative species for which habitat suitabilitiy models are available;

2) collect site-specific data on each habitat type of concern;

3) use field data and species model to estimate the average value of each habitat type for that particular species: the result is a number, the Habitat Suitability Index (HSI), having a range between 0.0 and 1.0;

4) determine the acreage of each habitat type;

5) calculate Habitat Units (HU) for each selected species as the product of habitat acreage and the HSI for that species;

6) if it is assumed that either acreages or HSI's will change over time, Average Annual Habitat Units (AAHU) are calculated by averaging HU's for each year over the period of concern.

This outcome of this procedure is sensitive to the number and identity of representative species used and how sample sites are selected within a habitat type, together with the methods used and effort expended in measuring habitat parameters. In addition, the assumptions made in preparing a particular analysis may strongly affect its outcome. For example, the U.S. Fish and Wildlife Service analysis of the Lake Bosque site assumes that both acreages and HSI's will remain the same for all habitat types during the life of the project (1990-2040) if the reservoir is not built. AAHU's for the various habitat types change considerably if different assumptions about land future land use is used.

For these reasons we regard the habitat values in Habitat Units (HU), presented in Table 4-4 as providing a general assessment which is open to interpretation based on regional environmental conditions and on data collected during the Baseline Ecology Survey of the reservoir site. Although we do not believe these HEP results to be biologically or statistically definitive, for the present purpose, the U.S. Fish and Wildlife Service analysis appears to provide values for the important habitat types (bottomland and upland deciduous woodland) that are unlikely to be substantially improved by additional analysis.

4.5.2.2 Construction Effects

Construction of Lake Bosque will result in the direct loss of approximately 192 acres of terrestrial vegetation through construction of the dam, spillway, and related facilities (Table 3-3). Reservoir maintainence at the conservation pool level (830 MSL) will inundate an additional 4564 acres of existing vegetation. The majority of this 4765 acres consists of cropland (22%), native grassland (32%), and improved pasture (20%). Riparian and bottomland woodlands account for 17% of the affected vegetation and less than 8% is upland woodland. Vegetation between the conservation pool elevation and the level of the 100 year flood (841.3 MSL) is not expected to be substantially affected because of the very short duration (<1 week) of flood inundation above 830 MSL. Floodwaters will be rapidly drained from the reservoir following an inflow event by the 250 foot wide uncontrolled service spillway.

The most extensive and economically important vegetational units on the site are native grassland, improved pasture, and cropland. The loss of these areas will not constitute an economically significant impact considering the approximately 500,000 acres of these habitats in Bosque

Table 4-4 Summary of U.S. Fish and Wildlife Service HEP Analysis of Major Habitat Types on the Proposed Lake Bosque Site

Species/Habitat	Area (acres)	HSI	HU
Dove/NP	2,277.00	0.84	1912.68
Dove/IP	1,247.00	0.51	635.97
Dove/CR	1,180.00	0.78	920.40
Kestrel/NP	2,277.00	0.87	1980.99
Kestrel/IP	1,247.00	0.85	1059.95
Kestrel/CR	1,180.00	0.49	578.20
S-T Flycatcher/NP	2,277.00	0.98	2231.46
S-T Flycatcher/IP	1,247.00	0.74	922.78
S-T Flycatcher/CR	1,180.00	0.78	920.40
B-C Chickadee/DF	202.00	0.81	163.62
B-C Chickadee/DFW	899.00	0.82	737.18
Barred Owl/DF	202.00	0.77	155.54
Barred Owl/DFW	899.00	0.89	800.11
Raccoon/DFW	899.00	0.94	845.06
Fox Squirrel/DF	202.00	0.68	137.36
Fox Squirrel/DFW	899.00	0.8	719.20
W-T Deer/CR	1,180.00	0.12	141.60
W-T Deer/DF	202.00	0.37	74.74
W-T Deer/DFW	899.00	0.5	449.50
Cottontail/NP	2,277.00	0.45	1024.65
Cottontail/IP	1,247.00	0.03	37.41

Note: Area assessed includes dam, spillway and lake area up to 100 year flood pool.
NP = native (unimproved) pasture
IP = improved pasture
CR = cropland
DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
Dove = mourning dove
Kestrel = American Kestrel
S-T = Flycatcher = scissor-tail flycatcher
B-C = Chickadee = black-capped chickadee (Parus atricapillus)
Cottontail = eastern cottontail

Source: U.S. Fish and Wildlife Service

County. The native grasslands tend to be overgrazed, except in the extreme northeast section of the project area, as evidenced be the abundance of numerous plant species indicative of wastelands and disturbed areas. Improved pastures, on the other hand, are reseeded on a regular basis or maintained with desirable forage species. Row crops occupy the majority of the cropland habitat and are almost entirely limited to the bottomlands since the valley slopes and uplands are unsuited to this land use.

While open plant communities may be adequate or even excellent habitat for a number of wildlife species (e.g. mourning dove, American kestrel, etc.), they tend to be impoverished in terms of native plant species. Projected losses of cropland and improved pasture habitats can be expected to result in insignificant losses to native plant populations while native pasture losses will tend to be limited to local increasers and weedy species. Bosque County presently contains about 142,000 acres of cropland and over 450,000 acres of native and improved pasture. Historical data indicates that changes in agricultural practice probably have a more pronounced effect on plant species diversity than will the inundation of 3589 acres of cropland and pastureland.

A large proportion (75%) of the habitat value in Table 4-4 is accounted for by crop, pasture and grazing land which may or may not be overvalued by that analysis, but is certainly very common in Bosque County and in Central Texas generally. We do not believe that removal of these areas will result in any significant impacts to important vegetational communities or species, or to wildlife populations dependant on those habitat types.

In terms of species density, diversity, and locally adapted species assemblages, the most significant habitat impacted is bottomland woodland. Although the project site (up to 830 MSL) only contains 799.8 acres of this habitat type (including 6.9 acres of pecan cropland), the loss through inundation will be substantial when considering the large scale reduction in bottomland forest that has occurred throughout Texas. This area also contains 109.73 acres of upland decidous forest which has also been substantially reduced in Central Texas by agricultural practices and which is regarded as important wildlife habitat.

Table 4-5 presents AAHU's for the with and without project alternatives as estimated by U.S. Fish and Wildlife Service for the two decidous forest habitats on the reservoir site. Net habitat loss is shown as the difference between the with and without project columns. Also included is a column showing net change calculated on the assumption that either acreage or HSI's will decline by 25% over the life of the project. Based on past trends and agricultural practices, and the fact that most of the bottomland forest habitat is located on prime farming soils, we believe that this scenario is conservative and at least as likely as the assumption of no change.

Site preparation and construction is not expected to produce any substantial impacts to vegetation outside of the construction site, borrow areas and haul roads (about 430 acres, all of which are included in the conservation pool). Dust, or materials such as oil and grease found in run-off from haul roads, is not anticipated to have any detectable effects on terrestrial vegetation.

4.5.2.3 Operation Effects

Long-term operation effects of Lake Bosque are not anticipated to have much effect on terrestrial vegetation where inundation is not complete. Little or no change due

Table 4-5 Habitat Values in Average Annual Habitat Units (AAHU) and Net Change for Deciduous Forest Portions of the Lake Bosque Site With and Without the Proposed Project

Species/Habitat	AAHU Without	AAHU With	AAHU Net	AAHU Net (25%)
B-C Chickadee/DF	163.62	79.87	-83.75	-71.5
B-C Chickadee/DFW	737.18	125.94	-611.24	-526.8
Barred Owl/DF	155.54	75.92	-79.62	-68.0
Barred Owl/DFW	800.11	136.69	-663.42	-572.2
Raccoon/DFW	845.06	144.37	-700.69	-604.6
Fox Squirrel/DF	137.36	67.05	-70.31	-60.1
Fox Squirrel/DFW	719.20	122.86	-596.34	-513.8
W-T Deer/DF	74.74	36.48	-38.26	-32.7
W-T Deer/DFW	449.50	76.79	-372.71	-319.3
Total	4,082.31	865.97	-3,216.34	-2,769.0

DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
B-C = Chickadee = black-capped chickadee (Parus atricapillus)

Source: U.S. Fish and Wildlife Service, Paul Price Associates, Inc.

to flooding of vegetation above the conservation pool (830.0 foot contour) is projected since periods of inundation are not expected to be of significant frequency or duration. Reservoir operation studies indicate only two periods of inundation above 831 MSL lasting more than five days over the 20 year simulation period. Terrestrial habitat values in this zone will therefore be retained to a substantial extent, depending on the mix of affected cover types and the management practices applied.

The majority of the area disturbed during construction of the dam and spillway will be reseeded, providing habitat similar to the improved pastures presently found in the project area.

Below the dam, the riparian streambed and woody vegetation along the margins of the river may be subjected to less pronounced fluctuations in streamflow, although high flows sufficient to scour the channel will continue to occur. This should result in more stable stream edge plant communities. Lowland species such as box elder, green ash, and pecan will be expected to produce moderately well since spills from the reservoir and lateral inflows from tributaries and the valley alluvium will continue to maintain a high water table. These trees, and others present in existing riparian woodland strips, are known to have high transpiration rates and require ample and dependable moisture supplies. They are not, however, dependent on annual inundations by the Bosque River as evidenced by the current 2-5 year return interval for flooding of riparian soils. Thus, flora associated with downstream woody habitats should remain essentially unaffected.

4.5.2.4 Effects on Important Species and Habitats

At present, no federally listed endangered or threatened plant species are known to occur in the Lake Bosque project area. Therefore, the construction and operation of the lake will not adversely affect any of these important species.

Of the habitats present in the project area, riparian and bottomland woodlands are considered the most productive in terms of both diversity and density of plant species. Since the majority of the bottomlands in this area have already been cleared for agricultural purposes, the remaining acreage should be considered of high value.

4.5.3 Wildlife

4.5.3.1 Effects of No Action

The no action alternative will prevent both the adverse and beneficial impacts of construction and operation related to the proposed Lake Bosque project. In the absence of the project, the area will probably remain largely in its present state with livestock grazing and farming being the predominant activities affecting wildlife. Wildlife utilization of the proposed site will reflect the changes or lack thereof, in plant communities on the site due to land use practices during the period 1990-2040.

4.5.3.2 Construction Effects

Construction of the dam, spillway and associated facilities will result in the removal of about 192 acres of existing wildlife habitat. Filling of the lake after dam construction will result in the inundation of about 4564 acres at conservation pool elevation (830 feet, MSL). As is typical of the entire project area, most (75%) of the affected habitat is open herbland including improved pasture, cropland, and native pasture. As such, it is already greatly affected by human disturbance. However, certain wildlife species do well in these habitats, with native pasture generally being of greater wildlife value than improved pasture and cropland. It is important to note, however, that these habitat types are abundant and that the populations of species typical of such areas will not be significantly altered when considered on a countywide or regional basis.

As a result of construction activities in the area of the dam, spillway, and borrow areas (522 acres), resident wildlife will be destroyed or displaced from the area depending on the mobility of individual species involved. It is commonly understood that organisms most likely to be killed directly by such activities include species of amphibians, reptiles, and small mammals. If construction occurs during the breeding season, nestling and fledgling birds will also be affected to the extent that those areas are utilitized for reproductive activities. During the process of lake filling, more species should be able to disperse from the site. However, if periods of rapid filling occur there may still be some direct mortality.

The fate of individual animals that escape direct injury is less commonly understood. The concept of carrying capacity is well established in wildlife population ecology and is important in considering the future of displaced individuals. Carrying capacity is a fluctuating level (within limits) of population density that can be supported by a given habitat (Gills 1971, Dempster 1975). As the population of a wildlife species (for example, white-tailed deer) increases and approaches local carrying capacity, a number of population control factors increase in their effect. Food and other resource shortages can result from overcrowding, in turn increasing competitive stresses, resulting in both direct and indirect reductions in fecundity and increases mortality (Dempster 1975). Absorption of displaced individuals into surrounding habitats will depend on the condition of those habitats and on the conspecific population densities already resident there (i.e., the local carrying capacity and how closely it is already approached). While survival of refugee individuals may be a function of local conditions and recent historical circumstances, we can expect no change in the long-term average population sizes in surrounding areas unless carrying capacity is altered by environmental changes. This means that over the long term we should regard the removal of a portion of the species habitat (in this case that affected by construction of the lake) as removing that part of the population resident in the affected area.

4.5.3.3 Operation Effects

Wildlife impacts from the operation of Lake Bosque will be primarily positive over the long term. The presence of the lake will provide aquatic and some riparian (lake littoral) habitat which will be of high value to species such as wintering and migratory waterfowl, fish-eating birds, aquatic- associated reptiles and amphibians, and other similar aquatic species.

Over the long term, vegetational succession in the vicinity of the shoreline can, if properly managed, produce riparian communities of increasing wildlife value as woody species develop and various aspects of habitat diversity are increased. These include food and cover availability and diversity, foliage height (structural) diversity, and a broader range of microclimates as more mesic conditions prevail. This will have the effect of increasing the carrying capacity of terrestrial environments adjacent to the lakeshore for some of the species adversely affected by reservoir construction. Additional beneficial changes could be realized through implementation of appropriate land use and management practices in selected areas.

The potential downstream changes that might occur as a result of stream-flow alterations are not considered significant. If vegetational communities are affected by reduced peak flows downstream, then wildlife inhabiting those areas will also be indirectly affected. However, inundation frequency for existing riparian woodlands is presently 2-5 years so there is little reason to expect major shifts in dominant vegetation in downstream areas and wildlife inhabiting those areas should be relatively unaffected.

Barclay (1980) under contract with UFSWS can come to no definite conclusions with regard to the downstream effects of impoundment in south-central Oklahoma. He hypothesized that impoundment might indirectly simplify downstream terrestrial riparian systems but the data for birds showed that "...reduction of stream fluctuation downstream from the reservoirs had little detectable effect on the avian communities studied." He also states that his reptile and amphibian survey did "...not provide any clear evidence of impoundment effects." Mammal sampling was similarly inconclusive.

4.5.3.4 Effects on Important Species and Habitats

No federally listed endangered or threatened species are expected to be adversely affected by either construction or operation of the proposed Lake Bosque project, since none are known, or are likely, to inhabit the area at present.

One species, the bald eagle, is likely to be favorably affected by the substantial increase in its preferred wintering habitat. The bald eagle winters at various reservoirs throughout Texas, and it is not unlikely that they will utilize Lake Bosque for feeding and resting.

Of the state listed species, the Texas horned lizard has been observed in the immediate vicinity of Lake Bosque. If members of this species are present in construction or borrow areas, or within the conservation pool, individuals could be lost.

Adverse impacts will occur with regard to all terrestrial game and furbearing species that currently inhabit the project site due to inundation of currently occupied habitat. However, these impacts are not of great significance when viewed on a countywide or regional basis. For example, based on game population indices, comparisons between the Lake Bosque site and the Cross Timbers and Prairies Ecological Region indicate that game populations in the project area are typical or somewhat low for the region. Habitat Evaluation Procedure results (Table 4-2) showed that even the bottomlands (generally the best deer habitat) had a habitat suitability index (HSI) for white-tailed deer of only 0.50. Bottomland HSI values for two smaller species, the fox squirrel and northern raccoon, were better (between 0.80 and 0.94) but the requirements for these species are typically in ample supply in any older bottomland forest with water.

Conclusions of the baseline studies indicated that open habitat game species such as mourning dove and bobwhite are similar in abundance in the project area and in the region in general. This was supported by the HEP data (USFWS 1985) for the mourning dove which shows relatively high HSI's for two of the three open cover types.

In terms of value per acre, the most significant and valuable habitats of the project area are bottomland and riparian woodlands. These cover types are considered by wildlife biologists to be of particular concern due to the statewide trend of reduction and because of their overall higher wildlife diversity and production. Thus, even though the bottomlands of the project area have been mostly cleared due to agriculture, the remaining acreages are considered to have high value.

4.6 Socioeconomics and Land Use

4.6.1 Effects of No Action

4.6.1.1 Population

During the 1960s and 1970s the two county study area grew at rates lower than did the State as a whole. If the proposed reservoir is not built, growth in the area is expected to continue at a slower rate of increase than during the 1970s. Even without additional growth, communities relying on groundwater as the sole source of supply (all the project participating entities except the City of Waco), will in the next 10 to 30 years begin experiencing severe water quality supply problems, which could restrict local population growth. If these entities grow at the rate projected by the TWDB (either the high or the low series) an additional source of water will be necessary in even less time. All the other known alternatives now cost more than the Lake Bosque Project and future costs are likely to increase beyond present estimates.

Restricted population growth due to lack of water will discourage young people from remaining in the area or migrating to the two counties. The evential result, particularly in Bosque County, will be low population growth characterized by an increasing proportion of elderly people.

4.6.1.2 Local Economy

The effect of no action upon the local economy of areas depending on ground water will be extensive. The local economy will continue as it has during the last 20 years until overdrafting of the Trinity Aquifer curtails water supplies and restricts development. Continued growth or even water use at present levels will require the development of additional water sources. Future manufacturing growth will require a source of water more reliable and ample than available through ground water.

In 1980, 56% of all Bosque County families were in the two lowest (out of 5 possible) income brackets while the State average was 40%. Without economic growth this trend can be expected to continue and possibly become even more extreme. Income levels in McLennan County are not too different from the state average. However, without continued population and economic growth, these income levels may decline.

4.6.1.3 Community Facilities and Services

The tax base for education in the two county area will remain unchanged if the proposed reservoir is not built. Restricted population growth caused by water shortages will decrease the number of children in the area. Required investments in the education system will decrease as the number of children declined. However, it is possible that as the number of people in the area declines, the rate of taxation required to maintain a minimum level of service could increase.

Fire protection in the study area will decline as overdrafting of the Trinity Aquifer continues. Effective fire-fighting necessitates a reliable high pressure water system.

4.6.1.4 Public Finance

As discussed in the previous sections the effect of no action upon project participants and Bosque and McLennan Counties' population and economy would likely cause area growth trends to decline and even stagnate. If this were to occur it is possible that tax rates would increase in order to continue providing the minimum level of required public services.

4.6.1.5 Recreation and Aesthetics

Public access to water for recreation purposes is extremely limited in the vicinity of the proposed reservoir. There are no public access points to the Bosque River in the vicinity of the proposed site. There is no reason to believe that this condition will change if the proposed reservoir is not built.

Local views will probably continue to consist of a pastoral valley landscape dominated by strong horizontals and inhabited by plants and animals typical of Central Texas.

4.6.1.6 Land Use

Insufficient water supplies could restrict urban development, specifically, development growth in existing communities relying solely on ground water.

4.6.2 Construction Effects

4.6.2.1 Population

HDR Infrastructure, Inc., consulting engineer for the owner, has estimated construction time for the proposed Lake Bosque at about two years. Because of the project's short construction time and proximity to the labor force of the Dallas-Fort Worth area and other surrounding communities, it is unlikely that a significant number of project workers will migrate to the area. It is more likely that workers will commute to the proposed project site as it is not uncommon for construction workers to average 50 miles one way in daily commuting. Therefore, substantial impact to housing availability, infrastructure, public safety, health services and schools is not anticipated from this source.

4.6.2.2 Local Economy

It is estimated that construction of the proposed project will provide approximately 145 temporary jobs, of which about 12% (18 jobs) would occur during the pre-construction stage and 88% (116 jobs) would occur in the construction phase. Peak employment of approximately 79 jobs would occur during the early phase of construction, employment for any one construction phase would range from 4 to 60 jobs.

Direct economic impacts of constructing the proposed reservoir would be limited by the project's relatively small construction crew and short construction time. Direct employment benefits (i.e., job creation) would be determined by the location of the contractor responsible for constructiong the dam. Undoubtedly, a small proportion of semi-skilled and unskilled jobs would be filled locally, but the majority of supervisory and highly-skilled positions (the best paying jobs) would be filled from within the contracting company's area of employment.

The presence of additional workers in the local area would be expected to generate a temporary demand for local acquisition of miscellaneous goods and services, i.e., food and beverages, gas, etc.

4.6.2.3 Community Facilities and Services

If Lake Bosque is built, Walnut Springs, Iredell and Meridian Independent School Districts (ISDs) would lose a small portion of their tax base. The percent of net ISD taxes accrued from lands affected by the proposed Lake Bosque site ranges from 2.40% to 3.86% of each ISD's tax revenue assuming that tax revenue reduction would be equal to reduction in the area of the tax base. We believe this to be a reasonable approximation because of the countervailing effects of higher bottomland values versus the usual location of improvements above the area affected by the reservoir. The existing tax rate for each school district ranges from 40% to 55% of the maximum $1.50 per $100 valuation tax rate and could be increased if needed. However, increases in property value associated with recreational and residential use of lands near Lake Bosque are expected to offset these losses.

Construction of the proposed reservoir would affect only 11 single family homes and a number of other structures largely related to farming activities. The market value of homes definitely located within the 100 year flood elevation ranges from $27,190 to $84,460.

As proposed, reservoir construction would require the relocation of small sections of county and state roadways, as well as abandonment of several county roads which cross the proposed site. Several powerlines would also be relocated. Construction generated traffic would not adversely affect major roads accessing the site because traffic counts for these roads are relatively low.

4.6.2.4 Public Finance

Approximately 54 landowners owning 13,629 acres will be affected to some extent by the proposed Lake Bosque. In some cases all of a particular land parcel will be inundated; in other cases, only a portion of the parcel. Eleven homes and 6,143.26 acres of the 13,251 acres will be included in the proposed Lake Bosque up to the 100 year flood elevation (841.3 feet, MSL).

Total 1985 property assessments for Bosque County stood at $385,630,342. The proposed project will remove about 4756 acres from the county tax roles, assuming that only flood easements will be obtained for land above the conservation pool elevation. The property removed from the tax roles by the construction of the proposed reservoir will be about 35% of the 13,629 acres partially affected by the project. The 1985 assessed property valuation of the 13,629 acres was $2,827,655, thirty-five percent of which would be $989,679, or 0.26% of the county's tax base. This could be offset by increases in property values and sales tax revenues resulting from residential and recreational development associated with Lake Bosque.

Municipal tax bases will not be affected by construction of the project as the site does not lie within the boundaries of a municipal jurisdiction. However, to finance the project, tax or water rates in the participating municipalities are expected to rise.

4.6.2.5 Recreation and Aesthetics

Recreational opportunities in the vicinity of the proposed Lake Bosque are severely restricted by the private ownership of everything except county roads and the stream bed. Construction activities are not expected to have significant adverse effects on local recreation since there is no public access to the dam and borrow areas. The approximately 500 acres included in these areas might support two to six deer leases if it were fully utilized. There is no public access to the Bosque River in the vicinity of the dam site.

Adverse effects of construction on local aesthetics will be temporary. Visual and audial disturbances will occur from construction machinery and workers. The dam is about seven miles from the nearest community and there are about 20 houses within a three mile radius. Because of the small number of people in the immediate vicinity, impacts on aesthetics from dam construction are expected to be slight.

The site would be transformed from a pastoral valley landscape into a 4,564 surface acre lake encompassed by gently sloping, flat-topped hills with local relief of about 200 feet. Thus, the waters of Lake Bosque, varying in color and textural quality with the seasonal and climatic extremes of the region and supporting an otherwise restricted aquatic community, will have a beneficial impact on local viewsheds and constitute an aesthetic amenity.

4.6.2.6 Land Use

Construction of the proposed Lake Bosque will change 4,756 acres of privately owned agricultural land into public water supply and recreation land. The Brazos River Authority will also obtain flood easement on an additional 1,387 acres up to the 100 year flood elevation that would be inundated occasionally.

The 4,756 acres to be occupied by the dam and spillways and the conservation pool account for about 0.8% of the county's 595,172 acres of cropland, pastureland, hayland and rangeland. This includes a rough estimate of about 3,000 acres of prime farming land, approximately 1.5% of the county total. Fifty-four landowners owning 13,351 acres would be affected to varying degrees. Eleven homes and 6,143.26 acres (45%) of the 13,251 acres would be impacted by the proposed Lake Bosque's conservation pool and 100-year floodplain.

4.6.3 Operation Effects

4.6.3.1 Population

Dam operation will require one or two full time employees living at or near the site. Some additional employment will result from recreational and residential development stimulated by the reservoir. However, these jobs would most likely be filled from the local area and therefore result in an insignificant impact upon the area's population.

Developed recreation areas would be expected to attract new visitors to the area, but no parks or other facilities are presently known to be planned. It is expected that such facilities would be developed by private interests or local governments in response to the demand identified in the 1985 Texas Outdoor Recreation Plan (TORP).

Residential development and consequent population growth in response to reservoir construction depends on several site specific factors including: availability of waterfront property, proximity to established population centers, access, aesthetics and the presence of recreational or other entertainment opportunities. Lake Bosque will have privately owned waterfront and view property and is within an hour's drive, about 50 miles, of the Waco metropolitan area.

Lake Granbury, located on the Brazos River about 35 miles southwest of Fort Worth, is an example of a reservoir in close proximity to an urban area with available, private waterfront property. Since construction in 1969, about 140 residential developments have been built on the 30 miles of lakeshore nearest the City of Granbury. These developments include approximately 31,078 lots, 3,672 single family homes and 3,494 mobile homes (PPC, 1984). Realtors in the Granbury area report that the current population mix is evenly distrubuted among seasonal residents, retired couples, commuters, and those who are locally employed.

Lakes O. C. Fisher and Proctor are both located in Central Texas, and are similar in size and location to the proposed Lake Bosque. However, these lakes were built by the U. S. Army Corps of Engineers and do not have private waterfront acreage available for purchase and development. Area realtors report only minor residential development of view lots near these lakes.

Because Lake Bosque is located relatively near Waco (1980 population was 101,261), will have property available for purchase and will have reasonably good access by SH 6, its development potential must be considered moderate to high. This potential may be limited to some extent by building restrictions below the 100 year flood elevation and by the relatively large, frequent changes in water surface elevation likely to be experienced during reservoir operation at less than maximum demand conditions. Waterfront property will presumably become more attractive for development as system demand increases and Lake Bosque surface elevation becomes more stable.

4.6.3.2 Local Economy

Following completion of construction, operation of the reservoir would require a work force of one or two people. These individuals would be responsible for reservoir operation and maintenance and would live near the site. The presence of these individuals and their familiiies will generate an insignificant demand for local goods and services and possibly require the purchase or construction of a permanent residence.

The major effect on the local economy will result from expenditures associated with recreational activities. In 1986, yearly visits to Lakes O. C. Fisher and Proctor totaled 552,732 and 983,170, respectively. The higher the percentage of nonlocal visitors to Lake Bosque, the greater the economic impact on the local area economy. Potentially, the economic impact of these visitors could be great.

4.6.3.3 Facilities and Services

Operation of the proposed reservoir would require that at least one or two employees live near the site. From this source, impact on the area's education system, public safety, health services and facilities, transporation system and local housing would be negligible. Depending on the number of nonlocal visitors drawn to the lake for recreation purposes and on possible population increases due to residential development, impacts on public safety, health services and facilities, and transportation could be significant. Bosque County is relatively well equipped to handle an influx of visitors and permanent residents, as the county has a surplus of medical personnel, two hospitals and well maintained roads with low traffic volumes. The only potential inadequacies could result from the relatively small police and fire-fighting force and from the presently low availability of rental housing and temporary lodging.

Increases in land value resulting from recreational and residential development over the life of the project are expected to offset losses in ISD tax bases caused by construction of the proposed reservoir. At least as much land as is removed by the reservoir will either have views of the proposed lake or else direct access to water, making the property potentially suitable for land uses other than agriculture.

Operation of the proposed Lake Bosque will significantly enhance the amount of available water supplies in the area. Currently, project participating municipalities, except the City of Waco, rely solely on ground water supplies. Operation of Lake Bosque will help end overdrafting of the Trinity Aquifers and insure the availability of a secure water source.

4.6.3.4 Public Finance

Reservoir construction and operation will remove about 0.26% of the county's tax base and not impact municiapal tax bases. As discussed with regard to school taxes, land values near the proposed site could increase and offset the initial reduction of the county's tax base. A secure water supply will insure that ample water is available for future population expansion and area development.

Property values near the proposed Lake Bosque site are not expected to be be adversely impacted by operation of the lake. On the contrary, land values could increase significantly in response to residential and recreational demand. Realtors experienced in reservoir associated development indicate that land up to three miles distance from a lake shore, if suitable views are available, can be marketed as water oriented, or recreational, property.

Lakeview property within one to three miles of Lakes Proctor and O.C. Fisher reportedly range in price from $9,000 to $11,000 per acre for small, relatively undeveloped acreages, to $50,000 for developed residential lots. Realtors report prices for developed residential property at Lake Granbury ranging from $40,000 to $600,000, with mobile homes and lake view sited homes occupying the lower range and single family waterfront homes accounting for the higher price range. Residential development adjacent to the proposed Lake Bosque will most likely result in development intensities and property values that fall within the range observed at Lakes Proctor, O.C. Fisher and Granbury.

4.6.3.5 Recreation and Aesthetics

The proposed site is situated on private land and is not open for public use. Operation of the reservoir will displace possibly 20 deer leases within the conservation pool. Water oriented recreation in the vicinity of the Lake Bosque site is currently available only to individuals with access to private lands bordering the North Bosque River. Since the Brazos River Authority will provide two public access points to Lake Bosque, and since the lake will be suitable for a much wider range of activities and will accommodate many more people than the river (4500 acres of reservoir vs 160 acres of stream bed), the net effect on recreational opportunities is expected to be beneficial.

Although Lake Bosque is located near major population centers (Waco and the Dallas Fort Worth area) over 50,000 surface acres in Lakes Whitney, Waco, Aquilla, Limestone and other popular recreation lakes are present in the Texas Outdoor Recreation Plan Region 11. While total lake acreage and boat launching facilities are considered adequate in Region 11, lake access is not, particularly on a local basis, and provision for enhanced access is a listed priority in the recreation plan.

Visitation records from existing reservoirs indicate that if recreational amenities are available, visitations in the range of 500.000 to 1,000,000 per year could occur at Lake Bosque. Although many, if not most of these visitors will be local residents, this level of activity is expected to generate a strong demand for miscellaneous goods and services (food and beverages, gas, camping equipment, recreation equipment, boat equipment, hotel acommodations, etc.), as well as increased demand for health and public safety services.

Factors influencing the visitor count to Lake Bosque will include proximity to a major population center, convenience of access and the availability of recreational facilities. No recreational facilities are known to be planned at this time but it is anticipated that private interests will construct some of the types of recreational facilities needed at Lake Bosque. Meridian State Park does provide camping facilities and is located within 10 miles of the site.

4.6.3.6 Land Use

Operation of the proposed Lake Bosque will result in conversion of some existing agricultural lands in the vicinity of the reservoir to recreational, residential and commercial uses. The extent to which this is likely to occur and the major factors influencing the outcome have been discussed in preceeding sections. Land within three miles of the lakeshore is most likely to be affected. The extent to which recreational facilities are provided, either by public or private interests, will have an effect on the rapidity and degree to which such changes take place.

4.7 Cultural Resources

4.7.1 Effects of No Action

In the absence of Lake Bosque, archaeological sites in the vicinity of the proposed reservoir will continue to be adversely affected by climatic forces and soil processes such as erosion and solution, bioturbation, and cultural disturbances including development and agricultural activities. Site loss from pot-hunting might be enhanced by location and recording of the 145 sites.

4.7.2 Construction Effects

Table 3-8, reproduced from the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), summarizes the type and magnitude of potential impacts to be expected on the Lake Bosque site. As a result of construction activities, 15 (seven National Register eligible) sites located in the immediate vicinity of the embankment and borrow areas will be lost by disturbance or deep burial. An additional 57 sites, 29 of which appear to be National Register eligible, will be covered by water within the conservation pool of Lake Bosque. The adverse, neutral or beneficial nature of this effect is dependent on the nature of the site.

Sites located between the conservation elevation (830 feet MSL) and the 100 year flood elevation (841.3 feet MSL) will tend to be exposed to increased erosion from wave action. The magnitude of this effect will vary from a maximum at sites located at 830 feet to vanishingly small at 841.3 feet where 0.5 inundations lasting about one day are expected over the 50 year life of the project. The nature of the site, its geologic and soil context and its orientation will substantially influence the effectiveness of wave induced erosion. Increased public access to this zone could result in increased site disturbance, but its inclusion in a 100 year floodplain will tend to reduce disturbance from construction activities. The 39 sites located above 843.1 feet MSL will not be directly affected by the construction of Lake Bosque.

4.7.3 Operation Effects

Direct effects to archaeological sites, other than those outlined in the preceeding section, are not expected to result from reservoir operation under maximum demand conditions. During less than maximum demand conditions, when releases would be made from Lake Bosque to stabilize Lake Waco, those sites located in the zone of frequent drawdown will be subject to accelerated erosion, slumping and human disturbance as artifacts are exposed on the surface.

Indirectly, enhanced residential and recreational development in the vicinity of the reservoir could lead to increased rates of site disturbance and loss. No effects on cultural resources downstream of the proposed dam site are expected to result from Lake Bosque operation.

5.0 Mitigation Plans

The following proposals address the balance of potential adverse and beneficial impacts resulting from construction and operation of the proposed Lake Bosque. Adverse impacts identified in foregoing sections may be avoided by modification of some aspect of the project; they may be mitigated to reduce the severity of the effect; and they may be compensated for in those cases where substantial impacts cannot be avoided. These types of actions are summarized below in a series of mitigation plans that will be carried out by the Brazos River Authority when the permits necessary for construction and operation of the proposed project have been obtained.

Substantial mitigation has already been accomplished through the generation of site specific data sets and analysis of that data in a regional context during the baseline studies of the Lake Bosque site. The aquatic surveys provide information on habitats, fisheries, and invertebrate assemblages unique in the North Bosque River. Likewise, no other data set for the region exists that is comparable to that for terrestrial communities on the reservoir site. These studies contain both taxonomic and quantitative population information that is considered in the context of regional physical and biotic conditions together with human influences.

The Cultural Resources survey has resulted in the location and description of 145 additional archaeological sites, resulting in a substantial increase in the number of recorded sites in Bosque County. Even in the absence of further study, this additional information is expected to add to our understanding of the lifeways of both aboriginal and European inhabitants of the area.

5.1 Aquatic Communities

I. Avoidance or Mitigation of potentially adverse impacts

A. To avoid violations of Stream Segment Standards downstream of the dam, and associated impacts, a multilevel withdrawl structure will be used to insure that dissolved oxygen concentrations remain above 5.0 mg/l in reservoir releases.

B. The multilevel withdrawl structure will also be used to maintain seasonal temperature patterns in reservoir releases within the normal ranges reported in existing North Bosque River water quality data. Suggested seasonal temperature limits for releases from the dam, based on seven years of monthly temperatures records at a station near Clifton, Texas, are as follows:

Dec-Feb	< 15° C
March	10-20
April	15-25
May-August	22-32
Sept-Oct	15-25
Nov	10-20

II. Measures to compensate for unavoidable adverse impacts

A. When inflows are available (see Table 4-1) during the April-August reproductive period, up to a total of 2.0 cfs will be continously maintained in the channel below the dam. A minimum of 0.5 cfs will be maintained in the channel below the dam at all times regardless of inflows. Fish populations can be maintained at levels reasonably near their present levels by providing a 0.5 cfs low flow augmentation sufficient to maintain pools at their "full" level at all times. The 2.0 cfs flow during April-August will inundate the shallow runs and assure access to creek mouths, which will provide additional space and sheltered habitat for the development of the year's juveniles.

5.2 Terrestrial Communities

Significant avoidance or mitigation of adverse impacts to terrestrial environments beyond that discussed in Section 5.0 is of limited feasibility for this project. A plan to compensate for these unavoidable effects is therefore proposed.

I. Significant, unavoidable impacts to be compensated for

A. As discussed in the preceeding sections, we believe that loss of the deciduous woodland areas of the reservoir site constitutes a significant adverse impact. We further agree with the USFWS that a net decrease in the vicinity of 3,000 Average Annual Habitat Units (Table 4.5) represents a reasonable index of that impact.

B. Although other areas are also to be affected by Lake Bosque, the quality and abundance of these habitat types is such that vegetation and wildlife impacts will be insignificant, even on a local basis. We do not believe that the potential costs of compensating for impacts to pasture and cropland is justified by the wildlife benefits that could be obtained.

II. Proposed Compensation

A. The Brazos River Authority intends to acquire a contiguous tract of land that, with appropriate management over the life of the Lake Bosque project, will produce a net gain in habitat value comparable to the losses described above. In addition, ancillary acreages acquired in the vicinity of the dam for other purposes will be managed appropriately, where possible, to complement the efforts in the main compensation tract.

B. The tract will probably be acquired fee simple and conveyed to an appropriate governmental agency (e.g., Texas Parks and Wildlife Department) for stewardship following any necessary initial management actions. Some other mechanism of acquisition and protection could be used if practical and necessary in a particular circumstance.

C. Several candidate tracts have been examined and two have been evaluated by USFWS personnel. We believe one of these will produce sufficient habitat value (in AAHU) to compensate for the Lake Bosque impacts with the application of an appropriate planting and management plan. Production of sufficient net habitat value on any given tract is understood to be a function of its size, initial condition, potential productivity and required managment inputs.

D. The Brazos River Authority is continuing to examine potential compensation tracts, as they have a responsibility to the project participants to seek an optimum solution. From this standpoint it is desirable to minimize not only land costs but also long term management and commitments to reforestation efforts having significantly uncertain outcomes. Preliminary search criteria for compensation tracts are listed below:

1) Minimum size, 1,000 contiguous acres
2) Soils must be at least occasionally flooded (2-5 years) sandy or silty clay bottomland soils. The local Soil Conservation Service office to be contacted to ascertain if any significant soil impairment is known.
3) The tract should be reasonably accessible for management activities.

4) High quality bottomland hardwood tracts are to be avoided unless they are very large, since potential net change in habitat value would be small.

5) Other factors being equal, tracts closer to Lake Bosque or in the Bosque River basin are preferred.

E. As candidate tracts are identified, HEP evaluations by the U.S. Fish and Wildlife Service and input from Texas Parks and Wildlife Department may be requested as necessary to evaluate acreage requirements and aid in development of appropriate management strategies. Target date for final selection of a compensation tract is by the end of the year.

5.3 Cultural Resources

The Archaeological and Historical Survey Report presents in detail a proposed plan to mitigate or compensate for the impacts of Lake Bosque on area Cultural Resources. Input from concerned state and federal agencies has been sought during the planning process. The specific methods used and the locations investigated will be approved by the appropriate authorities before the study begins.

In summary, this plan involves a standardized, limited sampling program at 34 sites to be affected by dam construction and inundation and at 12 sites within the 100 year flood pool to establish equivalent units. This will provide information on the diversity and relative density of cultural material within and among sites and allow the sites to be compared quantitatively. A subset of these sites will be excavated *in toto*. The results of this effort will provide the data to attempt the synthesis of a comprehensive history of this segment of the North Bosque River Valley.

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picnic tables, soccer fields, softball fields, swimming areas, walking and hiking trails.

An aesthetic survey of the proposed Lake Bosque site was conducted in February of 1987. Five viewsheds were photographed and evaluated for aesthetic values including topographical features, coloration, vegetational diversity and vividness, unique geological formations, man-made structures and uniqueness of view with respect to the region. The survey emphasized views presently available to the public from area roads.

The surveyed area is located in a transitional zone and includes rolling pastures and farmland with interspersed woodlands and grasslands. The Bosque River valley is characterized by river-bottom land of 800 feet mean sea elevation (MSL), is dotted with 900-1,050 foot high hills and encompassed by an 800-1,000 foot high ridge. Panoramic views of the valley and the proposed lake site are available almost anywhere at elevations above 850 feet. Natural vegetation and animal life includes grasses, trees, flowers and animals typical of Central Texas.

From each vantage viewshed, visual landscape elements of the proposed Lake Bosque site include pastureland, cropland, some wooded areas, farm machinery, an occasional farm house, livestock, natural vegetation (scrub oak, brush, cactus, etc.), and barbed wire fences. See Paul Price Associates Inc., 1987, for photographs.

3.8.6 Land Use

Land uses identified in the evaluation of the proposed Lake Bosque site include cropland, pastureland, woodland, residential, wetland and stockponds. Of the total 641,337 acreas in Bosque County, 595,172 acres (92.8%) consist of cropland, pastureland, hayland and rangeland.

The most significant changes in land use in Bosque County since 1958 have been a 127% increase in pasture and hayland, a 33% decrease in cropland and an 18% increase in land designated as Other land (includes water, urban, roads, railroads, and recreation land uses).

Since 1970, the majority of Bosque County's total market cash receipts were from livestock and livestock products. When compared to market cash receipts for the other 25 counties in the Blackland Agriculture District, the County was above average overall for livestock and livestock products market cash receipts, and slightly below average for crop cash receipts and total crops and livestock cash receipts.

3.9 Cultural Resources

3.9.1 Regional Setting

Bosque County lies near the northern margin of the Central Texas Archaeological Region in which the terms Paleoindian, Archaic, Neoarchaic and Historic have been used to describe major periods of cultural history (Howard, 1983). Prehistoric cultural associations and chronologies are based primarily on projectile point assemblages supplemented with radiocarbon dates.

Paleoindian people are believed to have been migratory with a hunting economy, but most of our knowledge of them has come from excavations remote from Central Texas. Radiocarbon studies from a relatively few sites in Central Texas date Paleoindian occupation of the region as being prior to about 8500 years before the present (B.P.). These early sites tend to be difficult to recognize, perhaps because of an overreliance by American archaeologists on the use of chronologies linked to the presence of projectile points. Accordingly, there are probably sites in the vicinity of Lake Bosque which are older than the one located during this survey. However, this Paleoindian site is an indicator, along with other work in Central Texas, that human occupation of the North Bosque River Valley has continued (perhaps intermittently) for the last 14,000 to 15,000 years. Previous surveys have located Paleoindian sites in the vicinity of Lake Waco, Lake Whitney, Squaw Creek Reservoir and several locations on the Brazos River. Several sites on the Brazos River are of such depth and density of projectile points as to indicate either sedentary occupation or numerous short-term occupations over a very long period.

Archaic peoples, distinguished on the basis of tool forms, are believed to have also been primarily migratory with a hunting and gathering economy. The Archaic, occuring roughly between 8500 and 1250 B.P., has been extensively studied in Central Texas where early, middle and late periods are distinguished on the basis of apparantly differing subsistence strategies. While early Archaic sites are relatively rare, middle Archaic (beginning about 5,000 B.P.) sites are more common and those of the late Archaic (3,000 B.P.) are fairly abundant. As population densities presumably increased throughout the Archaic, evidence indicates that both the variety of food sources and the technological developments neccessary to exploit them increased. Several Archaic sites are known from the North Bosque River including one at Comanche Crossing, between the proposed reservoir site and Meridian.

During the Neoarchaic period (1250 to 250 B.P.) the subsistance economy did not appear to differ substantially from that of the Archaic. These people engaged in hunting, gathering, fishing and some agriculture. River terrace and shelter sites in Central Texas, and in the vicinity of the proposed project, often contain indications of a riverine subsistence orientation. Some of these sites contain Caddoan artifacts, or exotic materials such as obsidian that do not occur naturally in Texas, implyimg considerable movement or contacts with other, remote cultural groups.

The Historic period dates from the advent of Europeans into the Central Texas area during the early eighteenth century. Aboriginal tribes resident in the area at the begining of the nineteenth century include Tawakoni, Tonkawa and Hainai. The town of Waco was surveyed in 1849, settlement of the Bosque County area by whites became significant during the 1850's, and Meridian was established in 1854. The earliest settlers from Norway, the descendants of whom still maintain a distinct community in Bosque County, also established themselves during that year.

Conflicts with the aboriginal inhabitants continued throughout the mid-century and was particularly intense during and after the War Between the States. The "Indians of the Brazos" were transferred to the Wichita Agency in Oklahoma in 1869 but the threat of hostilities did not cease completely until the Comanche were finally expelled from Central Texas in the mid 1870's.

The railroad was important in helping establish local communities, including Walnut Springs and Morgan, and linking them with existing towns like Iredell. A section of roadbed and artifacts believed to belong to the Texas Central Railroad and dating from the last quarter of the nineteenth century is present on the reservoir site. The decline and eventual abandonment of the railroad in the 1940's adversely affected the local economy, as did the decrease in economic importance of farming in Bosque County. During the twentieth century, and continuing to the present, ranching has become a more important part of the county economy as farm yields and profits have declined. At present, less than a dozen families are now living in or adjacent to the reservoir site, probably the smallest number of people since Paleoindian times.

3.9.2 Lake Bosque Site Survey

Prior to the archaeological survey performed in response to the permitting requirements of the proposed Lake Bosque project, no sites, either prehistoric or historic, had been recorded from the vicinity of the project area in the Texas Archaeological Research Laboratory files (Howard, 1983). A total of 145 sites were located and recorded during the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987). Of these, 77 were prehistoric, 49 were historic and the remainder contained material from both periods. The sites recorded in the project area reflect human use from the Paleoindian period to the present century, including the Great Depression of the 1930's. In addition to a 100% pedestrian survey and probing, selected sites were subjected to additional testing appropriate to the location and resource, including large-scale excavation using power equipment. The latter technique was useful primarily in locating, defining and evaluating buried terrace deposits.

In the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), each recorded site is mapped, fully described, and evaluated in terms of its potential value for additional study and with respect to its eligibility for inclusion either in the National Register of

Historic Places or as a State Archaeological Landmark. Table 3-8 summarizes the primary characteristics of these sites. Of the 63 sites located that are eligible for nomination to the National Register of Historic Places, 34 were prehistoric, 20 were occupied during historic times and the remaining nine exhibited multiple periods of occupation. The 36 sites consisting of those National Register sites to be encompassed by the conservation pool of Lake Bosque will be State Archaeological Landmarks by the Provisions of the Antiquities Code of Texas (Title 9, Section 191.092).

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

76 affected

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ219	846-851	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ220	840-852	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	-
41BQ221	828-832	historic	-	-	disturbed	road	unknown	damage	dam	dam	loss	none	-	-	-
41BQ222	836-848	historic	-	-	disturbed	house	unknown	damage	none	-	-	inundation	lake	flood	-
41BQ223	820-830	prehistoric	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ224	860-862	historic	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ225	828-840	prehistoric	-	-	erosion	road	seasonal	damage	none	-	-	inundation	lake	pool	-
41BQ226	834-842	historic	-	-	construction	pens	once	loss	none	-	-	inundation	lake	flood	-
41BQ227	820-850	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	-
41BQ228	860+	historic	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ229	900-920	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ230	845-848	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ231	860+	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ232	860-870	prehistoric	-	-	erosion	road	on-going	loss	none	-	-	none	-	-	-
41BQ233	850-860	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ234	834-838	historic	-	-	cleared	highway	once	loss	none	-	-	none	-	-	-
41BQ235	820-842	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ236	822-832	historic	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ201	856-862	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ202	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ203	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	flood	-
41BQ204	821-830	multiple	⊠	⊠	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ205	835-845	historic	-	⊠	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ206	838-850	prehistoric	-	⊠	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ207	835-842	historic	-	⊠	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ208	842-849	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ209	841-846	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ210	843-845	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ211	832-836	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ212	830-835	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	flood	-
41BQ213	842-846	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ214	846-849	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	unknown	-	-	-
41BQ215	848-858	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ216	839-845	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ217	830-840	prehistoric	-	-	redeposit	wash	on-going	loss	none	-	-	none	-	-	-
41BQ218	846-854	prehistoric	-	⊠	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ183	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ184	850-853	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ185	800-802	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	
41BQ186	829-834	historic	☒	☒	displaced	machine	unknown	damage	none	-	-	inundation	lake	pool	loss
41BQ187	840-844	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ188	802-806	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ189	825-828	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ190	828-830	historic	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ191	839-842	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ192	830-832	prehistoric	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	flood	-
41BQ193	826-829	historic	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ194	825-828	prehistoric	-	-	eroded	road	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ195	810-818	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ196	822-829	multiple	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ197	900-905	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ198	853-857	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ199	846-850	historic	-	☒	none	-	-	-	none	-	-	unknown	-	-	-
41BQ200	860	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ165	835-838	historic	-	-	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ166	842-845	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ167	832-835	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ168	774-788	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundaton	lake	pool	loss
41BQ169	763-766	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ170	800-820	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	pool	-
41BQ171	830-840	historic	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ172	830-835	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ173	788-790	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ174	835-841	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	damage
41BQ175	812-814	geological	-	-	-	-	-	-	-	-	-	-	-	-	-
41BQ176	859-861	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ177	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ178	840-843	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ179	845	multiple	-	-	cleared	machine	once	loss	none	-	-	none	-	-	-
41BQ180	813-823	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ181	820-826	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ182	833-836	historic	-	-	displaced	machine	once	loss	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ147	820-830	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ148	800-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ149	810-823	multiple	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ150	848-850	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	none	-	-	-
41BQ151	840-851	prehistoric	-	☒	clearing	highline	once	damage	dam	spillway	loss	none	-	-	-
41BQ152	815-828	historic	☒	☒	erosion	wash	seasonal	damage	dam	dam	loss	none	-	-	-
41BQ153	785-805	historic	☒	☒	filling	wash	seasonal	positive	spillway	haul road	loss	none	-	-	-
41BQ154	800-838	prehistoric	-	-	erosion	wash	seasonal	damage	spillway	haul road	loss	none	-	-	-
41BQ155	790-830	prehistoric	-	-	clearing	highline	once	damage	none	-	-	none	-	-	-
41BQ156	775-780	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ157	820-825	historic	-	-	altered	building	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ158	774-779	prehistoric	☒	☒	sloughing	river	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ159	833-843	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	damage
41BQ160	810-811	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ161	812-824	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ162	800-810	historic	☒	☒	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ163	815-817	prehistoric	-	-	eroded	wash	on-going	loss	dam	dam	-	none	-	-	-
41BQ164	869	historic	-	-	none	-	-	-	none	-	-	none	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ129	820-828	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	normal	loss
41BQ130	845-846	historic	-	☒	clearing	owner	unknown	damage	none	-	-	none	-	-	-
41BQ131	826-836	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	pool	none
41BQ132	870	historic	-	-	cleared	owner	unknown	loss	none	-	-	none	-	-	-
41BQ133	856-860	historic	-	-	cleared	owner	once	loss	none	-	-	none	-	-	
41BQ134	850-854	historic	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ135	858-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ136	830-850	historic	-	-	cleared	dozer	once	loss	none	-	-	none	-	-	-
41BQ137	810-822	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ138	808-812	multiple	☒	☒	cleared	owner	once	disturbed	none	-	-	inundation	lake	pool	loss
41BQ139	796-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ140	802-804	historic	-	-	razed	owner	once	loss	none	-	-	inundation	lake	pool	-
41BQ141	780-793	historic	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ142	810-820	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	inundation	lake	pool	-
41BQ143	800-810	prehistoric	☒	☒	erosion	rill	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ144	805	historic	-	-	erosion	drain	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ145	856-862	prehistoric	-	☒	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-
41BQ146	860-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ111	805-808	prehistoric	⊠	⊠	turned	tillage	annual	damage	none	–	–	inundation	lake	pool	loss
41BQ112	828-830	historic	⊠	⊠	altered	building	on-going	damage	removal	clearing	damage	inundation	lake	pool	loss
41BQ113	845-860	prehistoric	-	-	eroded	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ114	820-850	historic	-	-	eroded	slope	on-going	damage	none	-	-	none	-	-	-
41BQ115	842-848	prehistoric	-	-	eroded	wash	on-going	-	none	-	-	none	-	-	-
41BQ116	815-820	prehistoric	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ117	840-855	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ118	840-850	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ119	860-868	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	none	-	-	-
41BQ120	853-856	multiple	-	-	altered	building	once	loss	none	-	-	none	-	-	-
41BQ121	838-850	prehistoric	-	-	cleared	dozer	once	damage	none	-	-	inundation	lake	flood	loss
41BQ122	820-828	multiple	⊠	⊠	buried	alluvial	flooding	preserved	none	-	-	inundation	lake	normal	loss
41BQ123	842-845	historic	-	⊠	none	-	-	-	F.M. 927	relocation	unknown	none	-	-	-
41BQ124	818-822	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ125	818-819	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ126	818-820	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	normal	none
41BQ127	819-824	historic	-	-	razed	owner	unknown	loss	none	-	-	inundation	lake	normal	none
41BQ128	810-816	historic	-	-	none	-	-	-	none	-	-	inundation	lake	normal	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ93	840-842	prehistoric	-	-	erosion	cattle	seasonal	damage	none	-	-	erosion	waves	once	damage
41BQ94	832-835	multiple	-	-	scouring	creek	seasonal	damage	none	-	-	erosion	waves	-	-
41BQ95	850-860	prehistoric	-	☒	erosion	cattle	seasonal	damage	none	-	-	looting			
41BQ96	833-835	historic	-	-	mixing	vehicles	on-going	damage	mixing	dam	loss	none	-	-	-
41BQ97	820-842	prehistoric	-	-	erosion	cattle	seasonal	damage	mixing	clearing	loss	none	-	-	
41BQ98	812-820	historic	-	-	scouring	creek	seasonal	damage	none	-	-	siltation	lake	seasonal	-
41BQ99	802-806	historic	-	-	mixing	human	on-going	damage	none	-	-	siltation	lake	seasonal	damage
41BQ100	809-812	prehistoric	-	-	erosion	cattle	seasonal	neutral	none	-	-	none	-	-	-
41BQ101	820-830	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ102	828-840	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ103	832-836	historic	-	-	none	-	-	-	mixing	clearing	loss	none	-	-	-
41BQ104	820-870	historic	-	-	erosion	wash	seasonal	damage	-	-	-	none	-	-	-
41BQ105	834-839	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ106	805-806	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ107	820-824	multiple	☒	☒	erosion	wash	seasonal	damage	none	-	-	erosion	lake	on-going	loss
41BQ108	805	historic	-	-	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ109	837-840	prehistoric	-	☒	erosion	wash	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ110	820-825	multiple	☒	☒	erosion	cattle	on-going	damage	none	-	-	erosion	lake	on-going	loss

Table 3-8

Effects-On-Sites Characterization for lake Bosque Project

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ237	778-780	prehistoric	☒	☒	sloughing	creek	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ238	789-791	prehistoric	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	unknown

4.0 Environmental Effects of the Proposed Project

4.1 Climatology and Air Quality

4.1.1 Effects of no action

In the absence of the proposed project regional climate and air quality will continue to be influenced by the factors outlined in Section 3.1. Air quality is not anticipated to undergo substantial change as a result of local influences for the forseeable future.

4.1.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any substantial effect on regional climate. However, localized effects, including some amelioration of diurnal temperature ranges and the creation of more mesic microclimates can be expected to occur in the immediate vicinity of the reservoir.

Some local and temporary increases in airborne particulates (dust) may result from disturbance of the vegetative cover in construction sites, borrow areas, and haul roads. Significant increases in areas other than the immediate vicinity of the work areas appears unlikely. Particulates are not presently a problem in Bosque County even though extensive soil disturbance now occurs as a result of agricultural practices. More than one thousand acres of seasonally plowed cropland and a considerable extent of unpaved road is present in the reservoir site.

With respect to near field effects, less than 10 residences are located within one mile of the proposed dam site and borrow area, and the nearest community, Meridian, is about four miles away. Two residences are located within the main embankment and borrow areas and may be vacated before construction begins. The other residences are in locations not expected to experience significantly increased dust levels. Construction machinery exhaust is not a large enough source to significantly affect air quality in the area.

4.1.3 Operation Effects

Reservoir operation is not expected to have any significant effect on climate or air quality, either locally or regionally.

4.2 Noise

4.2.1 Effects of No Action

In the absence of the proposed Lake Bosque, local and regional noise sources and levels will continued to be affected by ongoing economic and technological forces.

4.2.2 Construction Effects

Some localized increases in noise levels will accompany construction activities in the vicinity of the proposed dam. However, there is a paucity of receptors in the area, and less than seven residences within one mile of the dam and borrow areas will be occupied during the construction period. Wildlife in the immediate vicinity of work areas might experience some noise related disturbance, but most species accommodate rather rapidly to mechanical noise that is not accompanied by other threat stimuli.

4.2.3 Operation Effects

Operation of the proposed reservoir is not expected to have any direct effect on local or regional noise levels. Increase in residential land use and recreational activities in the vicinity of the reservoir can result in some local increases in noise, including that resulting from higher traffic volumes on surrounding roads and operation of power boats (see Section 4.5, Socioeconomics and Land Use).

4.3 Geology and Soils

4.3.1 Effects of No Action

Geological resources and soils in Bosque and McLennan Counties will continue to be affected by ongoing population, economic and technological forces in the absence of the proposed reservoir.

4.3.2 Construction Effects

Construction of the proposed Lake Bosque is not anticipated to have any significant effects on the geological resources of the region. Within the reservoir site, various soil and rock materials will be utilized in dam construction. Sand and gravel deposits to be inundated by Lake Bosque do not appear to have much potential for economic recovery and off site sale.

Area palaeontological resources are centered in the Walnut and Glen Rose formations. Outcrops of these formations will be affected only slightly on the reservoir margins and in the river channel at the extreme upstream limit of inundation.

Roughly 3,000 acres of prime farming soils will be affected by dam construction and by inundation as a result of the construction of Lake Bosque. This is about 1.5% of the prime soils in Bosque County and is not anticipated to constitute a significant effect on a limited resource.

4.3.3 Operation Effects

Operation of the proposed Lake Bosque is not expected to have any substantial effect on either the geological or soil resources of Bosque and McLennan Counties. Effects upstream of the dam have been addressed in the preceeding sections, while downstream effects are expected to be negligible. Although Lake Bosque will not have a designated flood control function, flood peaks will be substantially attenuated by the presence of the dam and reservoir. As a result, the 100 year floodplain in the 6.3 mile reach from the proposed dam site to Meridian will be narrowed by about 58% from the present average width at maximum stage of 1200 feet to about 500 feet with the dam in place. Mean area inundated during the 100 year flood will be decreased from 145 acres per mile to 60 acres per mile. Neither direct effects nor resultant land use changes are expected to exert significant adverse effects on soils or geologic resources.

4.4 Water Resources

4.4.1 Effects of No Action

Unless another comparable alternative was selected, failure to construct Lake Bosque will result in continued overdrafting of groundwater resources. Declining water levels will result in increased pumping costs in the short term, a continuing decrease in groundwater quality and contribute to the continuing decline in water availability.

Existing surface water resources will have to be more intensively utilized, possibly to the detriment of other uses. Development of alternative surface water sources will impose financial burdens on project participants substantially greater than that required for the Lake Bosque alternative.

North Bosque River discharge may remain relatively unchanged in the absence of Lake Bosque. However, other projects may be constructed that will affect river flow. For example, additional flood and sediment retention structures might be built in the basin, or water from a project in the Paluxy River Basin may be discharged into the North Bosque from the City of Stephenville's wastewater treatment facilities.

Municipal wastewater discharges and agricultural runoff will continue to contribute sediment, oxygen demanding material, nutrients and toxic compounds to the river, and biotic responses to nutrient loading will continue to be evident. It is to be hoped that improved wastewater treatment and changes in agricultural practices, such as reduced dependence on pesticides or better soil retention of fertilizers, will result in improvements in water quality. However, population increases, or other changes in agricultural land uses and practices might result in adverse changes in surface water quality.

Based on recent past and present trends, it is likely that wastewater effluent quality will improve but that quantities will increase. Because of technological change and economic forces, future agricultural activity is not very predictable. However, it appears probable that the use of more specifially targeted pest and weed control practices will increase, resulting in fewer adverse environmental impacts, while the present pesticide burden in river sediments will continue to decline slowly through deep burial, degradation, and transport downriver to Lake Waco. On balance, it is unlikely that any great improvement in water quality can be expected in the North Bosque River or Lake Waco, considering present trends.

4.4.2 Construction Effects

Construction of the proposed Lake Bosque dam and reservoir will result in a decrease in pumping from presently used ground water resources. This can result in the eventual recharge of the important Trinity Group aquifers which will decrease pumping costs, improve quality and allow time for development of mechanisms to regulate withdrawl to long term sustainable levels.

Although some enhanced recharge of the Paluxy Sands was originally expected, geotechnical investigations indicated very low transmissivity in this formation, and consequently only small seepage losses from the reservoir. The reservoir site does not coincide with the recharge area of any important aquifer, so neither enhanced recharge nor potential contamination of a source can be expected to result from project construction.

As a result of the presence of Lake Bosque and planned conservation programs, regional surface waters can be managed to allow beneficial uses in addition to municipal water supply to be simultaneously realized.

Water quality in the proposed reservoir is expected to be similar to that now seen in Lake Waco since water chemistry is essentially the same throughout the lower North Bosque River. Based on experience at Lake Waco the proposed reservoir will likely be somewhat enriched and may exhibit DO depletion in the hypolimnion during stratification. Most reservoirs in the region have oxygen depleted bottom water during the summer and it is not considered a major problem. No substantial water quality problems are anticipated for Lake Bosque, standards for TWC Segment 1226 are not expected to be violated and no water quality conditions are indicated either by available data or by experience in Lake Waco that will prevent the use of Lake Bosque for public water supply or recreation.

4.4.3 Operation Effects

Operation of Lake Bosque is not expected to have any substantial effect on ground water resources beyond those items discussed above. Lake operation will decrease streamflow downstream of the dam. Table 4-1 presents flow frequencies at the proposed dam site derived from simulated reservoir operations under maximum demand (2040) conditions, using the 1946-1965 period of record. This table reflects "maintenance" maintenence of a minimum release of 0.5 cfs and release of up to a total of 2.0 cfs during April-August periods when inflows are available (see Section 5.0 Mitigation Plans). Comparison of Tables 3-1 and 4-1 shows that the lower flows, those equal to or less than the median for any given month are substantially reduced during the winter and spring but are augmented during the summer and fall months.

Under less than maximum demand conditions, Lake Bosque can be operated to maintain Lake Waco at a relatively stable elevation to enhance recreational benefits there. In that case more frequent releases will result in annual flows intermediate between the extremes exhibited in Tables 3-1 and 4-1, although the seasonal pattern of flows may be altered.

In order to assess the downstream extent of potential hydrologic changes, the reduction in stream discharge at Clifton due to the presence of the dam and reservoir was

Table 4-1 Monthly Flow Frequency Distribution at the proposed Dam Site, Lake Bosque operation under Maximum (2040) Conditions												
Percent of Days with Less Than Tabulated Flows	January	February	March	April	May	June	July	August	September	October	November	December
50%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
30%	0.50	0.50	0.50	2.00	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50
20%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
10%	0.50	0.50	0.50	2.00	2.00	2.00	0.50	0.50	0.50	0.50	0.50	0.50
5%	0.50	0.50	0.50	0.50	2.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Note: Tabulated values are average daily flows in cubic feet per second.
Source: HDR Infrastructure, 1987

examined for the lower flow ranges. The large base flows available from the perennial tributaries (e.g., Meridian Creek) whose drainage basins include significant areas of Edwards Limestone, and the broad, deep valley alluvium and Paluxy Sands that begin to be present below Iredell are important contributors to flow in the North Bosque River below the proposed dam site.

Table 4-2 shows the percent change in tabulated values for the low flow percentiles at the Clifton gage resulting from the flow reduction due to the proposed project (cell by cell subtraction of the contents of Table 3-1 from Table 4-1, divided by the corresponding cell contents of the Clifton gage flow frequency table without the project). Table 4-2 shows that lower flows at Clifton will usually be reduced by substantially less than 50% and will often, particularly during the summer and fall, be increased. With regard to somewhat higher flows, analysis of reservoir inflow-outflow relationships were utilized to estimate the probable return interval for flows in the 1,000-2,000 cfs range at the proposed dam site. These flows are expected to recur at intervals of one to two years under 2040 operating conditions.

Drainage area runoff relationships were used to estimate the magnitudes of the two- and five-year flood peaks originating solely from storm runoff below the proposed dam site. These results are presented in Table 4-3.

Table 4-2 Percent Decrease, or Increase (+), in flows of Constant Frequency at Clifton, Texas due to the Operation of Lake Bosque under Maximum Demand (2040) Conditions

Flow Percentiles	January	February	March	April	May	June	July	August	September	October	November	December
0.50	41.50%	64.10%	61.90%	56.10%	64.10%	61.80%	19.50%	12.00%	22.70%	10.70%	32.00%	50.00%
0.30	36.00%	43.30%	62.70%	18.30%	54.50%	54.30%	(+85.10%)	(+52.10%)	(+82.00%)	0.00%	43.30%	32.80%
0.20	36.00%	42.00%	38.30%	15.00%	25.00%	24.40%	(+52.10%)	(+66.70%)	(+200.00%)	(+45.00%)	25.00%	32.60%
0.10	72.20%	29.50%	27.70%	18.10%	28.60%	(+30.00%)	(+250.00%)	(+416.70%)	(+833.30%)	(+72.00%)	(+55.60%)	26.70%
0.05	89.30%	33.30%	* 19.90%	63.60%	169.10%	(+43.20%)	(+333.30%)	*	*	(+208.30%)	(+80.60%)	(+47.00%)

Note: Percent change = (flow at dam with Project - flow at dam without Project) + (flow at Clifton without Project)
*= Zero flows augmented by the 0.5 cfs release from Lake Bosque.
Source: HDR Infrastructure, 1987

Table 4-3

Two and Five Year Flood Flows Originating in Drainage Areas below the Proposed Lake Bosque Dam

Stream miles below dam:	5	12	18*
2 year flood (cfs)	1,000	2,300	7,000
5 year flood (cfs)	2,000	4,300	15,000

*Meridian Creek

Considering highest flow regimes, although the proposed dam and reservoir will not have flood control as a specific purpose, its presence will result in the attenuation of flood peaks. Discharge of storm water will take place over a longer period of time and maximum flows reached will be less compared to the present conditions. For example, the 100 year flood peak will be reduced about 59%, from 94,500 to 39,100 cfs. Lesser floods will be attenuated to a proportionately greater degree; the 50 and 10 year flood peaks will be reduced by 62 and 68%, respectively, over present conditions. Maximum water surface elevations downstream of the reservoir will be reduced along with peak flows. Flooding in the reach between the proposed dam site and Meridian by the 100 year flood will be reduced by about 58%, from an average of 145 acres per mile to 60 acres per mile. This corresponds to a reduction of average inundated surface width from 1200 feet to 500 feet at the 100 year flood peak.

Potential effects on water quality in the tailwater reach include reductions in suspended solids, nutrients and coliform bacteria, discharge of oxygen depleted water with elevated hydrogen sulfide levels and alteration of water temperature patterns. By providing additional assimilatory capacity for the load of nutrients and other materials transported down the North Bosque River, the proposed reservoir is anticipated to result in improved water quality in the downstream portion of the river and in Lake Waco. Storage in Lake Bosque will result in enhanced oxidation of organic material, uptake of nutrients and sedimentation of algae, bacteria and non living material. The adverse effects, those involving low D.O. and temperature change, can be avoided with established operational techniques while retaining the beneficial effects.

4.5 Ecology

The following sections contain discussions of the potential effects of reservoir construction and operation on the biotic communities of the proposed Lake Bosque Site and downstream areas. Although the U.S. Fish and Wildlife Service has conducted Instream Flow (IFIM) studies on this reach of the North Bosque River, that has not been made avaliable at this time. Therefore, the discussion in Section 4.5.1, Aquatic Biology, and the mitigation plan proposed for aquatic environments in Section 5.1 does not make use of the formal IFIM methodology.

Terrestrial habitat values were also examined by the U.S. Fish and Wildlife Service using the Habitat Evaluation Procedure (HEP). These results are discussed in Section 4.5.2, Vegetation, and were used in formulating the mitigation plan proposed for terrestrial vegetation and wildlife in Section 5.2.

4.5.1 Aquatic Biology

4.5.1.1 Effects of No Action

In the absence of the proposed Lake Bosque, the North Bosque River will continue to be affected by the natural and cultural conditions prevailing in the basin. The river will still be subject to the regional climatic patterns and basin characteristics that produce its typical discharge levels, water quality and habitats. Biotic communities will continue to reflect the prevalence of pool habitats and sandy gravel/cobble substrates, the dependence of aquatic food webs on in situ production by algal species, the intense colonization of solid surfaces by these same algal species and the wide range and low predictability of river discharges.

Improvements in water quality will have to be substantial to result in appreciable changes to the biological community. Reduction of epilithic algal growth might result in some change in macroinvertebrate relative abundance, but other habitat factors, including the dominant character of the food webs, lack of structural diversity and periodic low flow episodes will continue to strongly influence the fish community.

4.5.1.2 Construction Effects

Construction of the proposed Lake Bosque will convert about 160 acres of stream bed to permanently inundated, deep water habitat, and about 4400 acres of dry land to aquatic habitats experiencing varying frequencies of inundation and depths. While some groups, including the filter feeding invertebrates and forage fish, may experience changes in species composition, most of the remainder of the community is capable of survival and reproduction in a reservoir habitat. None of the species reportedly fished for in the North Bosque River, nor the fish assemblage reported in TCA, 1985, will experience substantial adverse impacts as a result of construction of Lake Bosque. Table 3-2 lists fish species collected in the North Bosque River and notes those also reported from Lake Waco. Because of its size and potential habitat diversity it is expected that the 4564 acre conservation pool will support a significantly larger biomass, and probably a more diverse community than now occurs in the 160 acres of stream bed to be inundated, or even the approximately 350 acres of stream bed in the reach from the proposed reservoir to Clifton.

Water quality in the proposed reservoir is not expected to exert any substantial adverse influence on the resident biological community. Low D.O. levels in reservoir bottom waters during stratification may make that volume seasonally unavailable to fish and other aerobic organisms. This condition is very common in Texas reservoirs and although it might be supposed that it will result in reduced carrying capacity, it is in fact generally reflective of a more productive system, which supports higher growth rates and biomasses than more oligotrophic waters. Available water quality data and experience in Lake Waco indicates a lack of any other water quality problems that will adversely affect the biotic community of the reservoir.

4.5.1.3 Operation Effects

Effects on aquatic populations resulting from Lake Bosque operation can occur through three major routes. These are (1) the consequences of fluctuations in water surface elevation in the reservoir, (2) changes in the amount and timing of flows in the tailwater and (3) alteration of downstream water quality as a result of discharge of impounded water.

Fluctuations in reservoir elevation can have direct adverse effects on the reproductive success of fish species that spawn in shallow water, particularly those such as the centrarchids (sunfish) that construct nests. However, fluctuating reservoir surface elevation are not always problems. Precise effects are highly site specific and depend on a large number of factors including the nature of the drawdowns (seasonality, frequency, amount, rapidity), reservoir bathymetry, water quality and substrate distribution, and biotic community characteristics. The frequency and duration of water surface elevation changes will also affect development of littoral vegetation and, consequently, influence aquatic habitats. Too frequent fluctuation will result in suppression of vegetational development in the band between high and low water, while a constant level can lead to undesirably dense and extensive stands of aquatic macrophytes. The former situation is undesirable because it results in reduced aquatic habitat diversity, while the latter condition is a nuisance to human use.

Reservoir simulation studies for maximum demand (2040) conditions showed water surface elevations below 826 MSL occurred only infrequently (during the critical drought period). Considering April-July spawning periods, water surface elevations were stable within 2 feet in 15 of 20 years simulated, and changes of more than 3 feet occured only twice. Under 2040 conditions this route of impact is unlikely to be significant.

More frequent releases to Lake Waco during less than maximum demand conditions will result in somewhat more frequent and extensive drawdowns. However, extensive spring drawdowns are not expected under this operating condition either, because of the large water availability at that season. Consequently, we do not expect significant adverse impacts to biotic communities during less than maximum demand operation.

Changes in tailwater discharge patterns (see Section 4.4.3) will result in a reduction in the total inundated channel area, with most of this loss occuring in riffles, runs and shallow water habitats at the upper ends of pools. Substantial effects to the lotic environment will not extend below Clifton because of inflow from tributaries and aquifer outcrops. Downstream effects due to low flows will be most pronounced under maximum demand conditions. While Lake Bosque is operated to stabilize Lake Waco, large releases (about 1,000 cfs) will be made periodically in response to requests from the City of Waco. To ameliorate the potential effects of sudden changes in flow, particularly stranding during cessation of the release, a stepped discharge protocol will be employed (see Section 5.1).

Riffles occupy about 10% of the channel length (and a smaller proportion of channel area) between the dam site and Clifton. Aerial photography flown in September, 1984, after several months of zero discharge shows about half the stream bed occupied by permanent pools in the lower half of the reservoir reach and downstream to Meridian. Observations at Comanche Crossing (Station 1 in the Ecology Baseline Survey), between the proposed dam site and Meridian, indicate that substantial inundation of shallow channel reaches occurs when pools are filled. Flows of 2 cfs, or less, will inundate significantly more of these shallow areas, covering about 70-80% of the area wetted at median discharge.

In a pool dominated system such as this, inhabited by species that typically do not require flowing water for survival, it does not appear that reduced riffle habitat will be a substantial adverse effect. Obligate riffle species are largely absent from the North Bosque River, probably because of a combination of stress from low flow episodes and water quality conditions. While riffles have been identified as a source of prey items for fish, food limitation seems an unlikely circumstance for a river showing as much evidence of enrichment as this one.

It is most likely that long term carrying capacity for fish populations in the present North Bosque system is determined by the periodic occurence of low flow episodes. During very low flow summer conditions juveniles and all stages of forage fish can be exposed to intense predation if they are confined to the permanent pools where there is little cover and the water becomes clear as suspended materials settle out and nutrients are depleted and not replenished by inflows. Constant maintenence of some some shallow water non-riffle habitat, particularly during the summer, is probably far more important for resident fish populations than is the provision of flows high enough to inundate substantial riffle areas.

The attenuation of flood peaks resulting from the presence of the dam and reservoir has potential adverse consequences in that periodic flood flows are necessary to remove sands and silts deposited by minor runoff events, or sloughed from the banks, and to prevent invasion of the channel by terrestrial vegetation. Flows sufficient to scour the channel appear to be those in excess of 1,000 cfs which presently recurr more often than once per year. This flow will result in average current velocities of 3-5 feet per second and general mobilization of particles of one to three inches in size into the bed load. Flows of this magnitude are expected to occur at an interval of once in one to two years at the dam site under maximum demand conditions. Flows originating below the impounded part of the basin will substantially augment this scour regime.

Under less than maximum demand conditions, total annual flows will be similar to the present condition but low flow episodes will be periodically interuppted by large (ca. 1,000 cfs) releases to Lake Waco. No adverse impacts from lack of scouring events is expected to result from the proposed project.

Water quality changes as a result of impoundment include those that can be beneficial to downstream environments (reduction of suspended solids, nutrients and fecal coliforms), and those that tend to have adverse effects (release of hypolimnitic water depleted in dissolved oxygen and changes in seasonal temperature regimes). Discharge of relatively clear, low nutrient water will tend to reduce filamentous algal growth and substrate siltation in the tailwater reach possibly extending downstream as far as Clifton. This would tend to have the beneficial effect of altering shallow habitat areas to be more like those characteristic of the tributary streams, such as the East Bosque, and providing somne additional habitat diversity.

Discharge of water low in dissolved oxygen and, even more importantly, disruption of seasonal temperature patterns are widely recognized as having potentially adverse effects on macroinvertebrate and warm water fish assemblages. Avoidance of such impacts can be accomplished with appropriate operational protocols utilizing a multilevel withdrawl and outlet structure (Section 5.1).

4.5.1.4 Effects on Important Species and Habitats

No aquatic species, listed as endangered or threatened by either the State of Texas or the U.S. Fish and Wildlife Service, is known or is likely to occur in either the Lake Bosque site or in the downstream reach. No other important species (Section 3.5.2) are known that will suffer substantial adverse impact as a result of construction and operation of the Lake Bosque Project.

Habitats in the North Bosque River appear to be similar and widely distributed throughout the reach studied. Adverse impacts to unique habitats or communities is considered unlikely to occur as a result of reservoir construction or operation.

4.5.2 Vegetation

4.5.2.1 Effects of No Action

The no action alternative will eliminate both adverse and beneficial effects of construction and operation related to the proposed Lake Bosque project. The future status of the terrestrial flora of the project site will continue to be strongly affected by regional agricultural economics and management practices. Changes in these practices are not presently predictable. For example, during the interval 1958-1987 pasture and haylands increased from 396 to 50,855 acres in Bosque County, primarily at the expense of cropland. At the same time the "Otherland" use category (including public, recreation, wildlife, water, urban, and transportation route lands) increased from 30,450 to 46,165 acres.

Maintenance of current agricultural practices in the vicinity of the proposed reservoir site will probably result in the continued loss of species and habitat diversity through additional clearing of brush and woodland, planting and management for hybrid pasture grasses, and overgrazing in areas dominated by native vegetation. Substantial loss in habitat value can occur in the bottomland woodland map unit (TCA, 1985) as a result of continued conversion to cropland and improved pasture. Woodland areas amounting to at least half the 799.8 acres contained within the proposed conservation pool are probably at risk. These areas are scattered throughout the reservoir site along the North Bosque and its tributaries where the woodlands are more than just narrow, riparian strips.

The U.S. Fish and Wildlife Service has estimated the value of habitats in the project area using their Habitat Evaluation Procedure (HEP). The following is a simplified outline of the procedure, for a complete explanation of the HEP, see USFWS, 1980.

1) Select important, representative species for which habitat suitabilitiy models are available;

2) collect site-specific data on each habitat type of concern;

3) use field data and species model to estimate the average value of each habitat type for that particular species: the result is a number, the Habitat Suitability Index (HSI), having a range between 0.0 and 1.0;

4) determine the acreage of each habitat type;

5) calculate Habitat Units (HU) for each selected species as the product of habitat acreage and the HSI for that species;

6) if it is assumed that either acreages or HSI's will change over time, Average Annual Habitat Units (AAHU) are calculated by averaging HU's for each year over the period of concern.

This outcome of this procedure is sensitive to the number and identity of representative species used and how sample sites are selected within a habitat type, together with the methods used and effort expended in measuring habitat parameters. In addition, the assumptions made in preparing a particular analysis may strongly affect its outcome. For example, the U.S. Fish and Wildlife Service analysis of the Lake Bosque site assumes that both acreages and HSI's will remain the same for all habitat types during the life of the project (1990-2040) if the reservoir is not built. AAHU's for the various habitat types change considerably if different assumptions about land future land use is used.

For these reasons we regard the habitat values in Habitat Units (HU), presented in Table 4-4 as providing a general assessment which is open to interpretation based on regional environmental conditions and on data collected during the Baseline Ecology Survey of the reservoir site. Although we do not believe these HEP results to be biologically or statistically definitive, for the present purpose, the U.S. Fish and Wildlife Service analysis appears to provide values for the important habitat types (bottomland and upland deciduous woodland) that are unlikely to be substantially improved by additional analysis.

4.5.2.2 Construction Effects

Construction of Lake Bosque will result in the direct loss of approximately 192 acres of terrestrial vegetation through construction of the dam, spillway, and related facilities (Table 3-3). Reservoir maintainence at the conservation pool level (830 MSL) will inundate an additional 4564 acres of existing vegetation. The majority of this 4765 acres consists of cropland (22%), native grassland (32%), and improved pasture (20%). Riparian and bottomland woodlands account for 17% of the affected vegetation and less than 8% is upland woodland. Vegetation between the conservation pool elevation and the level of the 100 year flood (841.3 MSL) is not expected to be substantially affected because of the very short duration (<1 week) of flood inundation above 830 MSL. Floodwaters will be rapidly drained from the reservoir following an inflow event by the 250 foot wide uncontrolled service spillway.

The most extensive and economically important vegetational units on the site are native grassland, improved pasture, and cropland. The loss of these areas will not constitute an economically significant impact considering the approximately 500,000 acres of these habitats in Bosque

Table 4-4 Summary of U.S. Fish and Wildlife Service HEP Analysis of Major Habitat Types on the Proposed Lake Bosque Site

Species/Habitat	Area (acres)	HSI	HU
Dove/NP	2,277.00	0.84	1912.68
Dove/IP	1,247.00	0.51	635.97
Dove/CR	1,180.00	0.78	920.40
Kestrel/NP	2,277.00	0.87	1980.99
Kestrel/IP	1,247.00	0.85	1059.95
Kestrel/CR	1,180.00	0.49	578.20
S-T Flycatcher/NP	2,277.00	0.98	2231.46
S-T Flycatcher/IP	1,247.00	0.74	922.78
S-T Flycatcher/CR	1,180.00	0.78	920.40
B-C Chickadee/DF	202.00	0.81	163.62
B-C Chickadee/DFW	899.00	0.82	737.18
Barred Owl/DF	202.00	0.77	155.54
Barred Owl/DFW	899.00	0.89	800.11
Raccoon/DFW	899.00	0.94	845.06
Fox Squirrel/DF	202.00	0.68	137.36
Fox Squirrel/DFW	899.00	0.8	719.20
W-T Deer/CR	1,180.00	0.12	141.60
W-T Deer/DF	202.00	0.37	74.74
W-T Deer/DFW	899.00	0.5	449.50
Cottontail/NP	2,277.00	0.45	1024.65
Cottontail/IP	1,247.00	0.03	37.41

Note: Area assessed includes dam, spillway and lake area up to 100 year flood pool.
NP = native (unimproved) pasture
IP = improved pasture
CR = cropland
DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
Dove = mourning dove
Kestrel = American Kestrel
S-T = Flycatcher = scissor-tail flycatcher
B-C = Chickadee = black-capped chickadee (Parus atricapillus)
Cottontail = eastern cottontail

Source: U.S. Fish and Wildlife Service

County. The native grasslands tend to be overgrazed, except in the extreme northeast section of the project area, as evidenced be the abundance of numerous plant species indicative of wastelands and disturbed areas. Improved pastures, on the other hand, are reseeded on a regular basis or maintained with desirable forage species. Row crops occupy the majority of the cropland habitat and are almost entirely limited to the bottomlands since the valley slopes and uplands are unsuited to this land use.

While open plant communities may be adequate or even excellent habitat for a number of wildlife species (e.g. mourning dove, American kestrel, etc.), they tend to be impoverished in terms of native plant species. Projected losses of cropland and improved pasture habitats can be expected to result in insignificant losses to native plant populations while native pasture losses will tend to be limited to local increasers and weedy species. Bosque County presently contains about 142,000 acres of cropland and over 450,000 acres of native and improved pasture. Historical data indicates that changes in agricultural practice probably have a more pronounced effect on plant species diversity than will the inundation of 3589 acres of cropland and pastureland.

A large proportion (75%) of the habitat value in Table 4-4 is accounted for by crop, pasture and grazing land which may or may not be overvalued by that analysis, but is certainly very common in Bosque County and in Central Texas generally. We do not believe that removal of these areas will result in any significant impacts to important vegetational communities or species, or to wildlife populations dependant on those habitat types.

In terms of species density, diversity, and locally adapted species assemblages, the most significant habitat impacted is bottomland woodland. Although the project site (up to 830 MSL) only contains 799.8 acres of this habitat type (including 6.9 acres of pecan cropland), the loss through inundation will be substantial when considering the large scale reduction in bottomland forest that has occurred throughout Texas. This area also contains 109.73 acres of upland decidous forest which has also been substantially reduced in Central Texas by agricultural practices and which is regarded as important wildlife habitat.

Table 4-5 presents AAHU's for the with and without project alternatives as estimated by U.S. Fish and Wildlife Service for the two decidous forest habitats on the reservoir site. Net habitat loss is shown as the difference between the with and without project columns. Also included is a column showing net change calculated on the assumption that either acreage or HSI's will decline by 25% over the life of the project. Based on past trends and agricultural practices, and the fact that most of the bottomland forest habitat is located on prime farming soils, we believe that this scenario is conservative and at least as likely as the assumption of no change.

Site preparation and construction is not expected to produce any substantial impacts to vegetation outside of the construction site, borrow areas and haul roads (about 430 acres, all of which are included in the conservation pool). Dust, or materials such as oil and grease found in run-off from haul roads, is not anticipated to have any detectable effects on terrestrial vegetation.

4.5.2.3 Operation Effects

Long-term operation effects of Lake Bosque are not anticipated to have much effect on terrestrial vegetation where inundation is not complete. Little or no change due

Table 4-5 Habitat Values in Average Annual Habitat Units (AAHU) and Net Change for Deciduous Forest Portions of the Lake Bosque Site With and Without the Proposed Project

Species/Habitat	AAHU Without	AAHU With	AAHU Net	AAHU Net (25%)
B-C Chickadee/DF	163.62	79.87	-83.75	-71.5
B-C Chickadee/DFW	737.18	125.94	-611.24	-526.8
Barred Owl/DF	155.54	75.92	-79.62	-68.0
Barred Owl/DFW	800.11	136.69	-663.42	-572.2
Raccoon/DFW	845.06	144.37	-700.69	-604.6
Fox Squirrel/DF	137.36	67.05	-70.31	-60.1
Fox Squirrel/DFW	719.20	122.86	-596.34	-513.8
W-T Deer/DF	74.74	36.48	-38.26	-32.7
W-T Deer/DFW	449.50	76.79	-372.71	-319.3
Total	4,082.31	865.97	-3,216.34	-2,769.0

DF = (upland) decidous forest
DFW = decidous forested wetlands (bottomland forest)
B-C = Chickadee = black-capped chickadee (Parus atricapillus)

Source: U.S. Fish and Wildlife Service, Paul Price Associates, Inc.

to flooding of vegetation above the conservation pool (830.0 foot contour) is projected since periods of inundation are not expected to be of significant frequency or duration. Reservoir operation studies indicate only two periods of inundation above 831 MSL lasting more than five days over the 20 year simulation period. Terrestrial habitat values in this zone will therefore be retained to a substantial extent, depending on the mix of affected cover types and the management practices applied.

The majority of the area disturbed during construction of the dam and spillway will be reseeded, providing habitat similar to the improved pastures presently found in the project area.

Below the dam, the riparian streambed and woody vegetation along the margins of the river may be subjected to less pronounced fluctuations in streamflow, although high flows sufficient to scour the channel will continue to occur. This should result in more stable stream edge plant communities. Lowland species such as box elder, green ash, and pecan will be expected to produce moderately well since spills from the reservoir and lateral inflows from tributaries and the valley alluvium will continue to maintain a high water table. These trees, and others present in existing riparian woodland strips, are known to have high transpiration rates and require ample and dependable moisture supplies. They are not, however, dependent on annual inundations by the Bosque River as evidenced by the current 2-5 year return interval for flooding of riparian soils. Thus, flora associated with downstream woody habitats should remain essentially unaffected.

4.5.2.4 Effects on Important Species and Habitats

At present, no federally listed endangered or threatened plant species are known to occur in the Lake Bosque project area. Therefore, the construction and operation of the lake will not adversely affect any of these important species.

Of the habitats present in the project area, riparian and bottomland woodlands are considered the most productive in terms of both diversity and density of plant species. Since the majority of the bottomlands in this area have already been cleared for agricultural purposes, the remaining acreage should be considered of high value.

4.5.3 Wildlife

4.5.3.1 Effects of No Action

The no action alternative will prevent both the adverse and beneficial impacts of construction and operation related to the proposed Lake Bosque project. In the absence of the project, the area will probably remain largely in its present state with livestock grazing and farming being the predominant activities affecting wildlife. Wildlife utilization of the proposed site will reflect the changes or lack thereof, in plant communities on the site due to land use practices during the period 1990-2040.

4.5.3.2 Construction Effects

Construction of the dam, spillway and associated facilities will result in the removal of about 192 acres of existing wildlife habitat. Filling of the lake after dam construction will result in the inundation of about 4564 acres at conservation pool elevation (830 feet, MSL). As is typical of the entire project area, most (75%) of the affected habitat is open herbland including improved pasture, cropland, and native pasture. As such, it is already greatly affected by human disturbance. However, certain wildlife species do well in these habitats, with native pasture generally being of greater wildlife value than improved pasture and cropland. It is important to note, however, that these habitat types are abundant and that the populations of species typical of such areas will not be significantly altered when considered on a countywide or regional basis.

As a result of construction activities in the area of the dam, spillway, and borrow areas (522 acres), resident wildlife will be destroyed or displaced from the area depending on the mobility of individual species involved. It is commonly understood that organisms most likely to be killed directly by such activities include species of amphibians, reptiles, and small mammals. If construction occurs during the breeding season, nestling and fledgling birds will also be affected to the extent that those areas are utilitized for reproductive activities. During the process of lake filling, more species should be able to disperse from the site. However, if periods of rapid filling occur there may still be some direct mortality.

The fate of individual animals that escape direct injury is less commonly understood. The concept of carrying capacity is well established in wildlife population ecology and is important in considering the future of displaced individuals. Carrying capacity is a fluctuating level (within limits) of population density that can be supported by a given habitat (Gills 1971, Dempster 1975). As the population of a wildlife species (for example, white-tailed deer) increases and approaches local carrying capacity, a number of population control factors increase in their effect. Food and other resource shortages can result from overcrowding, in turn increasing competitive stresses, resulting in both direct and indirect reductions in fecundity and increases mortality (Dempster 1975). Absorption of displaced individuals into surrounding habitats will depend on the condition of those habitats and on the conspecific population densities already resident there (i.e., the local carrying capacity and how closely it is already approached). While survival of refugee individuals may be a function of local conditions and recent historical circumstances, we can expect no change in the long-term average population sizes in surrounding areas unless carrying capacity is altered by environmental changes. This means that over the long term we should regard the removal of a portion of the species habitat (in this case that affected by construction of the lake) as removing that part of the population resident in the affected area.

4.5.3.3 Operation Effects

Wildlife impacts from the operation of Lake Bosque will be primarily positive over the long term. The presence of the lake will provide aquatic and some riparian (lake littoral) habitat which will be of high value to species such as wintering and migratory waterfowl, fish-eating birds, aquatic- associated reptiles and amphibians, and other similar aquatic species.

Over the long term, vegetational succession in the vicinity of the shoreline can, if properly managed, produce riparian communities of increasing wildlife value as woody species develop and various aspects of habitat diversity are increased. These include food and cover availability and diversity, foliage height (structural) diversity, and a broader range of microclimates as more mesic conditions prevail. This will have the effect of increasing the carrying capacity of terrestrial environments adjacent to the lakeshore for some of the species adversely affected by reservoir construction. Additional beneficial changes could be realized through implementation of appropriate land use and management practices in selected areas.

The potential downstream changes that might occur as a result of stream-flow alterations are not considered significant. If vegetational communities are affected by reduced peak flows downstream, then wildlife inhabiting those areas will also be indirectly affected. However, inundation frequency for existing riparian woodlands is presently 2-5 years so there is little reason to expect major shifts in dominant vegetation in downstream areas and wildlife inhabiting those areas should be relatively unaffected.

Barclay (1980) under contract with UFSWS can come to no definite conclusions with regard to the downstream effects of impoundment in south-central Oklahoma. He hypothesized that impoundment might indirectly simplify downstream terrestrial riparian systems but the data for birds showed that "...reduction of stream fluctuation downstream from the reservoirs had little detectable effect on the avian communities studied." He also states that his reptile and amphibian survey did "...not provide any clear evidence of impoundment effects." Mammal sampling was similarly inconclusive.

4.5.3.4 Effects on Important Species and Habitats

No federally listed endangered or threatened species are expected to be adversely affected by either construction or operation of the proposed Lake Bosque project, since none are known, or are likely, to inhabit the area at present.

One species, the bald eagle, is likely to be favorably affected by the substantial increase in its preferred wintering habitat. The bald eagle winters at various reservoirs throughout Texas, and it is not unlikely that they will utilize Lake Bosque for feeding and resting.

Of the state listed species, the Texas horned lizard has been observed in the immediate vicinity of Lake Bosque. If members of this species are present in construction or borrow areas, or within the conservation pool, individuals could be lost.

Adverse impacts will occur with regard to all terrestrial game and furbearing species that currently inhabit the project site due to inundation of currently occupied habitat. However, these impacts are not of great significance when viewed on a countywide or regional basis. For example, based on game population indices, comparisons between the Lake Bosque site and the Cross Timbers and Prairies Ecological Region indicate that game populations in the project area are typical or somewhat low for the region. Habitat Evaluation Procedure results (Table 4-2) showed that even the bottomlands (generally the best deer habitat) had a habitat suitability index (HSI) for white-tailed deer of only 0.50. Bottomland HSI values for two smaller species, the fox squirrel and northern raccoon, were better (between 0.80 and 0.94) but the requirements for these species are typically in ample supply in any older bottomland forest with water.

Conclusions of the baseline studies indicated that open habitat game species such as mourning dove and bobwhite are similar in abundance in the project area and in the region in general. This was supported by the HEP data (USFWS 1985) for the mourning dove which shows relatively high HSI's for two of the three open cover types.

In terms of value per acre, the most significant and valuable habitats of the project area are bottomland and riparian woodlands. These cover types are considered by wildlife biologists to be of particular concern due to the statewide trend of reduction and because of their overall higher wildlife diversity and production. Thus, even though the bottomlands of the project area have been mostly cleared due to agriculture, the remaining acreages are considered to have high value.

4.6 Socioeconomics and Land Use

4.6.1 Effects of No Action

4.6.1.1 Population

During the 1960s and 1970s the two county study area grew at rates lower than did the State as a whole. If the proposed reservoir is not built, growth in the area is expected to continue at a slower rate of increase than during the 1970s. Even without additional growth, communities relying on groundwater as the sole source of supply (all the project participating entities except the City of Waco), will in the next 10 to 30 years begin experiencing severe water quality supply problems, which could restrict local population growth. If these entities grow at the rate projected by the TWDB (either the high or the low series) an additional source of water will be necessary in even less time. All the other known alternatives now cost more than the Lake Bosque Project and future costs are likely to increase beyond present estimates.

Restricted population growth due to lack of water will discourage young people from remaining in the area or migrating to the two counties. The evential result, particularly in Bosque County, will be low population growth characterized by an increasing proportion of elderly people.

4.6.1.2 Local Economy

The effect of no action upon the local economy of areas depending on ground water will be extensive. The local economy will continue as it has during the last 20 years until overdrafting of the Trinity Aquifer curtails water supplies and restricts development. Continued growth or even water use at present levels will require the development of additional water sources. Future manufacturing growth will require a source of water more reliable and ample than available through ground water.

In 1980, 56% of all Bosque County families were in the two lowest (out of 5 possible) income brackets while the State average was 40%. Without economic growth this trend can be expected to continue and possibly become even more extreme. Income levels in McLennan County are not too different from the state average. However, without continued population and economic growth, these income levels may decline.

4.6.1.3 Community Facilities and Services

The tax base for education in the two county area will remain unchanged if the proposed reservoir is not built. Restricted population growth caused by water shortages will decrease the number of children in the area. Required investments in the education system will decrease as the number of children declined. However, it is possible that as the number of people in the area declines, the rate of taxation required to maintain a minimum level of service could increase.

Fire protection in the study area will decline as overdrafting of the Trinity Aquifer continues. Effective fire-fighting necessitates a reliable high pressure water system.

4.6.1.4 Public Finance

As discussed in the previous sections the effect of no action upon project participants and Bosque and McLennan Counties' population and economy would likely cause area growth trends to decline and even stagnate. If this were to occur it is possible that tax rates would increase in order to continue providing the minimum level of required public services.

4.6.1.5 Recreation and Aesthetics

Public access to water for recreation purposes is extremely limited in the vicinity of the proposed reservoir. There are no public access points to the Bosque River in the vicinity of the proposed site. There is no reason to believe that this condition will change if the proposed reservoir is not built.

Local views will probably continue to consist of a pastoral valley landscape dominated by strong horizontals and inhabited by plants and animals typical of Central Texas.

4.6.1.6 Land Use

Insufficient water supplies could restrict urban development, specifically, development growth in existing communities relying solely on ground water.

4.6.2 Construction Effects

4.6.2.1 Population

HDR Infrastructure, Inc., consulting engineer for the owner, has estimated construction time for the proposed Lake Bosque at about two years. Because of the project's short construction time and proximity to the labor force of the Dallas-Fort Worth area and other surrounding communities, it is unlikely that a significant number of project workers will migrate to the area. It is more likely that workers will commute to the proposed project site as it is not uncommon for construction workers to average 50 miles one way in daily commuting. Therefore, substantial impact to housing availability, infrastructure, public safety, health services and schools is not anticipated from this source.

4.6.2.2 Local Economy

It is estimated that construction of the proposed project will provide approximately 145 temporary jobs, of which about 12% (18 jobs) would occur during the pre-construction stage and 88% (116 jobs) would occur in the construction phase. Peak employment of approximately 79 jobs would occur during the early phase of construction, employment for any one construction phase would range from 4 to 60 jobs.

Direct economic impacts of constructing the proposed reservoir would be limited by the project's relatively small construction crew and short construction time. Direct employment benefits (i.e., job creation) would be determined by the location of the contractor responsible for constructiong the dam. Undoubtedly, a small proportion of semi-skilled and unskilled jobs would be filled locally, but the majority of supervisory and highly-skilled positions (the best paying jobs) would be filled from within the contracting company's area of employment.

The presence of additional workers in the local area would be expected to generate a temporary demand for local acquisition of miscellaneous goods and services, i.e., food and beverages, gas, etc.

4.6.2.3 Community Facilities and Services

If Lake Bosque is built, Walnut Springs, Iredell and Meridian Independent School Districts (ISDs) would lose a small portion of their tax base. The percent of net ISD taxes accrued from lands affected by the proposed Lake Bosque site ranges from 2.40% to 3.86% of each ISD's tax revenue assuming that tax revenue reduction would be equal to reduction in the area of the tax base. We believe this to be a reasonable approximation because of the countervailing effects of higher bottomland values versus the usual location of improvements above the area affected by the reservoir. The existing tax rate for each school district ranges from 40% to 55% of the maximum $1.50 per $100 valuation tax rate and could be increased if needed. However, increases in property value associated with recreational and residential use of lands near Lake Bosque are expected to offset these losses.

Construction of the proposed reservoir would affect only 11 single family homes and a number of other structures largely related to farming activities. The market value of homes definitely located within the 100 year flood elevation ranges from $27,190 to $84,460.

As proposed, reservoir construction would require the relocation of small sections of county and state roadways, as well as abandonment of several county roads which cross the proposed site. Several powerlines would also be relocated. Construction generated traffic would not adversely affect major roads accessing the site because traffic counts for these roads are relatively low.

4.6.2.4 Public Finance

Approximately 54 landowners owning 13,629 acres will be affected to some extent by the proposed Lake Bosque. In some cases all of a particular land parcel will be inundated; in other cases, only a portion of the parcel. Eleven homes and 6,143.26 acres of the 13,251 acres will be included in the proposed Lake Bosque up to the 100 year flood elevation (841.3 feet, MSL).

Total 1985 property assessments for Bosque County stood at $385,630,342. The proposed project will remove about 4756 acres from the county tax roles, assuming that only flood easements will be obtained for land above the conservation pool elevation. The property removed from the tax roles by the construction of the proposed reservoir will be about 35% of the 13,629 acres partially affected by the project. The 1985 assessed property valuation of the 13,629 acres was $2,827,655, thirty-five percent of which would be $989,679, or 0.26% of the county's tax base. This could be offset by increases in property values and sales tax revenues resulting from residential and recreational development associated with Lake Bosque.

Municipal tax bases will not be affected by construction of the project as the site does not lie within the boundaries of a municipal jurisdiction. However, to finance the project, tax or water rates in the participating municipalities are expected to rise.

4.6.2.5 Recreation and Aesthetics

Recreational opportunities in the vicinity of the proposed Lake Bosque are severely restricted by the private ownership of everything except county roads and the stream bed. Construction activities are not expected to have significant adverse effects on local recreation since there is no public access to the dam and borrow areas. The approximately 500 acres included in these areas might support two to six deer leases if it were fully utilized. There is no public access to the Bosque River in the vicinity of the dam site.

Adverse effects of construction on local aesthetics will be temporary. Visual and audial disturbances will occur from construction machinery and workers. The dam is about seven miles from the nearest community and there are about 20 houses within a three mile radius. Because of the small number of people in the immediate vicinity, impacts on aesthetics from dam construction are expected to be slight.

The site would be transformed from a pastoral valley landscape into a 4,564 surface acre lake encompassed by gently sloping, flat-topped hills with local relief of about 200 feet. Thus, the waters of Lake Bosque, varying in color and textural quality with the seasonal and climatic extremes of the region and supporting an otherwise restricted aquatic community, will have a beneficial impact on local viewsheds and constitute an aesthetic amenity.

4.6.2.6 Land Use

Construction of the proposed Lake Bosque will change 4,756 acres of privately owned agricultural land into public water supply and recreation land. The Brazos River Authority will also obtain flood easement on an additional 1,387 acres up to the 100 year flood elevation that would be inundated occasionally.

The 4,756 acres to be occupied by the dam and spillways and the conservation pool account for about 0.8% of the county's 595,172 acres of cropland, pastureland, hayland and rangeland. This includes a rough estimate of about 3,000 acres of prime farming land, approximately 1.5% of the county total. Fifty-four landowners owning 13,351 acres would be affected to varying degrees. Eleven homes and 6,143.26 acres (45%) of the 13,251 acres would be impacted by the proposed Lake Bosque's conservation pool and 100-year floodplain.

4.6.3 Operation Effects

4.6.3.1 Population

Dam operation will require one or two full time employees living at or near the site. Some additional employment will result from recreational and residential development stimulated by the reservoir. However, these jobs would most likely be filled from the local area and therefore result in an insignificant impact upon the area's population.

Developed recreation areas would be expected to attract new visitors to the area, but no parks or other facilities are presently known to be planned. It is expected that such facilities would be developed by private interests or local governments in response to the demand identified in the 1985 Texas Outdoor Recreation Plan (TORP).

Residential development and consequent population growth in response to reservoir construction depends on several site specific factors including: availability of waterfront property, proximity to established population centers, access, aesthetics and the presence of recreational or other entertainment opportunities. Lake Bosque will have privately owned waterfront and view property and is within an hour's drive, about 50 miles, of the Waco metropolitan area.

Lake Granbury, located on the Brazos River about 35 miles southwest of Fort Worth, is an example of a reservoir in close proximity to an urban area with available, private waterfront property. Since construction in 1969, about 140 residential developments have been built on the 30 miles of lakeshore nearest the City of Granbury. These developments include approximately 31,078 lots, 3,672 single family homes and 3,494 mobile homes (PPC, 1984). Realtors in the Granbury area report that the current population mix is evenly distrubuted among seasonal residents, retired couples, commuters, and those who are locally employed.

Lakes O. C. Fisher and Proctor are both located in Central Texas, and are similar in size and location to the proposed Lake Bosque. However, these lakes were built by the U. S. Army Corps of Engineers and do not have private waterfront acreage available for purchase and development. Area realtors report only minor residential development of view lots near these lakes.

Because Lake Bosque is located relatively near Waco (1980 population was 101,261), will have property available for purchase and will have reasonably good access by SH 6, its development potential must be considered moderate to high. This potential may be limited to some extent by building restrictions below the 100 year flood elevation and by the relatively large, frequent changes in water surface elevation likely to be experienced during reservoir operation at less than maximum demand conditions. Waterfront property will presumably become more attractive for development as system demand increases and Lake Bosque surface elevation becomes more stable.

4.6.3.2 Local Economy

Following completion of construction, operation of the reservoir would require a work force of one or two people. These individuals would be responsible for reservoir operation and maintenance and would live near the site. The presence of these individuals and their familiies will generate an insignificant demand for local goods and services and possibly require the purchase or construction of a permanent residence.

The major effect on the local economy will result from expenditures associated with recreational activities. In 1986, yearly visits to Lakes O. C. Fisher and Proctor totaled 552,732 and 983,170, respectively. The higher the percentage of nonlocal visitors to Lake Bosque, the greater the economic impact on the local area economy. Potentially, the economic impact of these visitors could be great.

4.6.3.3 Facilities and Services

Operation of the proposed reservoir would require that at least one or two employees live near the site. From this source, impact on the area's education system, public safety, health services and facilities, transporation system and local housing would be negligible. Depending on the number of nonlocal visitors drawn to the lake for recreation purposes and on possible population increases due to residential development, impacts on public safety, health services and facilities, and transportation could be significant. Bosque County is relatively well equipped to handle an influx of visitors and permanent residents, as the county has a surplus of medical personnel, two hospitals and well maintained roads with low traffic volumes. The only potential inadequacies could result from the relatively small police and fire-fighting force and from the presently low availability of rental housing and temporary lodging.

Increases in land value resulting from recreational and residential development over the life of the project are expected to offset losses in ISD tax bases caused by construction of the proposed reservoir. At least as much land as is removed by the reservoir will either have views of the proposed lake or else direct access to water, making the property potentially suitable for land uses other than agriculture.

Operation of the proposed Lake Bosque will significantly enhance the amount of available water supplies in the area. Currently, project participating municipalities, except the City of Waco, rely solely on ground water supplies. Operation of Lake Bosque will help end overdrafting of the Trinity Aquifers and insure the availability of a secure water source.

4.6.3.4 Public Finance

Reservoir construction and operation will remove about 0.26% of the county's tax base and not impact municiapal tax bases. As discussed with regard to school taxes, land values near the proposed site could increase and offset the initial reduction of the county's tax base. A secure water supply will insure that ample water is available for future population expansion and area development.

Property values near the proposed Lake Bosque site are not expected to be be adversely impacted by operation of the lake. On the contrary, land values could increase significantly in response to residential and recreational demand. Realtors experienced in reservoir associated development indicate that land up to three miles distance from a lake shore, if suitable views are available, can be marketed as water oriented, or recreational, property.

Lakeview property within one to three miles of Lakes Proctor and O.C. Fisher reportedly range in price from $9,000 to $11,000 per acre for small, relatively undeveloped acreages, to $50,000 for developed residential lots. Realtors report prices for developed residential property at Lake Granbury ranging from $40,000 to $600,000, with mobile homes and lake view sited homes occupying the lower range and single family waterfront homes accounting for the higher price range. Residential development adjacent to the proposed Lake Bosque will most likely result in development intensities and property values that fall within the range observed at Lakes Proctor, O.C. Fisher and Granbury.

4.6.3.5 Recreation and Aesthetics

The proposed site is situated on private land and is not open for public use. Operation of the reservoir will displace possibly 20 deer leases within the conservation pool. Water oriented recreation in the vicinity of the Lake Bosque site is currently available only to individuals with access to private lands bordering the North Bosque River. Since the Brazos River Authority will provide two public access points to Lake Bosque, and since the lake will be suitable for a much wider range of activities and will accommodate many more people than the river (4500 acres of reservoir vs 160 acres of stream bed), the net effect on recreational opportunities is expected to be beneficial.

Although Lake Bosque is located near major population centers (Waco and the Dallas Fort Worth area) over 50,000 surface acres in Lakes Whitney, Waco, Aquilla, Limestone and other popular recreation lakes are present in the Texas Outdoor Recreation Plan Region 11. While total lake acreage and boat launching facilities are considered adequate in Region 11, lake access is not, particularly on a local basis, and provision for enhanced access is a listed priority in the recreation plan.

Visitation records from existing reservoirs indicate that if recreational amenities are available, visitations in the range of 500.000 to 1,000,000 per year could occur at Lake Bosque. Although many, if not most of these visitors will be local residents, this level of activity is expected to generate a strong demand for miscellaneous goods and services (food and beverages, gas, camping equipment, recreation equipment, boat equipment, hotel acommodations, etc.), as well as increased demand for health and public safety services.

Factors influencing the visitor count to Lake Bosque will include proximity to a major population center, convenience of access and the availability of recreational facilities. No recreational facilities are known to be planned at this time but it is anticipated that private interests will construct some of the types of recreational facilities needed at Lake Bosque. Meridian State Park does provide camping facilities and is located within 10 miles of the site.

4.6.3.6 Land Use

Operation of the proposed Lake Bosque will result in conversion of some existing agricultural lands in the vicinity of the reservoir to recreational, residential and commercial uses. The extent to which this is likely to occur and the major factors influencing the outcome have been discussed in preceeding sections. Land within three miles of the lakeshore is most likely to be affected. The extent to which recreational facilities are provided, either by public or private interests, will have an effect on the rapidity and degree to which such changes take place.

4.7 Cultural Resources

4.7.1 Effects of No Action

In the absence of Lake Bosque, archaeological sites in the vicinity of the proposed reservoir will continue to be adversely affected by climatic forces and soil processes such as erosion and solution, bioturbation, and cultural disturbances including development and agricultural activities. Site loss from pot-hunting might be enhanced by location and recording of the 145 sites.

4.7.2 Construction Effects

Table 3-8, reproduced from the Archaeological and Historical Survey (Lone Star Archaeological Services, 1987), summarizes the type and magnitude of potential impacts to be expected on the Lake Bosque site. As a result of construction activities, 15 (seven National Register eligible) sites located in the immediate vicinity of the embankment and borrow areas will be lost by disturbance or deep burial. An additional 57 sites, 29 of which appear to be National Register eligible, will be covered by water within the conservation pool of Lake Bosque. The adverse, neutral or beneficial nature of this effect is dependent on the nature of the site.

Sites located between the conservation elevation (830 feet MSL) and the 100 year flood elevation (841.3 feet MSL) will tend to be exposed to increased erosion from wave action. The magnitude of this effect will vary from a maximum at sites located at 830 feet to vanishingly small at 841.3 feet where 0.5 inundations lasting about one day are expected over the 50 year life of the project. The nature of the site, its geologic and soil context and its orientation will substantially influence the effectiveness of wave induced erosion. Increased public access to this zone could result in increased site disturbance, but its inclusion in a 100 year floodplain will tend to reduce disturbance from construction activities. The 39 sites located above 843.1 feet MSL will not be directly affected by the construction of Lake Bosque.

4.7.3 Operation Effects

Direct effects to archaeological sites, other than those outlined in the preceeding section, are not expected to result from reservoir operation under maximum demand conditions. During less than maximum demand conditions, when releases would be made from Lake Bosque to stabilize Lake Waco, those sites located in the zone of frequent drawdown will be subject to accelerated erosion, slumping and human disturbance as artifacts are exposed on the surface.

Indirectly, enhanced residential and recreational development in the vicinity of the reservoir could lead to increased rates of site disturbance and loss. No effects on cultural resources downstream of the proposed dam site are expected to result from Lake Bosque operation.

5.0 Mitigation Plans

The following proposals address the balance of potential adverse and beneficial impacts resulting from construction and operation of the proposed Lake Bosque. Adverse impacts identified in foregoing sections may be avoided by modification of some aspect of the project; they may be mitigated to reduce the severity of the effect; and they may be compensated for in those cases where substantial impacts cannot be avoided. These types of actions are summarized below in a series of mitigation plans that will be carried out by the Brazos River Authority when the permits necessary for construction and operation of the proposed project have been obtained.

Substantial mitigation has already been accomplished through the generation of site specific data sets and analysis of that data in a regional context during the baseline studies of the Lake Bosque site. The aquatic surveys provide information on habitats, fisheries, and invertebrate assemblages unique in the North Bosque River. Likewise, no other data set for the region exists that is comparable to that for terrestrial communities on the reservoir site. These studies contain both taxonomic and quantitative population information that is considered in the context of regional physical and biotic conditions together with human influences.

The Cultural Resources survey has resulted in the location and description of 145 additional archaeological sites, resulting in a substantial increase in the number of recorded sites in Bosque County. Even in the absence of further study, this additional information is expected to add to our understanding of the lifeways of both aboriginal and European inhabitants of the area.

5.1 Aquatic Communities

I. Avoidance or Mitigation of potentially adverse impacts

A. To avoid violations of Stream Segment Standards downstream of the dam, and associated impacts, a multilevel withdrawl structure will be used to insure that dissolved oxygen concentrations remain above 5.0 mg/l in reservoir releases.

B. The multilevel withdrawl structure will also be used to maintain seasonal temperature patterns in reservoir releases within the normal ranges reported in existing North Bosque River water quality data. Suggested seasonal temperature limits for releases from the dam, based on seven years of monthly temperatures records at a station near Clifton, Texas, are as follows:

Dec-Feb	< 15° C
March	10-20
April	15-25
May-August	22-32
Sept-Oct	15-25
Nov	10-20

II. Measures to compensate for unavoidable adverse impacts

A. When inflows are available (see Table 4-1) during the April-August reproductive period, up to a total of 2.0 cfs will be continously maintained in the channel below the dam. A minimum of 0.5 cfs will be maintained in the channel below the dam at all times regardless of inflows. Fish populations can be maintained at levels reasonably near their present levels by providing a 0.5 cfs low flow augmentation sufficient to maintain pools at their "full" level at all times. The 2.0 cfs flow during April-August will inundate the shallow runs and assure access to creek mouths, which will provide additional space and sheltered habitat for the development of the year's juveniles.

5.2 Terrestrial Communities

Significant avoidance or mitigation of adverse impacts to terrestrial environments beyond that discussed in Section 5.0 is of limited feasibility for this project. A plan to compensate for these unavoidable effects is therefore proposed.

I. Significant, unavoidable impacts to be compensated for

A. As discussed in the preceeding sections, we believe that loss of the deciduous woodland areas of the reservoir site constitutes a significant adverse impact. We further agree with the USFWS that a net decrease in the vicinity of 3,000 Average Annual Habitat Units (Table 4.5) represents a reasonable index of that impact.

B. Although other areas are also to be affected by Lake Bosque, the quality and abundance of these habitat types is such that vegetation and wildlife impacts will be insignificant, even on a local basis. We do not believe that the potential costs of compensating for impacts to pasture and cropland is justified by the wildlife benefits that could be obtained.

II. Proposed Compensation

A. The Brazos River Authority intends to acquire a contiguous tract of land that, with appropriate management over the life of the Lake Bosque project, will produce a net gain in habitat value comparable to the losses described above. In addition, ancillary acreages acquired in the vicinity of the dam for other purposes will be managed appropriately, where possible, to complement the efforts in the main compensation tract.

B. The tract will probably be acquired fee simple and conveyed to an appropriate governmental agency (e.g., Texas Parks and Wildlife Department) for stewardship following any necessary initial management actions. Some other mechanism of acquisition and protection could be used if practical and necessary in a particular circumstance.

C. Several candidate tracts have been examined and two have been evaluated by USFWS personnel. We believe one of these will produce sufficient habitat value (in AAHU) to compensate for the Lake Bosque impacts with the application of an appropriate planting and management plan. Production of sufficient net habitat value on any given tract is understood to be a function of its size, initial condition, potential productivity and required managment inputs.

D. The Brazos River Authority is continuing to examine potential compensation tracts, as they have a responsibility to the project participants to seek an optimum solution. From this standpoint it is desirable to minimize not only land costs but also long term management and commitments to reforestation efforts having significantly uncertain outcomes. Preliminary search criteria for compensation tracts are listed below:

1) Minimum size, 1,000 contiguous acres
2) Soils must be at least occasionally flooded (2-5 years) sandy or silty clay bottomland soils. The local Soil Conservation Service office to be contacted to ascertain if any significant soil impairment is known.
3) The tract should be reasonably accessible for management activities.

4) High quality bottomland hardwood tracts are to be avoided unless they are very large, since potential net change in habitat value would be small.

5) Other factors being equal, tracts closer to Lake Bosque or in the Bosque River basin are preferred.

E. As candidate tracts are identified, HEP evaluations by the U.S. Fish and Wildlife Service and input from Texas Parks and Wildlife Department may be requested as necessary to evaluate acreage requirements and aid in development of appropriate management strategies. Target date for final selection of a compensation tract is by the end of the year.

5.3 Cultural Resources

The Archaeological and Historical Survey Report presents in detail a proposed plan to mitigate or compensate for the impacts of Lake Bosque on area Cultural Resources. Input from concerned state and federal agencies has been sought during the planning process. The specific methods used and the locations investigated will be approved by the appropriate authorities before the study begins.

In summary, this plan involves a standardized, limited sampling program at 34 sites to be affected by dam construction and inundation and at 12 sites within the 100 year flood pool to establish equivalent units. This will provide information on the diversity and relative density of cultural material within and among sites and allow the sites to be compared quantitatively. A subset of these sites will be excavated *in toto*. The results of this effort will provide the data to attempt the synthesis of a comprehensive history of this segment of the North Bosque River Valley.

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BASELINE ECOLOGY REPORT SUPPLEMENT 1:

NORTH BOSQUE RIVER REGIONAL SURVEY

for the

LAKE BOSQUE PROJECT

BOSQUE COUNTY, TEXAS

Prepared for
The Brazos River Authority
Waco, Texas

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September, 1987

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1.0 Introduction

This document is intended to supplement the Lake Bosque Baseline Ecology Report (TCA, 1985) by providing additional regional information about the North Bosque River. It is to be used as background information for evaluating the potential impacts of the Lake Bosque project on the river reach from the proposed dam site to Lake Waco. In particular, Texas Water Commission (TWC) personnel have requested that this report address those factors affecting the human uses of the river.

This supplement is based on observations made on the North Bosque River during a brief survey 16-17 October, 1987, on observations made during numerous visits to the Bosque River, mostly in the vicinity of the proposed reservoir, and on literature reviewed pursuant to this and other environmental studies. Personnel from the U.S. Fish and Wildlife Service (USFWS) have visited Comanche Crossing, on the North Bosque River between Meridian and the proposed dam site, on three occasions (November, 1985; April, 1986; and April, 1987) to collect field data as input for their instream flow analysis and recommendations. The author assisted UFSWS personnel in collecting the survey and hydrological data during all three studies. In April 1987, representatives of the Texas Water Commission (TWC) and Texas Parks and Wildlife Department (TPWD) were also present and assisted survey efforts.

During the October, 1986 survey all public access points between the proposed dam and Lake Waco were visited, limited water quality sampling was performed, and observations were made with regard to channel morphology, substrates, river discharge, aquatic vegetation, invertebrates and human uses of the river. Additional information on the North Bosque River and its surroundings is presented in the Baseline Ecology

Report (TCA, 1985), Baseline Ecology Report Supplement II: Important Species, Baseline Socioeconomic Report (Paul Price Associates, 1987), and Reservoir Operation Studies for Proposed Lake Bosque and Lake Waco Enlargement (HDR Infrastructure Inc.,1987).

2.0 Regional Setting

The Bosque River is a major tributary of the Brazos, which it joins at Waco, Texas. The Bosque is dammed a few miles upstream of its confluence, forming Lake Waco. Above this impoundment, the North , Middle and South Bosque Rivers occupy a 1670 mi^2 drainage basin extending about 90 miles to the northwest (USCE, 1982). The three forks of the Bosque River above the headwaters of Lake Waco constitute TWC Segment 1226 (TDWR, 1980). The North Bosque River is the most extensive portion of this Segment, having a drainage area of about 1290 square miles and occupying portions of McLennan, Bosque, Coryell, Hamilton, Somervell, and Erath counties (Figure 2-1; Procter, 1969).

Basin geology and geomorphology is described in Procter (1969), Baylor Geological Society (1966), and in numerous unpublished Baylor University Master's theses. The lowermost reach of the North Bosque, below Valley Mills, is located in the Washita Prairie physiographic region. This is a rolling prairie exhibiting little relief and a vegetational cover primarily of grasslands with scattered stands of oak. Although the soils of the Washita Prairie are considered reasonably fertile, they are used almost exclusively for grazing. The notable exception is the complex of alluvial soils adjacent to the North Bosque River channel that has been extensively developed as crop and improved pasture and is reported to be among the best agricultural land in McLennan county (SCS, 1958).

From the vicinity of Valley Mills to Iredell, the North Bosque River flows through the Lampasas Cut Plain, a region characterized by broad, level to rolling valleys separated by steep sided, flat topped divides. Local relief is much greater than in the Washita Prairie, with elevation

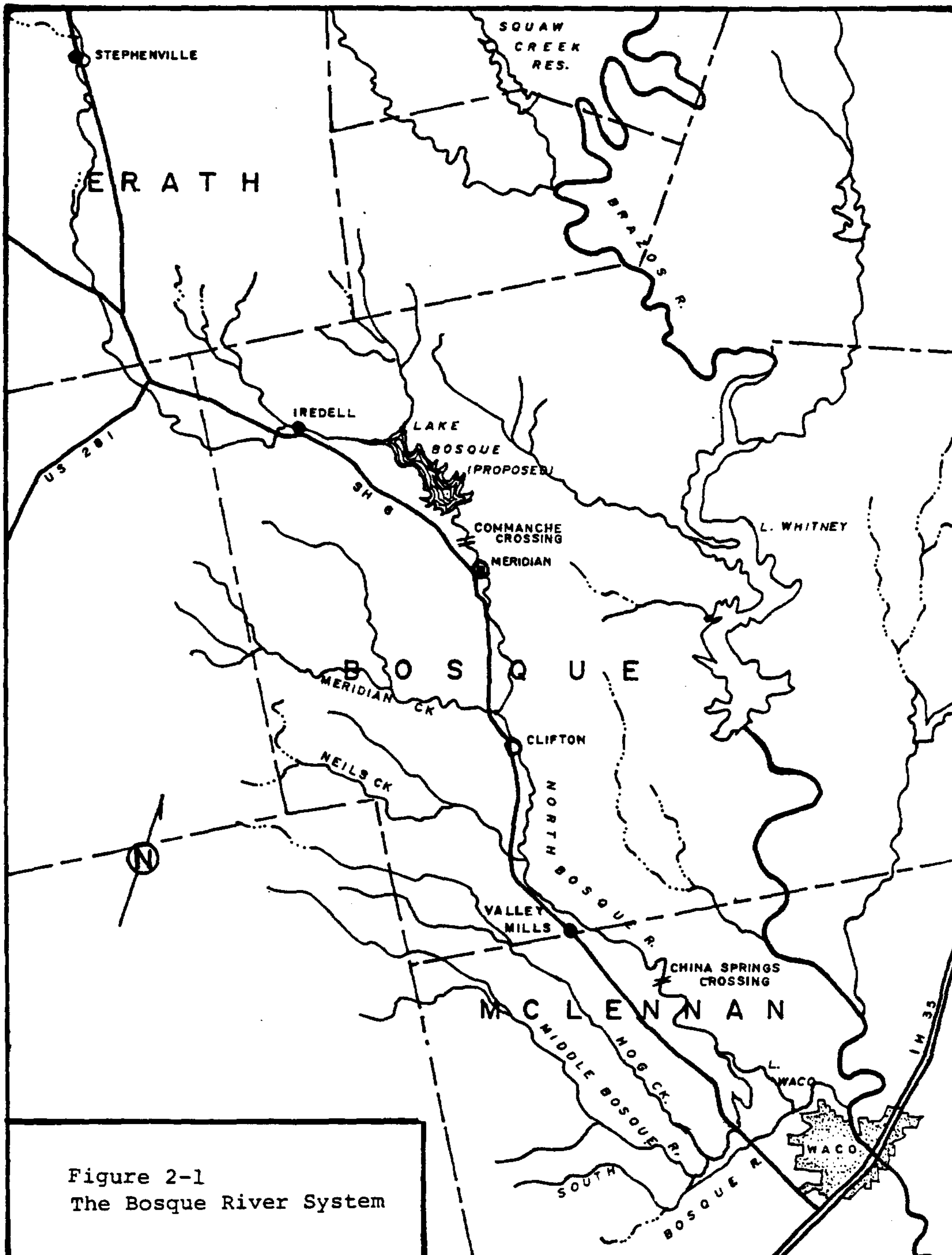

Figure 2-1
The Bosque River System

differences of 150 to 200 feet between valley floors and divides common. The distinct topography is largely the result of the physical resistance to weathering and hydraulic properties of the Edwards Limestone formation which forms a resistant cap on the tops of the divides. The less resistant Comanche Peak Limestone and Trinity Clay formations, which form (respectively) the steep, upper slopes below the Edwards cap and the lower slopes and valley floors, are eroded much more rapidly than the Edwards producing the characteristic mesa dominated topography. Procter (1969) reports that the Edwards limestone here is a perennial aquifer, exhibiting a "spring line" of seeps and springs at its base that increases erosional activity on the underlying Comanche Peak and Trinity formations and contributes to area streamflow. The Paluxy Sand formation also outcrops in a relatively narrow band along the Bosque River channel in the reach beginning below Iredell and ending upstream of Clifton (see figures 2 and 3 in Procter, 1969).

In the Lampasas Cut Plain, only soils developed on the Trinity Clays and Paluxy Sands are utilized for agricultural activities other than grazing. As in the Washita Prairie, the most intense agricultural activity is concentrated along the river, resulting in nearly complete deforestation of the valley floor, with only riparian strips of woodland remaining. Here too, the bottomland soils are easily cultivated since even adjacent to the river channel they are only occasionally flooded (SCS, 1980). The characteristic land use, vegetation, habitats and faunal communities of the reservoir site are extensively discussed in TCA, 1985 and Paul Price Associates 1987.

Above Iredell (and the proposed reservoir site) the remainder of the North Bosque basin lies in the Paluxy Cross Timbers and Glen Rose Prairie physiographic regions. These are regions of lesser relief and greater aridity, constituting the edge of the western grasslands. The Glen Rose formation begins to outcrop in the river channel in the vicinity of Iredell, above all but the extreme upper reach of the reservoir. This formation is known in particular for the dinosaur tracks that have been found at numerous outcrop locations from Glen Rose to Uvalde (EH&A, 1983).

3.0 The North Bosque River

The baseline Ecology Report (TCA, 1985) discusses in some detail the physical characteristics, hydrology, water quality, habitats, and biota of the North Bosque River reach between Iredell and Meridian. In general, the river all the way to Lake Waco appears much the same as it does in the lower portion of the proposed reservoir site. The channel is usually 75 to 150 feet wide, incised into an alluvial floodplain in which it is free to meander, typically with steep to vertical banks up to about 30 feet in height and bordered with a narrow strip of woodland. Except for these wooded strips, land adjacent to the river is almost exclusively cultivated (SCS, 1980).

3.1 Morphometry

The river tends to exhibit a characteristic pool-riffle sequence throughout the survey reach that consists of elongated pools, commonly 200 to 1000 yards, or more, in length, often occupying the full width of the bed, that terminate in short boulder/cobble/gravel riffles (Figures 3-1, 3-2). These reaches alternate with those in which bed elevation appears to drop sharply in a series of short boulder/cobble riffles and deeper runs over gravel/cobble substrates as a narrow channel meandering among an extended reach of gravel bars. These reaches are either channel segments having large accumulations of sediments, commonly occurring below tributary confluences or are areas of increased stream gradient, often marked by acute channel bends. An example is shown in Figure 3-1 (Station 3 in the proposed reservoir site; TCA, 1985) and others occur in the reaches below the the riffle shown in Figure 3-3 and below the mouth of Meridian Creek. More generally, runs are observed as the shallow upper ends of pools and as such may or may not

Figure 3-1. Riffle-pool sequences on the North Bosque River: within the proposed reservoir site (above) and at Clifton (below), 16 October 1986.

Figure 3-2. Deeper pools in the vicinity of Valley Mills. 16 October 1986.

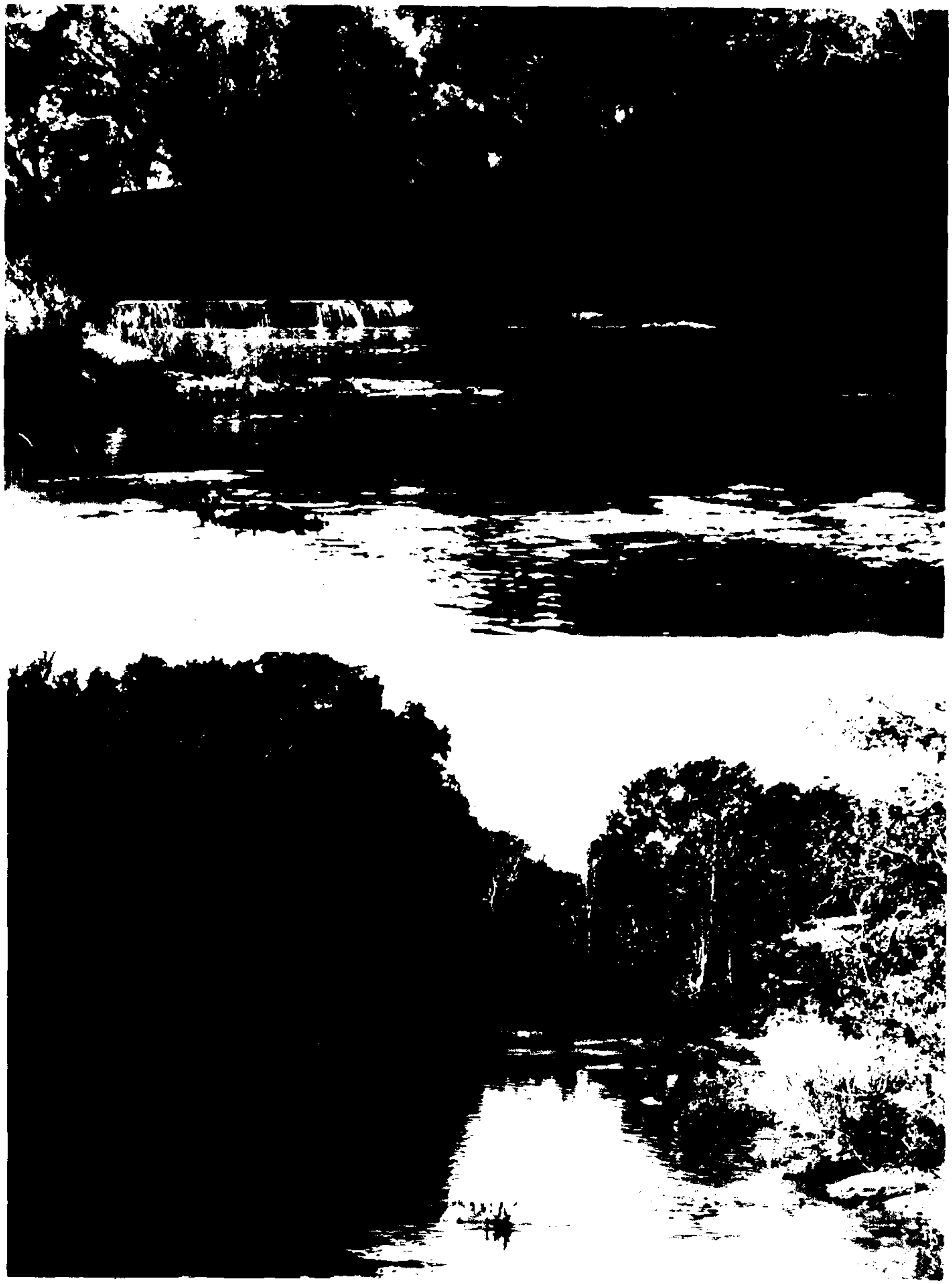

Figure 3-3. Ledge outcrop (above) and boulder riffle (below) in the high gradient reach between Meridian and Clifton.

exhibit perceptible flow at a given discharge or vary considerably in extent with changes in water level.

Pools terminate in riffles that are usually quite short (less than 50 yards) regardless of their composition. Ledge outcrops and boulder riffles occur occasionally, as in Figure 3-3, but riffles having gravel/cobble substrates are more common, particularly below Clifton, and these too can be relatively steep. For example, the riffle at Comanche Crossing (Station 1 in the Baseline Ecology Survey; Figures 3-4 through 3-7) drops nearly two feet in about 50 yards. Comanche Crossing can be considered a major riffle, since that drop occurs in a river reach having an average gradient of only about 5.5 feet/mile (Proctor, 1969; TCA. 1985). If we assume all changes in stream bed elevation occur in riffles, and that all riffles have the same gradient, we would expect about 150 yards/mile (8.5% of channel length) of riffle habitat in the low gradient reaches.

Figure 3 in Procter (1969) is a longitudinal profile of the North Bosque River showing the geological formations traversed and their effect on stream gradient. This figure shows that except for two relatively short reaches (one between Meridian and Clifton and another just above Lake Waco), the river exhibits a relatively uniform, gentle gradient similar to that in the reservoir reach throughout its lower segment. This strongly indicates that the channel morphology and associated habitat types described for the lower portion of the reservoir reach (TCA, 1985) are also typical of the river all the way to Lake Waco, assuming that substrates and water quality are also similar. That it is, in fact, the case was confirmed by the observations made during the October, 1986 survey. Channel bottom substrates are overwhelmingly gravels throughout the survey reach, although pool bottoms may contain sand and silt deposits and boulders and slabs are present as local outcrops in numerous locations. There also appears to be a tendency

Figure 3-4. Comanche Crossing. 18 November 1985, Discharge 0.14 cfs.

Figure 3-5. Comanche Crossing. 29 April 1986, Discharge 1.7 cfs.

[illegible]

[illegible]

for average particle size to decrease in a downstream direction, including an apparent lack of slab and boulder riffles below Clifton. They are, however expected to occur in the downstream high gradient reach just above Lake Waco where the river channel cuts into the Edwards Limestone.

A portion of the higher gradient reach was examined during the October survey. That reach differs from other locations on the North Bosque in several ways. The pools tend to be shorter (less than 300 yards), the riffles are more frequent, and outcropping limestone ledges visibly control the occurrence of riffles. The riffle-run morphology was quantified by recording the lengths of successive pools and riffles in an approximately 1400 yard reach. Pools were generally less than 200 yards in length, but riffles were also shorter, ranging from single falls over ledges (Figure 3-3), through cobble/gravel runs up to 30 yards in length. Riffles are estimated to account for about 20% of channel length in the reach examined.

3.2 Hydrology

Hydrologic characteristics of the North Bosque River are discussed at length in the Baseline Ecology Report (TCA, 1985). During the field survey, river discharge recorded at Clifton was about 40 cubic feet per second (cfs), according to the U.S. Geological Survey (USGS, pers. comm.). This discharge is twice the median annual flow, and is equaled or exceeded, on the average, about one third of the time (eg, about 135 days per year). Median flow, or discharge, is the flow at which one half the daily flows are greater and one half are less. That is, on the average the daily average discharges at Clifton will exceed 20 cfs for 182.5 days per year and be less than 20 cfs for the remainder. The average discharge for the period of record (1927-1984) is about 187 cfs. That the median discharge is only 10.7% of the average is a reflection of the statistical effect of infrequent, large flood flows and a rough indicator of the great variation in discharge regularly experienced at a given channel location.

The effect of discharge on Bosque River habitats is illustrated by the series of photographs in Figures 3-4 through 3-7. This series depicts a single location, Comanche Crossing, for which there is an extensive and varied data set, over a period of 17 months as discharge varied over two orders of magnitude. This location is about 15 miles upstream of Clifton and the confluence of Meridian Creek, a large perennial stream. Although this location encompasses about 80% of the drainage area above Clifton, the median annual flow here is about 11-12 cfs, based on the entire (1927-1984) period of record.

In November, 1985, at a very low flow of 0.14 cfs, the large riffle in the foreground (Figure 3-4) was nearly dry, the wetted channel only 2-3 feet wide. However, the shallow run (upper end of a pool) below the riffle was extensively inundated even at that low flow. The following April (Figure 3-5), at a discharge of 1.7 cfs, substantial inundation of the riffle area is evident (wetted channel 10-25 feet wide) and the run downstream inundates essentially the entire stream bed. The debris and the extensive vegetation visible in Figure 3-5 is the result of a low flow period of about eight months.

Figure 3-6 was taken during the October 1986 survey discussed in this report at a discharge of 20-30 cfs. The wetted area in the riffle was only a little wider than during the previous April but water depth and current velocity were both substantially greater. The run downstream was completely inundated to a maximum depth of about two feet. The channel had also been thoroughly scoured of debris and vegetation by flows high enough to rearrange the gravel bars and cause noticeable bank erosion. The final figure (3-7) shows almost complete riffle inundation at a discharge of about 40 cfs in April, 1987. The upper end of the run was scoured to a depth of about 3 feet but downstream areas were generally only 1 to two feet deep. During this period, the pool that extends upstream of the riffle did not appear to perceptibly change in size, except in October, 1984 following several months of zero discharge.

Figure 3-8 shows the present relation between discharge at the proposed dam site and that at Clifton, the two curves being plots of median discharge, by month, at those locations. The proposed Lake Bosque will generally reduce Clifton low flow discharges (less than median flows) by only one half to one forth in the absence of any release program, (HDR Infrastructure Inc., 1987). Impacts due to changes in the low flow regime in the North Bosque River below Clifton are expected to be insignificant because of the degree of flow recovery. This situation is possible because of the large base flows available from the perennial tributaries, Meridian Creek and Neils Creek, whose drainage basins include significant areas of Edwards Limestone, and the broad, deep valley alluvium and Paluxy Sands that begin to be present below Iredell. Higher discharges are more dependant on runoff from the upper North Bosque basin and are expected to be more affected by reservoir operation..

3.3 Water Quality and Biology

Table 3-1 summarizes the water quality measurements made during the October, 1986 survey. These appear to be consistent with other water quality data available for the North Bosque River and Lake Waco (TCA, 1985; TDWR, 1980; TPWD, 1974; 1975; 1976).

Figure 3-8 Median Discharges, by Month

1975-1985 data set

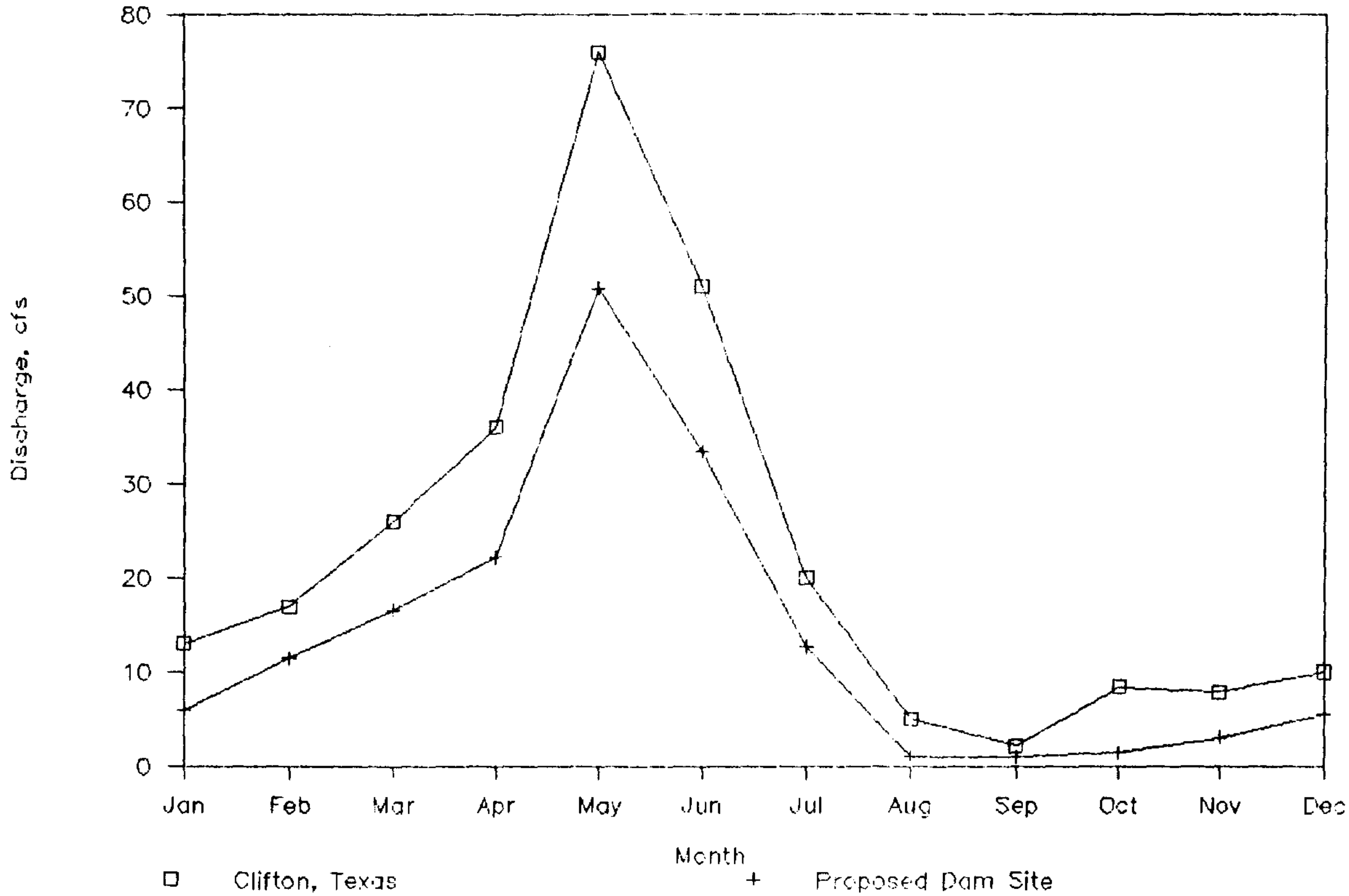

Table 3-1

Water Quality Data Collected 17 October 1986 from the North Bosque River.

Location:	Comanche Crossing	Clifton	Valley Mills	China Springs Crossing
Time	1230	1630	1730	1900
Discharge (cfs)*	31.8	51.6	**	60.8
Temperature (C)	18.0	20.0	**	20.0
Oxygen (mg/l)	11.1	12.0	**	10.2
Conductivity (umho/cm)	455	475	**	490
pH	8.0	8.4	**	8.4
NH_3-N (mg/l)	<0.03	<0.03	<0.03	<0.03
NO_3-N (mg/l)	0.41	0.28	0.47	0.49
Kjeldahl N (total, mg/l)	2.21	0.88	0.83	0.46
Phosphorus P (total, mg/l)	0.19	0.06	0.1	0.21

* Instantaneous flow measured in field; daily average flow from Clifton USGS Gage for 15, 16, 17 October: 54, 44, and 39 cfs, respectively.

** Data not collected

Although dissolved oxygen (D.O.) depletion is not a general problem in the North Bosque River, it is in Lake Waco where an aeration system is operated to destratify and oxygenate the water in order to minimize potable water treatment costs. An intensive monitoring survey (TDWR, 1980) identified only the reach below Stephenville as a problem due to organic loading from the city's sewage discharge.

Data for Segment 1226 from 1 January 1980 through 1 January 1987 was obtained from the Texas Water Commission. Dissolved oxygen concentrations were consistently above 5.0 mg/l except in the few samples from stations below Stephenville.

Dissolved oxygen concentrations commonly exhibited 4-5 mg/l excursions in diel samples collected in October, 1983 throughout the North Bosque River.

Ammonia (NH_3-N) was not detectable in about half of all measurements throughout the North Bosque River. The remaining values varied up to slightly above 0.5 mg/l, with most below 0.30 mg/l. Sixty-nine percent of all nitrate (NO_3-N) measurements in the North Bosque River (n=113) fell in the range 0.1 to 1.0 mg/l, with a further 26% falling below 0.1 mg/l. Chlorophyll a concentrations exceeded 0.02 mg/l in eight of 46 measurements (17.4%) throughout the North Bosque River..

Considering only Station 1226.0100, located just upstream of Clifton, during the period 1980 through 1983 33 to 82% of yearly total phosphorus (T-P) measurements were in the range 0.02-0.049 mg/l. Beginning in January, 1984, 54 to 75% of yearly T-P values exceeded 0.05 mg/l. Nearly all total phosphorus samples collected at China Springs Crossing October 1983 through November 1986 had concentrations in excess of 0.1 mg/l. Other locations on the North Bosque River, sampled 18 October 1983, also had high values but the two stations below Stephenville showed T-P concentrations of 1.59 and 4.40 mg/l.

Detectable levels of chlordane, DDT and its degradation products, pthalates and mercury are reported for a minority of sediment and tissue samples from Station 1226.0100. None of these materials were detected in North Bosque River water samples.

The water quality information, together with observations of consistently large filamentous algal biomass, dominance of the benthic invertebrate assemblage by detrital- and filter-feeding Collectors (Merritt and Cummins, 1978), and the conspicuous lack of significant numbers of forms such as darters, psephenids, riffle beetles and hellgammites is believed to indicate the North Bosque is substantially enriched, probably by a combination of agricultural runoff and domestic wastewater.

Considering the water quality and biological observations, and the experience of Lake Waco, it is likely that the proposed Lake Bosque will also exhibit hypolimnitic D.O. depletion during summer stratification. Impoundment of North Bosque water in Lake Bosque can be expected to result in improvements in downstream water quality to the extent that nutrients and dissolved organic materials are removed during detention.

Nearly all the species known to inhabit the North Bosque River are capable of survival and reproduction in a reservoir habitat. They are presently resident in and adapted to a river that experiences low (and zero) flows such that aquatic habitat consists only of isolated pools. Population sizes, particularly of large organisms like fish, are very likely limited by these periodic minima in physical habitat.

4.0 Human Use of the North Bosque River

Direct uses of the river appear to be limited to disposal of municipal wastewater, recreation, primarily fishing, and agricultural uses such as stock watering. Treated wastewater is presently discharged into the North Bosque River at Meridian, Clifton and Valley Mills. If segment standards are not being violated during naturally occurring low flow periods, they are not likely to be violated as a result of operation of the proposed reservoir, particularly as waste treatment facilities are upgraded by better operation, or with construction of new facilities in response to public demand and regulatory requirement. Meridian, where flow reductions as a result of Lake Bosque operations will be most pronounced, recently completed construction of a new wastewater treatment plant.

Recreational use of the North Bosque River is sharply limited by access. There is no public access to the river within the reservoir site. Between the proposed dam site and Lake Waco there are six public access points. Two, Comanche Crossing and China Springs Crossing, are unimproved fords and a third (above Valley Mills) is a county bridge crossing where it appears that private property must be crossed to reach the stream bed. The remaining three public access locations are in the three riverside communities. Although public parkland is located adjacent to the river in these communities, little or no provision for river access or recreation has been made.

Recreational use of the river is also limited by channel morphology, Where pools occupy the entire width of the river bed a boat may be required, but getting one in and out can be difficult. Boating is also limited by the shallow riffles that punctuate the stream. In May 1985 it was necessary to drag an unloaded canoe through the riffles between the proposed dam site and Comanche Crossing. This was during a period when the USGS reports that discharge at Clifton was 44 cfs. China Springs Crossing could be traversed without crossing water more than a foot deep in October 1986 when discharge was about 60 cfs.

Local fishermen and TPWD personnel report that fishermen (and women) most often fish for channel and yellow catfish using trotlines and simple poles. Bass and crappie are also sought, often incidentally to catfishing, and rough fish such as buffalo, carp and gar, are sometimes fished for. While Lake Waco supports a substantial fishery for white bass (*Roccus chrysops*), this species is not believed to run upstream even as far as China Springs Crossing, and no other strongly migratory fish is known from the Bosque River. None of the species fished for, nor the assemblage reported in TCA, 1985, would experience substantial adverse impacts as a result of construction and operation of Lake Bosque.

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BASELINE ECOLOGY REPORT

SUPPLEMENT II: IMPORTANT SPECIES

for the

LAKE BOSQUE PROJECT

BOSQUE COUNTY, TEXAS

Prepared for
The Brazos River Authority
Waco, Texas

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September, 1987

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1.0 Introduction

Ecological baseline studies of the Lake Bosque project area were conducted during 1984 and 1985 (Technical Consulting Associates 1985). This supplemental report updates and elaborates on information regarding important species that occur, or potentially occur, in the project area.

Important species are defined as those which (a) are commercially or recreationally valuable, (b) are threatened or endangered, (c) affect the well-being of some important species within criteria (a) or (b), or (d) are critical to the structure and function of the ecological system.

2.0 Recreationally or Commercially Valuable Species

2.1 Vegetation

Commercially important tree species in the Lake Bosque project area include ash juniper (*Juniperus ashei*) and hardwoods including cedar elm (*Ulmus crassifolia*), green ash (*Fraxinus americana*), pecan (*Carya illinoiensis*), Shumard red oak (*Quercus shumardii*), plateau live oak (*Q. fusiformis*), and others, which may be used for fence posts or firewood. In addition, pecans may be sold for profit or used for personal consumption. The regional diversity in soils and range sites leads to wide variations in the density and relative importance of tree species.

Both native and improved forage grasses and row crops are also of commercial importance as livestock feed and for profit from sales. Common and coastal bermuda grass (*Cynodon dactylon*), King Ranch bluestem (*Bothriochloa ischaemum* var. *songaricus*), and Kleingrass (*Paspalum coloratum*) are most important in the area's extensive improved pastures. Common and coastal bermuda grass and Johnson grass (*Sorghum halepense*) are the most important species in the hayfields, which are largely limited to bottomland areas. In addition, commercially important row crops such as oat (*Avena fatua*), sorghum (*Sorghum bicolor*), and wheat (*Triticum aestivum*) also are restricted to the bottomlands.

Numerous plant species on the site are ecologically important as browse and forage materials for important wildlife species. Examples include various grape species (*Vitis* spp.), cat-brier (*Smilax* spp.), common elderberry (*Sambucus canadensis*), numerous oak species (*Quercus* spp.), possum-haw (*Ilex decidua*), yaupon (*Ilex vomitoria*), rough-leaf dogwood (*Cornus drummondii*), common buttonbush

(*Cephlanthus occidentalis*), American beautyberry (*Callicarpa americana*), pecan, black hickory (*Carya texana*), black willow (*Salix nigra*), cedar elm, Texas sugarberry (*Celtis laevigata*) southern dewberry (*Rubus trivialis*), poison ivy (*Rhus toxicodendron*), Texas persimmon (*Diospyros texana*), red ash (*Fraxinus pennsylvanica*), and various sedges and grasses. Of particular importance to deer is oak mast (Halls and Ripley 1961, Martin et al. 1961).

2.2 Wildlife

Several species of game mammals and birds have geographic ranges that encompass Bosque County. The fact that such species are hunted and/or trapped indicates that they are an economic and recreational resource to the area. The status of each of these species in the region of the Lake Bosque project area is presented below.

Mourning Dove. The mourning dove (*Zenaida macroura*) is considered by many to be the most important game bird in Texas. More hunter-days are spent annually (1,749,856 in 1982-83) in Texas in pursuit of the mourning dove than any other species (TPWD 1985a). The mourning dove is a habitat generalist, and part of its popularity stems from the fact that it is so widely distributed across the state. In fact, Oberholser (1974) states that it "...is the only native Texas bird with written occurrence records in every one of the state's 254 counties...".

Data for the Cross Timbers and Prairies Ecological Region (which encompasses the project area) indicated a 1985 call count average of 19.3 doves heard per route, and a 15-year mean for the 1971-1986 period of 20.6 doves heard/route. These ranked fifth and fourth, respectively, among the ten ecological regions in Texas (TPWD 1987). In terms of birds per three-minute route stop, the 1985 figure for the Cross

Timbers and Prairies Ecological Region was 0.96 compared to 0.75 birds per stop during site-specific call counts of the project area conducted on 29 May 1985 (TCA 1985). Thus, mourning dove populations in the Lake Bosque seem to be typical for the region.

Northern Bobwhite. Like the mourning dove, the northern bobwhite (*Colinus virginianus*) is a very popular game bird in Texas. This species is most common in grasslands with scattered brush and along grassy fence rows. Diet of the bobwhite varies somewhat depending on such factors as season and range conditions (Campbell-Kissock et al. 1985), though important foods include the seeds of plants such as doveweed, ragweed, and sumac (*Rhus* spp.), leaves and fruits of plants, and insects (Martin et al. 1961).

The Cross Timbers and Prairies Ecological Region supported 0.53 quail per one mile interval in 1984 (TPWD 1985a). This was well below the 1976-1984 average of 0.91 birds per station, but still ranked second out of eight ecological areas in Texas which support populations of this species (TPWD 1985b). The results of the May 1985 survey of the project area showed a count of 1.05 birds per call count stop (TCA 1985). The single TPWD sampling route located in Bosque County showed a 1976-1984 average of 0.60 birds per interval in August when singing activity is likely to be lower (TPWD 1985a).

Wild Turkey. The wild turkey (*Meleagris gallopavo*) inhabits woodlands in the Cross Timbers and Prairies Ecological Region, where it roosts in large trees and nests on the ground. Food habits vary in relation to such factors as reproductive condition of females and food availability. Oak mast (*Quercus* sp.), sumac and hackberry are common plant foods according to Martin et al. (1961); however, during the breeding season, females consume increased quantities of snails and insects. Bottomland forests seem to provide the most attractive habitat for the wild turkey, although other habitats are utilized.

TPWD (1985b) reported an estimated post-hunting season turkey population of 1872 in Bosque County in 1985. This was 15th of the 25 counties in the Cross Timbers and Prairies Region and only 21.8% as much as the high county count in the Cross Timbers (8583 in Brown County). Two gobbler count sites (31° 58' N, 97° 50' W and 32° 00' N, 97° 50' W) used by TPWD in 1983 were located near the upper end of the project area. Results from these sites yielded 6.00 and 8.50 birds per count and 5.00 and 4.67 poults per count, respectively (TPWD 1984). In 1984, TPWD did not report figures for these sites, but the average number of birds per count for sampling sites in Bosque County (N = 10) was 10.7 (TPWD 1985b).

Waterfowl. Many species of waterfowl winter in or migrate through the Cross Timbers and Prairies Ecological Region. Approximately 19.9% of the total 1984-1985 Texas duck harvest was within the north-central reporting zone which includes the project area (TPWD 1986a). However, goose populations in this region are minimal (TPWD 1986a).

Waterfowl prefer bodies of water with abundant aquatic vegetation on which to feed. Green-winged teal (*Anas crecca*), mallard (*Anas platyrhynchos*), pintail (*Anas acuta*), lesser Scaup (*Aythya affinis*), and other species may be found in these areas while enroute to more favorable wintering grounds in Mexico and along the Texas Gulf Coast. The 1984-85 TPWD statewide midwinter waterfowl survey indicated the most common overwintering species in north central Texas to be the mallard (118,600 birds), pintail (8,800), American wigeon (*Anas americana*) (8,900), scaup (4,100), and ringneck (2,400) (TPWD 1986a). The wood duck

(*Aix sponsa*) is a potential nesting species in the region; other occasional nesters include the blue-winged teal (*Anas discors*) and mallard (Oberholser 1974).

Figures indicated that the most commonly harvested species in the North Central reporting region were the wood duck, mallard, gadwall, and green-winged teal (TPWD 1986a). No county specific figures for waterfowl were given in the TPWD reports; however, the project area did not appear to provide much habitat for these species. Farm ponds and the Bosque River are the primary areas where these species might be found.

White-tailed Deer. The white-tailed deer (*Odocoileus virginianus*) is the most important big game mammal in Texas. The Cross Timbers and Prairies supported approximately 7.8% (287,308) of the state's deer population in 1985, ranking fifth among 10 ecological areas (TPWD 1986b). Deer densities averaged one deer per 23.5 acres for the Cross Timbers and Prairies Ecological Region (1986b). Based on sampling in 6269 of 533,339 acres of deer range, TPWD (1986b) estimated a deer population in Bosque County of one deer per 11.1 acres. A nighttime spotlight survey of the Lake Bosque project area revealed 0.63 deer per km (TCA 1985). Many general observations of deer in the project area were in the bottomland woodlands; however, the species was widespread at various upland sites as well.

Rabbits. Large populations of eastern cottontail (*Sylvilagus floridanus*) and black-tailed jack rabbits (*Lepus californicus*) are present in the Cross Timbers and Prairies. The 1981-1984 average number of cottontails observed per 32-km route in the Cross Timbers and Prairies was 5.8 rabbits per route, which was first of all ecological regions in Texas (TPWD 1985b). Nineteen eighty-four was a low year at 2.0 cottontails per route, but was still the highest in

Texas that year (TPWD 1985b). Jack rabbits were detected at an average rate of 1.1 per route during 1981-1984, tied for third of ecological regions in Texas. The statewide high for this species, 7.9 per route, was on the Edwards Plateau. Cottontails and jack rabbits feed almost entirely on vegetation. In north central Texas, the leaves and green pods of mesquite (*Prosopis* spp.), various grasses and forbs, and the bark and twigs of shrubs comprise the bulk of their diet (Davis 1974). Competition between these two species is minimal because the black-tailed jack rabbit prefers sparsely vegetated areas such as overgrazed pastures, while the cottontail frequents brushland and marginal areas. Good habitat for both species existed in the Lake Bosque project area at the time of the baseline studies. The spotlight survey of the project area indicated 0.15 jack rabbits per km.

Furbearers. In addition to the game species discussed above, the range of several furbearers include Bosque County. Population index values (TPWD 1986c) for the Cross Timbers and Prairies Ecological Area indicate that in 1984, the following species were most common (in decreasing order): northern raccoon, skunks (species combined), Virginia opossum, ringtail (*Bassariscus astutus*), gray fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and bobcat. Habitat for all of these species was present in the project area, and northern raccoon, Virginia oppossum, gray fox, and bobcat were all observed during the surveys. County specific harvest figures for bobcat showed a 1984-1985 harvest of 40 males and 24 females in Bosque County (TPWD 1985d). Signs of the beaver were also observed during reconnaissance of the Lake Bosque project area.

3.0 Endangered, Threatened and Protected Nongame Species

3.1 Endangered and Threatened Plants

No threatened or endangered plant species of federal concern have been recorded from Bosque County or adjacent counties (USFWS 1986). Also, no plants of concern to either the Texas Department of Parks and Wildlife (Potter 1986) or Texas Organization for Endangered Species (1984) are known to exist in these counties.

3.2 Endangered and Threatened Wildlife Species

Twelve species of endangered, threatened or protected nongame wildlife species listed by the U. S. Fish and Wildlife Service (USFWS 1986) or the Texas Parks and Wildlife Department (TPWD 1977) potentially occur in Bosque County (Potter, 1986a; Landgowski, 1986; USFWS, 1984). These species and their status as determined by each organization are discussed in the following paragraphs. While the geographic range of these species encompasses the project area, the actual likelihood that they occur on the site or that suitable habitat is even present, varies depending on the biological requirements of each individual species. Thus, the following discussion is presented in order to give more realistic view of the value of the project area to these species of concern.

3.2.1 Federally Listed Species

Five species considered endangered or threatened by the U. S. Fish and Wildlife Service potentially occur in Bosque County. These are the bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), whooping crane (*Grus americana*), piping plover (*Charadrius melodus*) interior least tern (*Sterna albifrons athalassos*) and the black-capped vireo (*Vireo atricapilla*) which is currently proposed by USFWS for listing as endangered and is thus protected (Hoffman 1986). Aspects of the biology of these species and the potential value of the project area to them are discussed below.

Bald Eagle. The bald eagle is one of the largest birds of prey in North America and is considered endangered in Texas by both the USFWS and TPWD. The preferred habitat of the species can be described as large bodies of relatively clear water with nearby wooded areas containing tall trees (Oberholser 1974). Fish compose 50-90% of the bald eagle's diet, the balance of which consists of ducks, coots, other birds, rabbits, rodents, and carrion (Reilly 1968, Oberholser 1974).

Bald eagle breeding is mostly limited to the northern United States and to Canada; however, nesting occurs rarely at scattered localities in east Texas and at a number of sites on the central and upper Texas coastal plain (Johnsgard 1979, USFWS 1984) Oberholser (1974) reported a breeding record for McLennan County which borders Bosque County to the southeast. No nesting attempts have been reported for other bordering Texas counties, and the closest county in which recent breeding has been reported is Limestone County to the east (Oberholser 1974, USFWS 1984). Based on these facts alone, it is highly improbable that the bald eagle would nest in the project area even if suitable habitat were present.

The bald eagle has become an increasingly common winter resident at numerous sites with good habitat in Texas and Oklahoma. Large bodies of water throughout Texas (especially in the eastern half) often support from one to several winter resident bald eagles. The author of this section regularly sees from one to a few bald eagles on or near Tishomingo National Wildlife Refuge adjacent to Lake Texoma, an impoundment of the Red River between Texas and Oklahoma.

The USFWS (1984) lists Bosque County and bordering McLennan County as having wintering areas for the bald eagle, presumably around reservoirs in these counties. Considering this, it seems possible that bald eagles could occasionally pass through the project area and might find some feeding habitat along the Bosque River during periods when the river has low turbidity. However, no sightings have been reported for nearby Meridian State Park which has a small lake that could provide some potential habitat (Pulich 1980).

Peregrine Falcon. The peregrine falcon is a medium to large falconid whose populations were decimated largely due to the effects of environmental pollutants such as DDT (Farrand 1983). One of the two subspecies found in Texas (*Falco peregrinus tundrius*) is considered endangered by both the USFWS and TPWD, while the other subspecies (*F. p. anatum*) is listed as threatened by the USFWS and endangered by TPWD.

The peregrine falcon is a swift raptor which feeds almost exclusively on birds ranging in size from that of small passerines to ducks (Bent 1938). Peregrine falcons occur only as migrants in north Texas (USFWS 1984). During this time almost any area with trees or other perch structures and an adequate supply of prey might be considered potential habitat for this species. Thus, the importance of relatively small acreages considered individually in terms of peregrine falcon value is small.

There is at least one sight record for McLennan County which borders Bosque County to the southeast; however, no records are reported for Bosque County, including Meridian State Park (Oberholser, 1974; Pulich, 1980). The project area does contain some areas of habitat that could be occupied briefly by migrating peregrine falcons.

Whooping Crane. To the American public, the whooping crane is perhaps the best known of America's endangered species. The species is extremely rare with just over 90 individual birds existing in the traditional wild flock (Johnson 1986). It is listed as endangered by both USFWS and TPWD.

The whooping crane is the tallest native avian inhabitant of Texas where it is a winter resident of shallow wetland habitats of the Aransas National Wildlife Refuge and surrounding areas of the Gulf Coast (Farrand 1983). Oberholser (1974) described the whooping crane as an omnivore that feeds on crabs, shrimp, frogs, crawfish, plant roots and tubers, acorns, and sorghum and other grains.

Portions of north Texas including Bosque County lie within the migratory corridor that whooping cranes follow enroute to their nesting grounds in Wood Buffalo National Park, Canada (Whooping Crane Recovery Team, 1980). However, in Texas, there are no known regular migration stopover points such as are found in certain areas in Nebraska; in fact, there are only a few scattered confirmed ground sightings of whooping cranes anywhere in Texas other than on the wintering grounds on the coast (Whooping Crane Recovery Team, 1980; 1981). None of these are for Bosque County, and the likelihood of the whooping crane using the project area habitats is slim.

Interior Least Tern. The least tern is a miniature member of the family Laridae which includes (among others) the gulls, terns and skimmers. Like other members of the family, the least tern is an excellent flier and is found in association with aquatic habitats and their margins, especially in coastal regions. It feeds by hovering above the water and then diving for small fish and invertebrates at or near the surface (Oberholser 1974).

Inland breeding populations of the least tern are considered by some to be taxonomically distinct at the subspecific level from the more common coastal breeding populations; however, not all workers agree (Endangered Species Division 1986). The interior form breeds locally in the Missouri Valley along the larger streams from North Dakota south to the Brazos River system of north Texas. Here it nests in pairs or small colonies on river sandbars or sandflats, but is otherwise similar in behavior to the coastal subspecies (Johnsgard, 1979; Oberholser, 1974). Nesting and/or summer occurrence has been confirmed for areas along the Red River between Texas and Oklahoma (Ducey, 1981). During winter the interior least tern ranges from south Texas to Oaxaca, Mexico (Oberholser 1974). Alterations in its preferred riverine habitat due to such activities as reservoir construction and operation have apparently caused a decline in populations. This decline has led to the listing of the interior least tern as endangered by both the USFWS and TPWD.

Oberholser (1974) reported a summer specimen record of the interior least tern from Palo Pinto County (well to the northwest of Bosque County) and unconfirmed summer and breeding records for McLennan County. No sight or specimen records are reported for Bosque County or other bordering counties by Oberholser (1974). Inasmuch as there appears to be little, if any, preferred habitat for the least tern in the project area, it appears unlikely that the species would occur there, except perhaps as an extremely rare migrant.

Black-capped Vireo. The black-capped vireo is an inhabitant of well-drained bushy or thicket covered hills typical of many parts of the Edwards Plateau (Oberholser 1974). The species has become very rare in parts of its historic range, partly (or perhaps largely) due to the heavy strain of brown-headed cowbird (*Molothrus ater*) nest parasitism (Grybowski, 1986). Oberholser (1974) reports specimen and/or sight records for three counties bordering Bosque County. The species has been reported for Meridian State Park in Bosque County to the south of the Lake Bosque project area (Marshall et al., 1985), but despite having what appeared to be prime habitat, the area did not harbor the species during 1984 and 1985 surveys (Grybowski, 1986; Marshall et al., 1985). The upper slopes of the project area appeared to provide some potential habitat for the black-capped vireo; however, no individuals of the species were seen during the breeding season baseline surveys. Perhaps the high populations of the brown-headed cowbird prevent the occupation of these areas by black-capped vireos.

3.2.2 State Listed Species

Seven species in addition to the first five discussed above are listed as either endangered or protected nongame by the TPWD. The following paragraphs present a brief statement of the expected status of each species in the project area.

The Harter's Water Snake (*Nerodia harteri*) is listed as endangered by the TPWD. Potter (1986a) lists the species as "confirmed" In Bosque County. The Harter's water snake is a riverine species limited in distribution to the upper Concho and Colorado rivers (*N. h. paucimaculata*) and the upper Brazos River drainage (*N. h. harteri*). The former subspecies is listed as a "Category 1" species by USFWS (1985) and should be proposed for listing in the near future. The latter subspecies is the one that is known from Bosque County. Intensive surveys in its range indicate that it is highly unlikely to be found in the Bosque River (Scott and Fitzgerald, 1985; Maxwell, 1982). Further, the Brazos River subspecies is not currently believed to be in danger of extinction (USFWS 1985).

The white-faced ibis (*Plegadis chihi*) and the wood stork (*Mycteria americana*) are threatened avian species that do not breed in or near Bosque county (in the United States the latter nests only in Florida); however, both species often exhibit a postnesting wandering period during which they may occur very irregularly at inland locations (Oberholser, 1974). Based on past records of occurrence in north Texas, their presumed ranges include Bosque County. Potter (1986a) lists the wood stork as "probable" and the white-faced ibis as "confirmed" for the county.

The golden-cheeked warbler (*Dendroica chrysoparia*) is a state-listed threatened species that is endemic to central Texas where it nests in very old juniper (*Juniperus* spp.) woodlands (Pulich, 1976). This warbler species is also under review as a "Category 2" species by USFWS. With regard to Bosque County, Pulich (1976; 1980) reported a population in Meridian State Park, and he thought it probable that potential habitat might occur in upland cedar brake areas in other parts of Bosque County. Surveys of the project area did not reveal habitat that appeared likely to provide nesting habitat for the golden-cheeked warbler. Potter (1986a) lists the bird as being "confirmed" for Bosque County due to its known occurrence in Meridian State Park.

The American swallow-tailed kite (*Elanoides forficatus*) is currently considered threatened by TPWD, and is under review by USFWS as a "Category 2" species (further biological research needed to evaluate its status). The species is associated with wetland woodlands and associated native prairie type habitats and is not expected to nest in Bosque

County, nor are there any sight or specimen records for Bosque County. Based on the presumed potential migration range, TPWD lists the kite as "possible" for Bosque County.

The Texas horned lizard (*Phrynosoma cornutum*) has been recorded from Bosque County and is listed as "confirmed" for the county by TPWD. Individuals of this species have been observed in the northeastern portion of the project area on the arid upland terraces overlooking the alluvial valley floor. These sites are located at or above the conservation pool elevation (830 feet MSL), but individuals of this species may occur within the reservoir site, although none were collected with the 19 species of reptiles identified during the 1984-85 baseline ecology survey.

The Timber Rattlesnake (*Crotalus horridus*) is listed by TPWD as "confirmed" for Bosque County. A southeastern species typically inhabiting heavy cover, it has been reported from riparian environments on the Trinity and Brazos Rivers as far west as Bosque and McLennan Counties. None were observed on the reservoir site during either the Ecology or the Cultural Resources surveys.

4.0 Other Important Species

Species that can be considered critical to the well being of an endangered or commercially important species (see Section 1.0) include the abundant forest and grassland species used as forage or cover that are discussed in Section 2.1. Although sole or nearly sole dependence of one species on another is very rare among those species abundant enough to be useful to humans, major changes in the abundance of forage or cover vegetation would be expected to affect area carrying capacity to at least some extent. Conversion of forest to grassland is an obvious example that has extensive effects on resident populations but generally not because of single species interactions. The more abundant species tend to be resilient in the face of environmental change because they tend to have broad food and cover requirements.

Rare species, whether officially endangered or not, may not have the characteristics outlined above. For example, the golden-cheeked warbler is absolutely dependant on the presence of mature stands of large *Juniperus ashei*. The cedar is therefore an important species without which the bird cannot survive (and does not on the proposed reservoir site). None of the other endangered species discussed for Bosque County appear to exhibit this type of dependence, although it is not uncommon.

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An Archeological and Historical Survey

of

Proposed

Lake Bosque,

Bosque County, Texas

Prepared for
BRAZOS RIVER AUTHORITY
Waco, Texas

Alton K. Briggs
Principal Investigator

LONE STAR ARCHEOLOGICAL SERVICES
Austin, Texas
December, 1987

Texas Antiquities Permit Number 645

ABSTRACT

The Brazos River Authority, in Waco, McLennan County, Texas proposes to construct the Lake Bosque Project on an approximately 6000-acre tract north of Meridian, Bosque County, Texas. Located on the North Bosque River, a tributary of the Brazos River, the reservoir will pool at 830 feet above mean sea level, with a flood pool controlled by an emergency spillway at an elevation of 841.3 feet m.s.l. An archeological and historical survey of the project area was conducted, resulting in the locating and recording of 146 archeological sites.

Of these 146 sites, 77 are prehistoric, and 49 are historic. Twenty of these prehistoric sites also contain historic components. Of these sites, 62 are considered significant. Thirty-four sites are recommended for nomination as State Archeological Landmarks and 60 for determinations of eligibility for inclusion within the National Register of Historic Places. One site, and perhaps another, is a cemetery that requires special treatment.

The sites recorded in the area affected by the project reflect human use from the PaleoIndian period to the present century, including the Great Depression of the 1930's. Of the sites located, 77 are to be affected by Lake Bosque at normal pool elevation of +830 feet mean sea level. Twenty-nine are found from the purchased easement to the 100-year flood zone, or +830 to 842 feet mean sea level. Forty sites discovered as a result of this investigation are above 842 feet m.s.l., hence outside the direct affects of Lake Bosque.

ACKNOWLEDGEMENTS

No undertaking of any size can be conducted without the assistance of a great number of contributors and so it is with this project. The investigation of the proposed Lake Bosque Project was sponsored by the Brazos River Authority, the offices of which are located in Waco, Texas. We extend our appreciation for the assistance and direction provided to us by Roy Roberts, Assistant Director, and John Garland, Projects Division Manager, with the Brazos River Authority. HDR Infrastructure, in Austin, Texas, providing engineering services for the project, kept us up to date on the current engineering requirements, so that any changes in the structural or physical makeup of the project could be integrated in the final report on our archeological investigations. Special thanks go to G.E. Kretzschmar, P.E., Project Manager, Ken Choffel, P.E. Project Engineer, and Peter Manz, P.E., with HDR. Useful input and coordination came from the firm of Paul Price Associates, Inc., in Austin, retained to provide environmental and social assessment services for the project. Paul Price, President, and Sherry Cordry, Senior Planner, kept us advised of the schedule and any additional information which might be used to facilitate or enhance the quality of our work.

Once in the field, we made our initial quarters at Meridian State Park, the prime habitat of the Golden Cheek Warbler. Before the heat of summer forced us into other lodging, we could not only identify the Warbler, but had found new friends. Park personnel Kenneth R. Klose, Milton Cortez, Jr., Lanny Coffman and Betty Alexander helped us with reservations, let us temporarily modify a shelter for winter conditions, and watched our gear while we were conducting our long walk. They helped us break for the homefront when the rains of the fall, winter and spring came, and generally became our weather forecaster for the project, advising us when the rain ceased.

Residents of Meridian, Iredell and Walnut Springs welcomed us as one might new neighbors, which allowed us to get directly to our tasks. Landowners in the project area were generally receptive to allowing us access to their property; some went further and became genuinely interested in our work. Jack Gilleland became a friend, helping us find the names and addresses of owners of properties which had changed hands but were not reflected by our records. Ervin J. Moore shared his accumulation of aboriginal artifacts with us, providing us the opportunity to photograph a portion of them, and gave us useful insights into the transformation of forested bottomlands to agricultural use. Area geologists helped us interpret the fossiliferous beds of *Gryphaea* and gave us the benefit of their professional experience. Ben

Bourn educated us on the formation and alteration of pollen in a geological context and its interpretation. Furman Grimm confirmed our finding that chert was geologically essentially absent within the confines of the proposed project. When we visted the Bosque County Museum in Clifton, members of the Bosque County Historical Commission and museum staff allowed us to examine the collection at our leisure. They helped us obtain relevant historical documents about Bosque County. They let us examine the Museum's fossil collection, especially the mastodon teeth found both up-stream and downstream from the project area, along the Bosque River.

Other area residents shared their knowledge of history within the project; Roy V. Nichols described a cemetery, purported to contain the remains of slaves. While he had never been able to find the site, his description was extraordinarily accurate, enabling us to tentatively identify its location. Charlotte C. Martin described a site thought to have been occupied in the 1880's by a retired Texas Ranger and told us of its general location. This information led us directly to an historic site thought to have been occupied in the 1880's. E.J. Sadler led us directly to the remains of a structure thought to have been occupied by 1871. Jack Gilleland examined our map and then conducted us on a tour of more than a half-dozen prehistoric and historic sites with which he was familiar.

Ruth Farrel Bourn and Edward H. Moorman gave us permission to conduct additional investigations including sub-surface sampling of sites on their respective properties. Mrs. Bourn invited us to return when time was less pressing, to tour sites on their property. Moorman drove from his home in Wylie, Texas, took us to several sites he recollected, including one we had missed. And, he paused to tell us stories--the kind archeologists delight in hearing--stories about other archeologists in other times and places.

Curtis Tunnell, Executive Director of the Texas Historical Commission, and Texas' State Historic Preservation Officer for federal projects, gave freely of his time and expertise. A recognized scholar concerned with the early peoples of the Americas, Mr. Tunnell examined the PaleoIndian material we had collected, described in detail certain lithic reduction methods practised by Early Americans and offered guidance on approaches we might use to develop this potentially important cultural resource. J. Barto Arnold III, Marine Archeologist with the Texas Antiquities Committee guided the application for a Texas Antiquities Committee Permit for this undertaking. Skipper Scott, Archeologist with the U.S. Army Corps of Engineers, Fort Worth District, provided copies of the most recent archeological reports concerned with our area of interest and regulations to help guide our investigation. Carolyn Spock, Keeper of the Master File of archeological sites

at Texas Archeological Research Laboratories, worked diligently with us so that all sites recorded during this investigation are now plotted and all forms filed. The data recovered as a result of this project are now accessible to students, archeologists, and planners working in the general area. Raymond Neck, malacologist, examined molluscan materials recovered from sites and the Bosque River and offered insights into future methods of study. Special thanks are also due to Sam Valastro and the Radiocarbon Laboratory at the University of Texas at Austin for processing our samples as fast as possible, consistent with high standards.

Throughout the project, the principal investigator was assisted by William R. Bryant and R. Kenn Cargile. Together, we took the long walk required by a pedestrian survey. William kept records and site information so that the investigation moved along in a systematic fashion, and Kenn processed artifacts, washing, labelling, cataloging and drew artifacts, with both processing survey forms. Their contribution of time, energy and thought to this investigation is sincerely appreciated. Fred O. Weir and Evan A. Briggs also participated in the fieldwork. Jason Wolcott examined the records at the Meridian County Courthouse, and then continued research at the Barker Texas History Center at the University of Texas at Austin.

When it came time to leave the field and prepare this report, Bryant and Cargile assisted in the selection of artifacts for illustration, drew or copied them and laid out the figures in the report, tabulated much of the data utilized in this report, and read numerous draft copies and offered technical criticism. Mitzi Williams helped us get the kind of photocopies we needed to illustrate the report. Evan Briggs assisted in the drafting of the maps. Rae Briggs edited the report, offered technical advice and supported the overall effort. Any omissions or errors in the text or in interpretation remain with the writer.

OVERVIEW

The peopling of the Americas may have started earlier than the generally accepted date of about 27,000 years before the present, when the Bering Land Bridge was open as a result of a temporary drop in sea level, this a fuction of much of the water covering the land surface being bound in the form of snow and ice. Irrespective of differing opinions, sites of this early period are extremely rare and difficult to document. Sites generally regarded as PaleoIndian begin to appear toward the end of the late Pleistocene, or about 12,000 years before the present, with the extermination of many of the large animals then inhabiting the Americas. Earlier sites are difficult to recognize, perhaps because of an overreliance by American archeologists on the use of chronologies linked to the presence of projectile points. There is a good possibility that PaleoIndian sites which are of equal age or older have not been recognized, because of an absence of these tools.

Accordingly, there are probably sites in the general area of proposed Lake Bosque which are older than the PaleoIndian one located during this survey. But, this PaleoIndian site is an indicator, along with archeological work done by others in Bosque County, that human use and occupation of the Bosque River Valley, albeit sparse and perhaps intermittent, has continued for the last 14,000 to 15,000 years.

Archaic populations which are recognizable on the basis of a change of tool forms, perhaps 8000 years before the present, are the most common Native American sites in the area. Sites from the Early Archaic are relatively rare, with Middle Archaic sites, about 5000 years before the present, being more common, and those of the Late Archaic, beginning about 3000 years ago, fairly abundant. Neo-American sites associated with late tool forms, especially arrow points, are uncommon, likely a function of this period's short time span. These Archaic and later populations reflect regional adaptations to more effectively exploit the array of natural resources available in their local environment. Generally, the populations become restricted in area, but considerable movement of peoples is implied by the presence of rare materials, such as obsidian and other minerals from outside of Texas, in sites along the North Bosque River.

Historic populations move into the project area in the 1850's. An early group of settlers from Norway established themselves southwest of the project area starting in 1854; this community remains, with many of the families retaining their original property.

The settling of the project area was more sporadic, with the establishment of relatively small holdings, some growing cotton with the labor of slaves. The Civil War forced those not supporting the southern position to sell their land, abandon their property, or simply disappear until the end of this conflict. A period of agressive behavior, on the part of aborigines and outlaws followed the Civil War, which was reduced when local government was reestablished in the early 1870's. Cattle drives up the Chisholm Trail, which passes through the area, continued until the late 1870's. The raising of horses was important in the local economy until about 1880, with the coming of the railroad, more settlers and fencewire. More river bottoms were cleared of the timber and more fields were developed along the floodplains of the Bosque.

The railroad was important in helping establish local communities like Walnut Springs and Morgan, and in linking them with existing towns like Iredell. The railroad brought in the products which these communities served to distribute thoughout the populace, and provided transport for the agricultural commodities locally produced. The gradual abandonment of the railroad during the late 1940's adversely affected the local economy, forcing a change in the farming practices, generally back to ranching. At present, less than a dozen families are now living in the project area, probably the smallest number of people in the general area since PaleoIndian times.

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FIGURES

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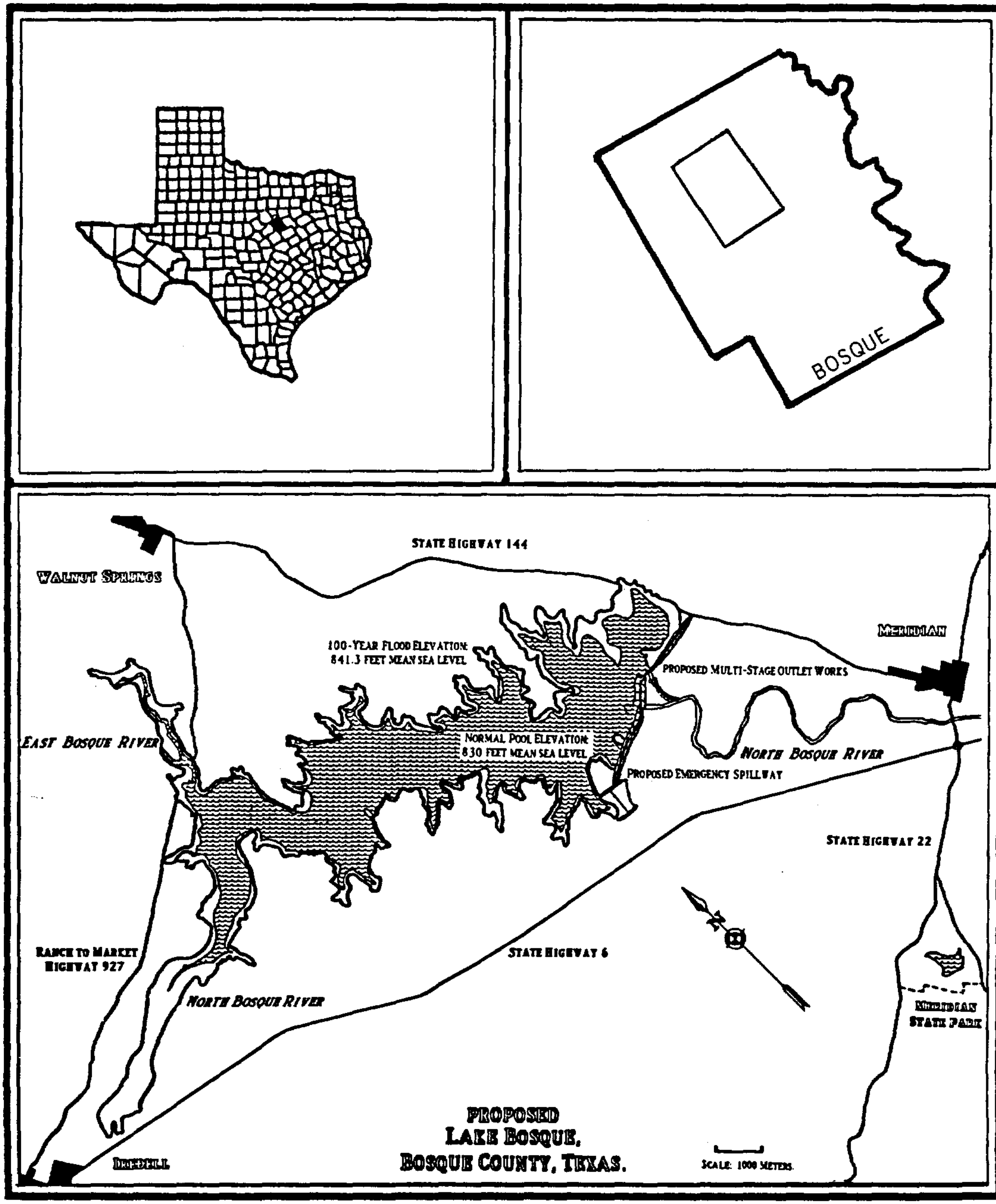

Figure 1. Map showing location of Bosque Dam and Reservoir

INTRODUCTION

The Brazos River Authority, located in Waco, Texas, proposes to construct Lake Bosque downstream from the confluence of the North and East Bosque rivers, north of Meridian, the county seat of Bosque County, Texas. The project will require the use of approximately 6000 surface acres to create Lake Bosque, behind a dam with a normal pool level elevation of 830 feet above mean sea level (m.s.l.). Above the conservation pool is the floodpool of the lake with an elevation of 841.3 feet m.s.l. In addition to the dam, construction in the project area includes a service spillway on the eastern side of the dam and two emergency spillways on the west (See Figure 1). Relatively few relocations of existing facilities, such as highways or transmission lines, are required to implement this project.

Part of the planning for the Lake Bosque Project includes the protection of cultural (prehistoric, historic and architectural) resources which might be affected by the construction, and operation and maintenance of the proposed dam and reservoir. Lone Star Archeological Services of Austin, Texas, has been retained to locate, identify, and appraise the significance of cultural resources within the project area and make recommendations concerning their management.

This investigation is being conducted in partial fulfillment of Federal and State laws oriented toward the identification and protection of cultural properties. The principal Federal legislation concerned with the management of cultural resources are the National Historic Preservation Act of 1966, as amended [Public Law 89-665, Public Law 96-515], and the Archeological and Historic Preservation Act of 1974, as amended [Public Law 93-291]. In Texas, such protection is offered by the Antiquities Code of Texas, as amended [Title 9, Chapter 191 of the Texas Natural Resources Code of 1977].

The National Historic Preservation Act (NHPA) of 1966 establishes the Advisory Council on Historic Preservation to advise the President and Congress on matters concerning historic preservation and to recommend measures to coordinate Federal activities in historic preservation. Perhaps the most important role of the Advisory Council is to comment on Federal actions which affect cultural properties eligible for or included within the National Register of Historic Places. The Advisory Council rules for the implementation of this law are detailed in *Procedures for the Protection of Historic and Cultural Properties* (36 CFR Part 800). The NHPA also sets up the National Register of Historic Places, an on-going inventory or catalog of American culture, that identifies the material remains and sites of cultural developments, from prehistory to the present, which have molded our nation.

To evaluate potential entries to the National Register, the United States Secretary of the Interior, Federal agencies, as well as State Review Boards and the State Historic Preservation Officer (SHPO) use the following criteria:

> The quality of significance in American history, architecture, archeology and culture is present in districts, sites, buildings, structures and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association, and:
> [1] that are associated with events that have made a significant contribution to the broad patterns of our history; or
> [2] that are associated with the lives of persons significant in our past; or
> [3] embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
> [4] that have yielded, or may be likely to yield, information important in prehistory or history (Texas Historical Commission 1979:7).

The Archeological and Historic Preservation Act of 1974 provides for the survey, recovery and preservation of significant scientific, prehistoric, historic, archeological or paleontological data when such data might be endangered by Federally funded, licensed or assisted undertakings. This law is implemented through *Standards and Guidelines* (48 FR 44716) published in 1983 by the Department of the Interior.

Construction of Lake Bosque will require Federal authorization under Section 404 of the Clean Water Act (33 U.S.C. 1344) and under Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403). Concerned with the discharge of dredged or fill material into the waters of the United States and work in any navigable water of the United States, such authorization is sought from the Department of the Army, through application for a permit from the U.S. Army Corps of Engineers. To address concerns on the effects of such licensing activities on cultural resources, the Department of the Army published proposed counterpart regulations in the *Federal Register* (45 FR 22112) in 1980, as *Appendix C. Procedures for the Protection of Cultural Resources* in *Part 325, Processing of Department of the Army Permits* (33 CFR Part 325).

Construction and impoundment of Lake Bosque will require the purchase of lands necessary for dam construction, ancillary features, relocations and the conservation pool. Easements will be sought in areas to be affected by intermittent or periodic flooding. In Texas, cultural resources on lands owned or controlled by state agencies or political subdivision are protected by the Antiquities Code of Texas. Permits for survey and discovery, excavation, restoration, demolition or study are sought from the Texas Antiquities Committee, the legal custodian of all cultural resources within the public domain of the State. The committee may issue a permit to other state agencies or political subdivisions or to qualified private institutions, companies or individuals for such investigation, if it is the opinion of the committee that the permit is in the best interest of the State of Texas (Section 191.054). Cultural resources located in such investigations are eligible for designation as State Archeological Landmarks.

> Sites, objects, buildings, artifacts, implements, and locations of historical, archeological, scientific, or educational interest, including those pertaining to prehistoric and historical American Indians or aboriginal campsites, dwellings, and habitation sites, their artifacts and implements of culture, as well as archeological sites of every character that are located in, on, or under the surface of any land belonging to the State of Texas or to any county, city or political subdivison of the state are state archeological landmarks and are eligible for designation (Section 191.092).

The objective of this investigation is to find the places and objects of our past which are within the area of the potential environmental impact of proposed Lake Bosque, be they potential nominees to the National Register of Historic Places or candidates for the designation of State Archeological Landmarks. The search will include examination of public records filed at the Capitol and the County Courthouse. The regional setting will be described through a study of environmental data. The work and results of previous cultural resource investigations in the general area will be reviewed. Those who know the land the best, the landowners and others who live there and work the soil, will be asked to reveal the locations of the old or unusual places and to recall their memories of other times. To locate these sites and objects "of every character...in, on, or under the surface of any land," the hunt will be conducted on foot. From the hilltop to the channel of the River, along the slopes and upland terraces, across deserted stream channels and deep into the earth where the streams of today cut into the alluvial terraces, the land will be explored. On the recently plowed agricultural terraces which make up the floodplain, soils will be traced until they disappear under the tall vegetation, fallen trees and branches under a canopy of relict eastern woodlands. Finally, the ground will be scraped, probed, and dug into, to learn if traces of the past lie buried in and under the earth. Those sites which contain, or seem to retain, useful or interpretable data concerning those who once peopled this area of the North Bosque Valley will be recommended for further investigation or protection.

RESEARCH DESIGN

The research design used for this project included, but was not limited to the following elements:

[1] Check records of previous archeological investigations in the area and plot known sites.

[2] Review local histories to determine if location is documented and integrate this information with any new findings resulting from the archeological investigation.

[3] Interview landowners and others in the area concerning the presence of cultural sites, such as Indian campsites, homesteads, cemeteries, old fords or crossings of Bosque, etc., as well as unusual natural features that might be encountered during our investigation.

[4] Obtain permission from landowners to enter property to conduct this investigation.

[5] Accomplish an archeological survey of the project area by conducting an on-the-ground search for prehistoric and historic areas, revealed by the presence of artifacts or cultural features, and to record these manifestations on current archeological site-data forms used by the State of Texas. Survey teams will be equipped with shovels, probes, and trowels, compasses, measuring tapes and cameras. Probing into the ground to discoverer buried cultural material will be an on-going aspect of the survey. Photographs of all standing structures will be taken. Time-diagnostic or site-function related artifacts and associated environmental data--such as snails, mussel shell, bone, lithic material, radiocarbon, etc.--will be collected.

[6] While on site, assess sites from the standpoint of condition, importance, and potential, leading toward a determination of significance. Revisit selected sites to recover additional data to determine the depth and character of deposits.

[7] Process and review collected data in the laboratory.

[8] Summarize data in a technical report, making recommendations for mitigation and management of cultural resources.

ENVIRONMENTAL SETTING

The environmental setting includes a description of the physiographic region, the climate and the watershed of the project area, along with a review of general floral and faunal background. The discussion of the watershed is a brief analysis of the drainage basin which will fill Lake Bosque; its surface and subsurface geology, streams and stream basins, sediments and soils in combination create the North Bosque valley and form the substrate for cultural development.

PHYSIOGRAPHY

Extending in Texas from the High Plains, south to the bottom of the Panhandle, then southeast to central Texas, the Great Plains Physiographic Province covers much of the northwest and central portions of the state. The northeastern portion of the Central Texas Section of the Province includes the Comanche Plateau. Bosque County is near the Comanche Plateau, as is the project area for proposed Lake Bosque (Carr 1967: 3, Sellards 1932). This northeastern extension is marked by Lower Cretaceous or Comanche series deposits, including the Trinity and Fredericksburg groups. More resistant to erosion than rock formations of the Blackland Prairie, the formations which have weathered to form the Comanche Plateau are among the most resistant rocks within the Great Plains Province. This differential erosion has resulted in the comparatively slow, rolling relief which distinguishes the Comanche Plateau. The Plateau and the adjacent Lampasas Cut Plain make up the physiography of the general area. The Lampasas Cut Plain Physiographic Region is,

> characterized by broad level to rolling valleys separated by steep-sided, flat-topped divides that are the remnant (cut) plain. Local relief is much greater than in the Washita Prairie, with elevation differences of 150 to 200 feet between valley floors and divides common. The distinct topography is largely the result of the physical resistance to weathering and hydraulic properties of the Edwards Limestone formation which forms a resistant cap on the tops of the divides. The less resistant Comanche Peak Limestone and Walnut Clay formations, which form (respectively) the steep, upper slopes below the Edwards cap and the lower slopes and valley floors, are eroded much more rapidly than the Edwards producing the characteristic mesa dominated landscape (Price 1987: 20).

In the Lampasas Cut Plain, the Edwards Limestone is a perennial aquifer, producing groundwater along a line of springs and seeps at the base of the formation, which also erodes those underlying Comanche Peak and Walnut Clay formations. The hydraulic weathering of the Province by ground- and surface water is driven by the climate.

CLIMATE

The project area is located on the dry side of the subtropical humid belt which extends 250 miles northwest of the Gulf of Mexico. The winters are cool and often dry; the summers, warm and sometimes humid. A thirty-year average of rainfall from 1931-1960 was slightly more than 32 inches, much of which falls during two periods, the middle through late spring and the early fall (Carr 1967: 4). A cyclical climatic extreme occurs in August, with little or no rainfall--the North Bosque River has been known to cease its flow in late August, only to resume in the early days of September with the coming of fall rains.

The ability of the Edwards Limestone to accept rainfall in the highlands and redistribute the water along a series of upland seeps and midland springs has a profound effect on the project area. Most of the flat-lying upland areas are wet much of the year. These upland seeps give rise to the drainage system which feeds the North Bosque and contains significant floral and faunal communities which characterize this area. Their impact on settlement and human use of the project area cannot be overemphasized--they are essentially impassable and unsuitable for settlement throughout much of the year. Well described, along with the effect of sunlight, by Price,

> local climate is variably affected by orientation and topography. Differential insolation on opposite valley walls can result in several degrees difference in both average surface temperature and in diurnal range, with commensurate differences in consequent characteristics such as soil moisture, erosion rates and vegetative cover. In the vicinity of the proposed reservoir, topography can be very important in determining local climate where steeper slopes may be quite arid and seepage onto flat limestone ledge outcrops may create mesic microclimates in otherwise upland areas (1987:16).

How these microclimates must have affected early peoples in this area in the ancient past remains to be learned, but paleoclimatic studies have been ongoing since the recognition that tree-rings were a response to a moisture cycle and hence, a growing season. So-called annuli are also found in fish scales, tusks and mussel shell and have been useful in determining relative age and time of death within a season, important in defining, with cultural association, subsistence strategies.

Most students concerned with the peopling of the Americas agree that a decrease in moisture, associated with an increase in temperature, occurred during the late Pleistocene. In Texas, this mesic to xeric change took place about 10,000 years ago and is thought to have resulted in the reduction of riparian and aboreal environments, altering the landform and reducing the population of large North American animals, the sloths, glyptodonts, camelops, dire wolf, Columbian mammoth, American mastodon, various bison, antelope, horses, and others. There is some evidence to indicate this change had been happening over a 4000-year period. Bryant, using paleobotanical samples from the Boriack Peat Bog, interpreted his findings to indicate a temperate deciduous forest with some conifers in Central Texas to 14,000 B.P. (before the present), with a transition to parkland after 10,000 B.P. (Valastro 1970: 625). Similar and slightly earlier indications in South Texas of a very dry climate in the late Wisconsin, the fourth stage of the last glacial epoch in North America, were found by Eargle (Valastro 1970: 624).

Recent archeological research into the climate of the Central Texas area is well presented by Prikryl. He discusses the recent work of Henry (1980) at Site 41BQ67 in Bosque County, which postulates a period of increased rainfall after 900 A.D. Shafer (1977) and Dillehay (1974) interpret their data differently, postulating an increase in grasslands attributable to a decrease in rainfall after 1200 A.D. The work of Skinner (1981) at Aquilla Creek and other valleys which feed the Brazos River led him to a similar conclusion, that of a regional drying with concomittant reduction of suitable habitat around 1200 A.D. The discussion also points out that Lynott's work at Bear Creek Shelter on Lake Whitney (1978) led him to reject a climatological hypothesis of changes at 1000-500 B.C. and 1200 A.D. (Prikryl and Jackson 1985: 14).

More data will be necessary before local climatological regimes and change can be accurately depicted. Hypotheses predicated on insufficient data cannot achieve the complexity required of useful paradigms. As an example, the C14 dates from sites in the Bosque Lake area could be used to support several of the above hypotheses, indicating human activity during the targeted time-frames.

THE WATERSHED OF PROPOSED LAKE BOSQUE

The North Bosque River drainage basin begins in north-central Erath County, passes through northeast Hamilton County to west-central Bosque County, and thence to northern McLennan County, where it forms Lake Waco and joins the basin of the Brazos River. Perhaps the most useful method of examining the morphology of the North Bosque watershed is proposed by

Proctor (1969). This approach consists of analyses of the major sub-basins which make up the larger portion of the drainage basin, offered after Proctor's review of the data revealed that information was available but restricted to a few small basins.

> The purpose for selecting the eight sub-basins studied was twofold. First, they are the largest basins within the North Bosque watershed and therefore form convenient units of study. Second, these basins embrace all the physiographic provinces that are characterized by the different lithologies and soils of the North Bosque watershed (Proctor 1969:25).

The sub-basins which combine to form the drainage basin of proposed Lake Bosque include that of the North Fork and South Fork above Stephenville, Green Creek southeast of Dublin, Honey Creek southwest of Hico, Duffau Creek above Iredell and the East Bosque River near Walnut Springs. The surface geology of the watershed and those sub-basins above the town of Iredell is Cretaceous, principally the Glen Rose Limestone, surrounded by the Paluxy Sand, with recent alluvium confined to the channel. Just below Iredell, a change in the surface geology is reflected by a relatively narrow exposure of the Paluxy Sand, surrounded by the outcropping Walnut Clay, with recent alluvium in the channel (See Price 1987: Figure 3-2).

The two sub-basins north of Stephenville are the North and South Forks of the North Bosque. The basins are similar, with the South Fork slightly larger and better drained. Both are predominately underlain by the Paluxy Sand, although more of the Glen Rose formation is exposed in the South Fork basin. The major topographic features in these basins are the resistant limestone ledges in the uplands formed by the Walnut Clay and the rolling hills typical of the Cross-Timbers physiographic area. The stream channels in these basins are drowned by sand eroded from the Paluxy Formation, more so in the North Fork basin.

Larger than the North and South Fork basins combined, the Green Creek basin is dominated by the same three lithologic units--a valley floor of Glen Rose Limestone, with midland slopes comprised of the Paluxy Sand, overlain by the limestone of the Walnut Clay which forms the upland edge. Drainage is slightly better in Green Creek than either of the two previously discussed basins. Where the Paluxy Sand underlies the upper portion of the Green Creek basin, the stream channels are choked with sand eroded from this formation.

About half the size of Green Creek basin and essentially similar although with lower relief, the basin of Honey Creek drains more slowly than the other basins which make up the North Bosque watershed. In streams of the lower portion of Honey Creek basin is a small but perennial flow of water which may derive from the Glen Rose Limestone.

Located northeast of Iredell, the Duffau Creek basin is only slightly smaller but otherwise similar to that of Green Creek with the exception that the upland valley margins on the northeast of the Duffau Creek basin are formed by limestones of the Comanche Peak and Edwards formations. Drainage channels which are formed in the Paluxy Sand are obscured and choked with sediment, as are those which are developed in the Walnut Clay. Virtually perennial streams flow from the formation of the Edwards Limestone found in the Duffau Creek basin. These streams become dry only during extended periods of drought.

Roughly three-fourths the size of the Duffau Creek basin, that of the East Bosque is essentially similar, notwithstanding the absence of the Glen Rose Limestone. Generally, the valley floor is Paluxy Sand with the marls and ledge-forming resistant limestones of the Walnut Clay forming the valley walls, midland and uplands, and Comanche Peak and Edwards Limestones forming the valley margin of the highlands in the northwestern and northern portion of the basin. Stream channels in the East Bosque are obscured as a result of drowning by sediments.

In combination, the six sub-basins comprise 395.3 square miles (Proctor 1969: 25-27). A few miles upstream of the confluence of the Bosque and Brazos Rivers is the dam which forms Lake Waco. The drainage basin for Lake Waco includes the sub-basins of the North, Middle and South Bosque Rivers, extends about 90 miles to the northwest and comprises an area of about 1670 square miles. The North Bosque is the major contributor of the three, covering about 1290 square miles or more than 77 percent of the Bosque watershed. Our rough calculations for the North Bosque watershed above river mile 58.3, or the location proposed for the construction of the dam to impound Lake Bosque, yield a drainage basin for the project of about 745 square miles or about 58 percent of the area of the North Bosque watershed. Excluding the area of the six sub-basins described above results in an area of 350 square miles which consist of the minor sub-basins as well as the mainstem of the North Bosque River. The six sub-basins of the North Bosque discussed by Proctor cover more than 53 percent of the watershed of the project area. Outside of the East Bosque sub-basin, none of these is directly affected by Lake Bosque, and in this study, their importance lies in their being major contributors of the sediments which make up the alluvial deposits on the valley floor of proposed Lake Bosque.

BASIN SEDIMENTS

In the project area, sediments are almost exclusively the product of fluviatic action on marine limestones, shales and sand. Above the project area, in the headwaters and the upper North Bosque watershed, sheet erosion is the producer of virtually all sediment--in the Green Creek watershed, Soil Conservation Service studies estimate that 97 percent of sediment yield results from sheet erosion, with streambank (2 percent) and gully erosion (1 percent) responsible for the remainder (Proctor 1969:16). Downstream, in the Lampasas Cut Plain physiographic province, gully erosion is a greater contributor (>1%) of sediments, especially in the project area. Here, gullies also play an important role in providing a pathway for entrained sediments resulting from sheet erosion in the uplands. In the project area, however, streambank or channel erosion plays a role of far greater importance--the broad alluvial floors of the valleys of the Lampasas Cut Plain, the physiographic province in which Lake Bosque is located, provide an opportunity for the streams to widen or undercut the bank and meander throughout the deposits. The effects of such streambank erosion are especially noticeable above the confluence of the East and North Bosque Rivers where recent meandering of both streams has profoundly altered the archeological and biological materials which were temporarily stored there, as was the alluvium itself, within the sediments and soils.

These sediments originate, as mentioned earlier, from the fluviatic erosion of Cretaceous limestones, shales and sands. The natural weathering of these sediments forms soils. As pointed out by Stein, *soils* should not be confused with *sediments*:

> Soils develop in sediments near the surface of the earth through weathering under the influence of plants, other biological elements, and atmospheric conditions. Soils exhibit vertical differentiation within the sediments, with horizons reflecting changes in mineralogy, texture and chemistry. Soil horizons must always be distinguished from depositional sedimentary strata (1985:6).

Soils, then, are a product which can form after the deposition of sediment, the last phase of the cycle of sedimentation. These phases include (1) a frangible source, either weathered bedrock or sediments, (2) a transport mechanism--a spectrum of possibilities ranging from the entrainment of particles of bedrock and the re-entry of sediments as a result of floods to the sediment particles on the feet of small animals, (3) a place of deposition, and (4) an alteration of sediments after deposition. When proper environmental conditions obtain, the cycle of sedimentation is restarted.

SOILS

In the Lake Bosque area, several soils can be related to parent geological formations. Upland soils found within the reservoir area are well drained and underlain by limestone. In the uplands north of the confluence of the North and the East Bosque Rivers are found those soils of the Purves-Maloterre associations, thought to be principally derived from the Comanche Peak Limestone and the Walnut Clay, whose clayey and loamy soils are described as being gravelly, shallow to very shallow, with gentle slopes and undulations. The eastern uplands of Lake Bosque are dominated by the Denton-Purves soils, the clayey soils of which are described as shallow to moderately deep, with gently sloping to sloping surfaces. These soils appear to be associated with the Comanche Peak formation, with contributions by the Walnut Clay and Edwards Limestone. The western uplands of proposed Lake Bosque are mostly the Tarrant-Denton soils. Associated with the Walnut Clay (Proctor 1969: Figure 4), these cobbly and clayey soils are thin to moderately deep, with gently sloping to sloping surfaces (Soil Conservation Service 1980:104).

In the midlands and lowlands, two major soils associations, the Krum-Sunev and Frio-Bosque, dominate. These deep, well-drained soils are found on flood plains in the valleys along the river and terraces along the stream courses. The Krum-Sunev groups occupy long, narrow strips of soils which have developed from sediments which have filled erosional zones within these valleys while the Frio-Bosque soils are adjacent to the rivers and streams in nearly level areas. One other group of soils found in the lowlands is the Bastrop-Minwells-Yahola soils association. Of this group, the Bastrop soils are considered to be particularly important in this study. The Bastrop soils are estimated to represent slightly more than one percent of the soils within Bosque County (Soil Conservation Service 1980: 4-5). The Bastrop soils are among the oldest alluvial ones which show evidence of early human use.

Among the older alluvial soils within the project area are those of the Minwells group. This fine sandy loam is found on gentle slopes of one to five percent. A deep soil, the Minwells is severely eroded to perhaps one-third of its original thickness. Generally brown to light-brown on the surface and reddish-brown beneath, the soil is slightly acid in the upper zones, and alkaline below (Soil Conservation Service 1980:19). Relatively rare in the project area, this soil is frequently adjacent to the Bastrop soils, which upstream appear to overlap the Minwells soils on the north side of the North Bosque, between Barry and Hester Branch (Soil Conservation Service 1980: Aerial Photograph Sheet No. 15).

Like the Minwells soils, the Bastrop soils are also uncommon. Bastrop soils are found as eroded remnants along the valley walls, in levee deposits and near interfluves. This deep and gently sloping soil is generally eroded, although more slightly so on slopes of one to three percent. The surface is generally reddish-brown, with varying amounts of yellow at depth. The soil is slightly acid in the upper portion and alkaline below.

The next most recent soil is thought to be the Sunev clay loam. The Sunev clay loam is found to overlap the Bastrop soils on the northeast side of the North Bosque, about 3500 feet downstream from Jackson Crossing Bridge (Soil Conservation Service 1980: Aerial Photograph Sheet No. 16). Unlike the alluvial Minwells and Bastrop soils which originate from sediments transported down river, the Sunev clay loam is a colluvial soil which is formed on sediments resulting from sheet erosion in the smaller valleys. Almost black when moist, this dark greyish-brown soil is a calcareous clay loam with small concretions of calcium carbonate at depth. Adjacent to the stream channels and along stream terraces, the Sunev soils are of minor importance to this study, except that they seem to reflect an erosional phase subsequent to the depositional ones which introduced the sediments which have weathered into the Minwells and Bastrop soils. In the project area, this deep, soil is found on gently sloping (one to three percent) surfaces. The Sunev clay loam is consistently found on the downstream ends of floodplain ridges, overlapped by the Frio silty clay loam.

A younger soil is the occasionally flooded Frio silty clay loam. Like the Sunev clay loam, this soil seems to have its origin in the sub-basins discussed above, as well as the smaller valleys, the streams of which feed the North Bosque. It is difficult to differentiate from the Sunev clay loam, to which it is frequently adjacent, in part because the constituents of the Frio silty clay include redeposited fractions of the Sunev clay loam as well as sheet eroded midland and upland valley soils. Dark greyish-brown in color, this alluvial-colluvial calcareous soil is found in nearly level areas as large as 1500 acres on bottom lands, and is briefly flooded every two to five years (Soil Conservation Service 1980:16). An excellent exposure of the sediments underlying the Frio silty clay may be seen in the stream channel of Gibson Branch, near its intersection with the North Bosque, where a profile exceeding twenty feet in thickness is revealed in the northern cutbank of Gibson branch. Here, the depositional regime is reflected by stratified cultural zones consisting principally of modified chert and mussel shell.

The youngest soils type in the project area is the occasionally flooded Bosque clay loam. This deep alluvial soil is found in long, narrow strips in the flood plains adjacent to major streams. Like the Frio silty clay loam, this flat-lying soil is flooded every two to five years, but is found in smaller areas, 300 acres or less. Perhaps the area of greatest interest associated with the Bosque clay loam is found downstream from Pilot Ford or Crossing, just upstream of the confluence of Hester Branch with the North Bosque River. Here may be seen *an abandoned confluence of a stream with the river,* the stream channel of Hester Branch intersecting with the North Bosque River, with the present channel and interfluve away to the North. Important not only as a feature of geomorphological interest, archeological sites are associated with the abandoned watercourse, sites which may be used to better understand the evolution of the river and stream system and which may be used for determining the period of abandonment.

In review, the watershed of the North Bosque River is fed by a number of small sub-basins, several of which have been discussed. All, including the North Bosque, are underlain by a bedrock of Cretaceous deposits of Paluxy Sand, Walnut Clay, and Comanche Peak, Edwards, and Georgetown Limestones, and have their channels choked with Quaternary colluviums and alluviums which now form the floodplains and terraces of the streams and rivers. The last time this bedrock geology of the North Bosque may have been significantly exposed is during the late Pleistocene, when channel scouring is thought to have occurred. Since then, several cycles of sedimentation have resulted in increased channel filling. Sediments in the channel have weathered to soils which seem to reflect episodes of deposition and erosion. From oldest to youngest, these are the Minwells, Bastrop, Sunev, Frio and Bosque soils. These soils will be discussed later in relation to sites and settlement and age.

FLORA

The project area lies within the southeast region of the Cross Timbers and Prairies Vegetational Area, one of ten such areas defined through plant research at Texas A & M University (Gould 1975; Dallas Morning News 1986: 55-59). Different soils and topography provide sharp changes in the vegetative cover, although grasses are fairly consistent in composition throughout the area.

Native grasses associated with the prairie soils include big bluestem, little bluestem, Indiangrass, switchgrass, blue grama, sideoats grama, hairy grama, tall grama, Canada wildrye, Texas wintergrass, tall dropseed, and buffalograss. In the Cross Timbers, the grasses include big and little bluestem, hooded windmillgrass, sand lovegrass, switchgrass and several species of legumes, with woody vegetation including shinnery, blackjack, post oak and live oak. Introduced secondary vegetation includes other oaks, mesquite and juniper, a group which contribute minimal forage for wildlife and livestock (Dallas Morning News 1986: 55). Additional naturally occurring woody vegetation and grasses from adjacent vegetational areas, the Blackland Prairies, the Edwards Plateau and the Rolling Plains, to the east, south and west, respectively, are also found throughout the Cross Timbers and Prairies (Price 1986: 45).

During initial baseline studies of the project area, more than 200 plant species were recognized and grouped by habitats into eight major plant communities: [1] Upland Woodlands, [2] Bottomland Woodlands, [3] Native Grasslands, [4] Improved Pastures, [5] Streambeds, [6] Aquatic Habitats, [7] Wetlands,and [8] Croplands (TCA 1985). Much of the following is derived from this study and the 1987 Environmental Assessment by Paul Price Associates, Inc.

Upland Woodlands constitute about three percent of the project area, and are found along the peripheral ridgetops near the area of the dam and spillways. Principal among the woody vegetation is ash juniper, with some plateau live oak, Texas red oak and cedar elm. Other common overstory species include Texas ash, post oak, and netleaf hackberry.

Bottomland Woodlands comprise nearly fifteen percent of the project area, along the primary, secondary terraces and bottomland slopes adjacent to the North Bosque, and along the stream courses. Relict, climax communities of eastern forestlands, described by Price as "the westernmost outliers of the extensive bottomland forests of the eastern United States," are found in inaccesible areas adjacent to the channels of the North and East Bosque rivers, in narrow strips adjacent to areas devoted to cropland, with larger areas found where channel migration has isolated small preserves of this remarkable vegetation. Chest-to-head height grasses camouflage forest floors littered with the decaying remains of the previous generation of trees, the limbs and trucks of which lie where they fell until they rot and become a constituent of the soil. Subject to wind, lightning, bank sloughing and insect damage, the trees are undistubed by humans or livestock. In the winter, with the annual dying of grasses, the floor of these forests are covered with fallen leaves, which, when combined with the coloration of the tree trunks, results in the area resembling a black-and-white photograph, a study in graytones. Species predominant in the bottomland woods include Cedar elm, with codominants including bur oak, pecan, American elm and Texas sugarberry.

Native Grasslands comprise about one-third of the project area. Although a few small and scattered remnants of native prairie remain, most of this plant community consists of overgrazed to well managed forage production units. Grasses found here include most of the prairie species already mentioned above.

Improved Pasture includes slightly more than one-fifth of the project area. Committed to forage production, these lands have been tilled to some extent, and sowed or sprigged with exotic grasses, such as K.R. bluestem, coastal or common bermudagrass and kleingrass. As in the native grasslands and cultivated croplands, forbs, herbs, and wildflowers are not uncommon in these former native grasslands.

Streambeds make up slightly less than three percent of the project area. Vegetation is generally restricted to American water willow and filamentous algae. Adjacent vegetated streambanks may contain sumac, smilax or cat brier, buffalo or stink gourd, eastern prickly pear and Johnson grass, with others in more elevated areas.

Aquatic Habitats are about .5 percent of the project area, and include farm and stock ponds which catch periodic surface runoff or exploit the extensive upland seeps and springs which slowly drain to erode and form the stream courses of the project. The edges of these ponds provide a habitat for American water willow, black willow, sedges, common bermudagrass and others.

Wetlands are less than .5 percent of the project area, along deserted meanders in the floodplain, immediately adjacent to ponds and streams, and a few beaver ponds. With the exception of a few plants found in the aquatic habitat listed above not being present, among them black willow, the plant community is much the same.

Cropland accounts for almost one-fifth of the project area. Row crops of sorghum (milo and sweet sudan), corn, along with small amounts of cotton, soybeans and peanuts are planted in the spring, followed by oats and wheat as winter crops. Coastal and common bermudagrass is cut, baled and stored for the winter feeding of cattle.

Plants common in old fields and disturbed soils as well as native grasslands include Texas bull nettle, Plains horsemint, milkweed, pigweed, rain lily, Texas thistle, coreopsis, Indian blanket, common sunflower, Texas star, long-headed coneflower, ironweed, buffalo gourd, Buckley centaury, Partridge Pea, Texas bluebonnet, wild onion, grape hyacinth, wine cup, turk's cap, Devil's claws, Pink evening primrose, scarlet paintbrush, purple horse nettle, poison hemlock, Eryngo, and Texas lantana were identified by crew members during the archeological fieldwork (Loughmiller 1984).

Plants potentially important to Native Americans include those for subsistence purposes, as well as for fiber, medicines, herbs or seasonings, wood for tools and construction. In the project area, those usable for food include acorns (especially bur oak), pecans, walnuts, hackberries, cactus (*Opuntia* and *Echinocerus*), and wild grape, along with yucca, bull nettle, buffalo gourd, and others.

We sampled the fruits of the cactus while in the field and found that of the echinocactus no different in flavor from the *pitaya,* or strawberry cactus of the desert southwest, while the *tuna,* the fruit of the Opuntia, was sweet, with an underlying bitterness, filled with hard seeds. The flowing stalks of yucca were harvested and cooked in salted water; the flowering parts were tender, not unlike asparagus, with a subtle bitterness which increased away from the flowers (Tull 1987: 27-29). Peeling the lower stalk removed the fibrous covering, exposing an edible interior with a slight soapy taste attributed to the saponin these plants contain.

A remarkable archeological site near the project area, Brawley's Cave, Site 41BQ20, produced a quantity of perishable plant materials from a dry cave deposit, the easternmost dry cave presently known in Central Texas. The cave deposits produced stone, shell, and bone items, along with one sherd of pottery (Olds 1965: 111). Specimens of shaped sticks of wood, unidentified as to species or function were recovered. Cordage (10 specimens) could be identified as sotol (7) and sisal (1). Fragments of basketry, sandals, nets, and unidentified items of fiber and grass, and twisted fur strips and hair, possibly buffalo, were also described. Ground stone artifacts were. a couple of boatstones, smoking pipes, sinkers, and manos. Chipped stone made up a variety of projectile points, bifacial tools and unifaces. Fragments of hematite and quartz were recovered, along with bone tools shaped from deer bone and antler. Mussel shells found show use-marks on the edge opposite the hinge, apparently used as tools. During the removal of this material from the cave, acomplished in a very unsystematic fashion, the reporter noted that, "Acorns, walnuts, and pecans were also found promiscuously scattered."

FAUNA

The area of proposed Lake Bosque falls within the Texan biotic province as defined by Blair (1950:101-02), who listed 49 species of mammals, 39 species of snakes, 16 species of lizards, 5 species of salamanders and newts (urodeles) and 14 species of frogs and toads (anurans). Field investigations during 1984-1985 by Technical Consulting Associates revealed sightings and identification of 14 species of mammals, 61 of birds, and 27 of reptiles and amphibians.

During our investigation, we sighted the following species:

CLASS	COMMON NAME	SCIENTIFIC NAME
	Mammalia	Virginia Opossum
Didelphis virginiana		
	Least Shrew?	*Cryptotis parva*
	Armadillo	*Dasypus novemcinctus*
	Eastern Cottontail	*Sylvilagus floridanus*
	Black-tailed Jackrabbit	*Lepus californicus*
	Fox Squirrel	*Sciurus niger*
	Beaver	*Castor canadensis*
	Raccoon	*Procyon lotor*
	Striped Skunk	*Mephistis mephistis*
	River Otter?	*Lutra canadensis*
	Bobcat	*Felis rufus*
	White-tailed Deer	*Odocoileus virginianus*
Aves	Great Blue Heron	*Ardea herodias*
	Cattle Egret	*Bubulcus ibis*
	Turkey Vulture	*Cathartes aura*
	Red-Tailed Hawk	*Buteo jamaicensis*
	Bobwhite	*Colinus virginianus*
	Turkey	*Meleagris gallopavo*
	Killdeer	*Charadrius vociferus*
	Mourning Dove	*Zenaida macroura*
	Roadrunner	*Coccyzus americanus*
	Great Horned Owl	*Bubo virginianus*
	Common Flicker	*Colaptes auratus*
	Scissor-tailed Flycatcher	*Muscivora forficata*
	Eastern Meadowlark	*Sturnella magna*
	Common Crow	*Corvus brachyrhynchos*
	Northern Mockingbird	*Mimus polyglottos*
	American Robin	*Turdus migratorius*
	Cedar Waxwing	*Bombycilla cedorum*
	Red-winged Blackbird	*Agelaius phoeniceus*
	Brown-headed Cowbird	*Molothrus ater*
	Cardinal	*Cardinalis cardinalis*
Reptilia	Texas Horned Lizard	*Phrynosoma cornutum*
Mollusca	unknown	*Potamilus purpuratus*
	unknown	*Lampsilis teres*
	unknown	*Tritogonia verrucosa*
	unknown	*Andonta grandis*
	unknown	*Amblema plicata*
	unknown	*Quadrula pustulosa mortoni*

The sighting of beaver is based on recovery of a skull from the west side of the North Bosque. The sighting of otter is based on the presence of an earth slide which crosses a dam and descends to the stream channel--a slide that was first discovered in 1985 and is still active. The furtive and fleet-footed shrew is notoriously difficult to identify in the field. The molluscan fauna was collected from the North Bosque River and from prehistoric archeological sites recognized during the field investigation.

We have identified bones of white-tailed deer from archeological sampling, with a piece of tooth enamel from another site thought to be bison. With the exception of a buffalo rib scraper, bone implements found in Brawley's Cave are fabricated from metapodials of white-tailed deer; other tools are made of antler. Bison ribs and joints were found in the cave, with "bones of most animals common to the country." As regards the molluscs found in the cave:

> Other domestic utensils found here are the beautiful mussel shells, some of which are highly polished from long use. They were evidently household utensils used in the capacity of spoons or scrapers. The end farthest from the hinge is gradually worked to a point from both sides. Although most of them have been broken or injured by fire, there are some good specimens. A number of them do not appear to have been "worked" or used at all. The shells belong to the common species from the river a mile away (Olds 1965: 147).

Not listed as to species within Olds' report, the "common" molluscs could be any of the six species which were recovered from sites or along the River during this investigation.

METHODOLOGY

Prior to any field efforts outside of locating general property boundaries, we inspected the map files and site files at Texas Archeological Research Laboratory (TARL), Balcones Research Center, The University of Texas at Austin, to determine if any recorded sites were near or in the project area. We reviewed the files and made copies of survey forms for sites in the general area, finding none inside the proposed lake. No sites were found to be listed as State Archeological Landmarks, nor were any included within the National Register of Historic Places. A review of all site locations was useful to help us better understand the settlement pattern of the general area. We reviewed some of the more recent historical accounts of the Meridian area, and we interviewed several informants who were long-time area residents. Interviews and archival research would continue throughout the remainder of the project, but we now had sufficient data to begin work in the field.

The on-the-ground pedestrian survey was conducted by a three to five person team. The work was completed in units generally outlined by fencing, one field or pasture being completed before moving to the next. Each unit surveyed in this manner got better-than-average coverage because of the overlap which occurs along the fence row, and we found we saved wear and tear on fences and field equipment by crossing each fence only once. Walking closely spaced transects usually parallel to the longer fence, the team members kept within voice and visual contact. Spacing between transects was determined by cover and land use, closely spaced in pasture and along the stream course, with more separation in areas recently plowed, mowed or grazed. Whenever artifactual material was observed, that team members called out the occurrence, which was mapped. Distribution of material along each transect would later be used to establish the boundaries of the sites located during the investigation.

As we progressed through the survey, we found that each micro-environment required alteration of our techniques. On level or nearly level soil surfaces, dense short and medium grasses tended to obscure the ground, causing the team to slow or stall as we looked for cultural material. On higher slopes and in certain soil types, erosion is a problem, which made the ground more difficult to traverse, but provided better ground exposure. In areas where soils are subject to high shrink-swell, we carried our shovels to dig into the soil to locate artifacts.

When we found sufficient artifacts within an area to indicate the probability of a site (a locality which bears the physical remains of past human activity), we would drop our packs or otherwise mark our transect, and concentrate our activities in a smaller area. Generally, this led to the recording of a site. Artifact collecting was very limited in scope, and in most instances, only enough material was recovered to date the site. Records were made on site worksheets, to be transferred later to survey forms required by the State of Texas. When the site was adequately recorded, the team returned to their equipment on the transect and the survey would resume. After the survey was completed, most of the sites were revisited; a few were visited several times.

Artifacts recovered during the survey were washed and cataloged with our temporary site numbers. Inventory of specimens was completed. Information gained from analysis of the specimens was integrated with other data on the survey forms to get a better understanding of the sites and their potential for yielding further information on the lifeway of the sites' inhabitants. The completed survey forms and key site file cards required by TARL were turned in, and permanent trinomial numbers were assigned to each site. Once we received the permanent numbers, the artifacts were re-processed, our temporary site numbers removed and the permanent numbers added in their place.

ARCHEOLOGICAL BACKGROUND

The discussion of the archeological background of the project area is divided into three sections. Of these, the first discusses current archeological dating methods using radiocarbon. The second reviews work done near the project area and includes sites discovered through individual efforts and professional investigations. The third section reviews cultural sequence and chronology. These and the following chapter on the local history are useful in describing the cultural manifestations which were found during the archeological survey, site inventory and assessment of proposed Lake Bosque.

DATING METHODS

Dating methods in archeology have their principal origins from within the domain of geology. Application of geological principles to interpret archeological sites initially resulted in relative dating through the use of stratigraphic separation, seriation, and cross-correlation (Michels 1973: 49-111). Chronometric dating is used to establish absolute dates which can be combined with data derived from relative dating to yield a more useful model of a cultural system changing through time. Chronometric data concerning the environment are often linked with these cultural models, resulting in a better understanding of the alteration of culture and the environment through time. Such models which link climatological and cultural data with absolute dates are archeologically important in learning about the human and cultural adaptive responses necessary to survive new constraints imposed by change. Such models have the potential for yielding important insights into the maintenance of the human species within a changing biosphere.

Chronometric dating is an integral part of any archeological investigation where datable materials might be found. Methods include dendrochronology (tree-ring dating), potassium-argon, thermoluminescence, obsidian-hydration, fisson-track dating and a host of others, including radiocarbon. Of these chronometric methods, radiocarbon has the widest application and is in most common use today.

Almost forty years have passed since Willard F. Libby announced the discovery of the carbon isotope with mass 14, better known today as radiocarbon, Carbon-14, C14, or preferred as most scientific, ^{14}C. His use of ^{14}C, the first nuclear species in nature known to be produced by cosmic radiation has irrevocably altered archeological field techniques and enhanced analyses of culture and associated processes. Libby, winner of a Nobel prize in chemistry for his contributions in pioneering this technique, attributed the discovery of the radioisotope to Serge Korff. Korff found that,

> neutrons are produced when cosmic rays enter the earth's atmosphere. These particles, being uncharged, are very effective in causing transmutations in the nucleus of any atom with which they collide. Neutrons were found to have an intensity that corresponded to the generation of about two neutrons per second for each square centimeter of the earths's surface. Libby theorized that, upon entering the earth's atmosphere, they would react with nitrogen-14. The reaction produces a heavy isotope of carbon, carbon-14, which is radioactive. Knowing that there are about two neutrons formed per square centimeter per second, each of which forms a carbon-14 atom, and assuming that the cosmic rays have been bombarding the atmosphere for a very long time in terms of the lifetime of carbon-14 (carbon-14 has a half-life of 5730 years), Libby observed that a steady-state condition should have been established in which the rate of formation of carbon-14 would be equal to the rate at which it disappears to reform nitrogen-14 (Michels 1973: 149).

Including carbon dissolved in the oceans as well as the biosphere, Libby calculated that there should be 8.5 grams of carbon per square centimeter from which would be two ^{14}C atoms disintegrating every second. With this in hand, Libbey asserted that ^{14}C in living organisms ceased to be assimilated after death and began radioactive decay. Only one-half of the ^{14}C in the organism at death would remain after 5730 years. At the moment of decay of the radioisotope to nitrogen-14, a particle of beta radiation would be emitted. By counting the number of emissions per minute per gram, the age of the sample could be estimated, within standard deviations (Michels 1973: 150).

Over the years, field and laboratory techniques have been altered which have significantly increased the accuracy as well as the reliability of test results. The physical limitation of ^{14}C, once thought to date to $<$ 40,000 years, has been extended by conventional means to 60,000 years (Geyh 1965) and to perhaps to 80,000 years through enrichment of the radiocarbon isotope (Erlenkeuser 1971), adequate to cover the spectrum of human presence in the New World. Radiocarbon should prove useful in dating the climatic history of the last 40,000 years, but not without limitations, for as Libby noted, especially concerning the dating of soils, "Much remains to be done in determining the rates of reactions of humus in soils and in marine organic sediments (1979: x)."

Radiocarbon dates are listed in years before the present (B.P.), with the present considered to be A.D. 1950, the year of the discovery of the dating potential of this isotope. The date A.D. 1950 should no longer be directly subtracted from the conventional ^{14}C age, because improvements in counting instrumentation and sampling techniques have revealed that over the last 10,000 years, there have been variations of ^{14}C within CO_2 of as much as 10 percent, resulting in revisions of dates with corrections as large as a thousand years. Also discovered are short-term variations which can result in imprecise measurements during certain time ranges. Research into this aspect of radiocarbon seems to reflect short-term deviation of "normal" solar radiation and/or altered climatological events (Berger and Suess 1979: xii). Because most of the dates used in this report were published before these corrections became available, new dates reported in this investigation have been adjusted to allow for the inclusion of inorganic carbon which makes the sample appear older. The dates reported in this investigation have not been corrected to reflect the variation of radiocarbon in carbon dioxide; and should not be subtracted from 1950 to obtain A.D./B.C. dates.

A large number and variety of materials may be used for radiocarbon dating purposes. That preferred is charcoal, but wood, bone, shell, peat, paper, parchment, cloth, animal tissue, leaves, pollen, nuts, carbonaceous soils, etc. can also be dated by most modern laboratories. Recently, the dating of soil fractions by ^{14}C techniques has become popular, but its feasibility depends entirely on precision in interpretation and site description, requiring at the least, that one "take a texture sample of coarse-silt to clay from the relatively oldest chemical fraction out of the relatively oldest zone of the soil profile, still containing 0.2% to 0.3% organic carbon (Scharpenseel 1979: 277-283). The best method of evaluating the accuracy of dates derived from such different materials is though the use of paired materials, two or more material specimens recovered from essentially the same position. A useful assessment of matched pairs is offered by Sheppard and others(1979). They found useful correlations between many materials, with average standard deviations of about a century. The largest deviations were with humic acid-charcoal and shell-charcoal samples, with several of the former with deviations larger than 103 years, attributable to real differences in age, or less likely, the effect of hardwater, and errors in counting and calculation. Their final assessment was that "radiocarbon dating of soils is still a questionable practice, except when mean residence times are being determined (284). As regards shell-charcoal data, they found that the pairs,

> have a small but statistically significant deviation which suggests that some C03 exchange has occurred and that the usual pre-treatment practice may be inadequate. The deviation is not large and shell dates may be useful for the radiocarbon dating of archaeological sites (Sheppard, Ali and Mehringer 1979: 284-305).

The use of shells, even those drawn from a marine context, to date land and sea level changes, has been demonstrated by Donner and Jungner (1979:

397-403), with special reference toward the careful selection of the appropriate species, noting considerable variation in dating between species, a variation related to the habitat of the species selected. Their findings also revealed that shell dates had good agreement with dates from organic lake deposits, but this work was done in Greenland, an environment deficient in carbonates.

In Texas, snail examined to determine the validity of dates derived from radiocarbon dating shells found in sites has been found to be inconsistent and of no archeological significance (Valastro1970: 631-632). Studies by Ambler(1970:266) using *Rangia cuneata*, a common mussel found in brackish waters along the Gulf coast, revealed a "good internal consistency,...shells in this particular locality can be used for dating, taking into account a correction for this amount of dead carbon. However, more work is necessary." Within Ambler's sample, *Rangia* shells dated from 100 to 400 years older than charcoal. Aten's further work in Trinity Bay Estuary (1975: 76-82), where charcoal is rare, but shells are abundant, used 13-paired samples, resulting in a corrected age through the use of a regression equation, with a standard deviation of 103 years, expressed as:

$$A_c = .995A_a - 225.41$$

where A_c = corrected age (based on predicted 14C activity if sample were wood charcoal)

A_a = apparent age (based on measure 14C activity of shell carbonate)

Aten (77) notes this equation is "applicable only to samples from upper reaches of Trinity Bay estuary and geochemically similar environments."

Shell is also abundant in the Lake Bosque area, the residue of food brought in by the inhabitants of sites. Proctor's work reveals that the environment from which they are derived is geochemically similar, with samples from five areas yielding total ion concentration of bicarbonate ranging from 56.3 to 68.6 percent(1969: 20). Further work should be oriented toward determining whether significant variability in dates exists between species as a result of different habitats and toward the determination of the difference between the apparent and corrected ages. Additional shell dating, linked with the dating of charcoal and sediments, could provide the key to understanding the distribution of sites through time, from microenvironments as disparate as the river channel and upland hilltops.

REGIONAL BACKGROUND

Perhaps the first archeological investigation reported in Bosque County is that by Frank E. Simmons, with George Anderson and Jacob Olsen, in the dry rockshelter known today as Brawley's Cave (41BQ20). From 1917-1919, a great amount of very rare material culture which had been preserved within the dry conditions of the shelter was unsystematically retrieved by the trio, reported in a manuscript by Simmons. A review of the artifacts by Olds reveals the site contains well developed Middle and Late Archaic components, followed by both foci of the Central Texas Aspect. Toyah Focus artifacts are more common than that of the Austin, with influences from north-central Texas and elsewhere (Olds 1965). The site was revisited in 1978 by Albert J. Redder. At the time of his visit, Redder found areas within the shelter which might remain undisturbed. He recommended additional investigation.

Albert J. Redder of Waco is the regional expert on prehistoric archeological resources in Bosque County. He has located and recorded the most sites, with the exception of this investigation, within the County. He has recorded another rockshelter, this one behind an intermittent waterfall, in the same general area of Brawley's Cave. This site, the Yellow Metate Shelter(41BQ70), is of unknown age, but Redder found an arrow point outside the shelter, resulting from an apparent use in the Late Prehistoric. In early 1978, Redder recorded a Native American burial just north of Comanche Crossing, about one-half mile northwest of Meridian, the county seat of Bosque. Found by Joe Cummings, the site was exposed in a spillway gully adjacent to an old dam. The burial was flexed, lying generally northeast-southwest, with the head to the southwest, apparently facing the northwest. It was associated with large chunks of charcoal, fist-sized fragments of limestone and mussel shell. Although little work was done to age or sex the skeleton, Redder's description of the jaw morphology points to the dental attrition normal on an individual over the age of forty-five years. Also in 1978, Redder reported on another site discovered along the southern boundary of Comanche Crossing Park. Recorded as the Dagley Site (41BQ71), this is a prehistoric one of Archaic age, with later historic material.

Redder also recorded sites in the area of Spivey Creek Crossing. Some of these were rockshelters known by their name and respective number, Horn's 1 (41BQ47), Horn's 2 (41BQ46), etc., for a total of ten rockshelters. Originally documented by Frank A. Watt, these sites contained, among others, stratified PaleoIndian deposits. These rockshelters, which overlook the Brazos River, yielded PaleoIndian materials including points and associated burials, with radiocarbon dating of charcoal, snail and mussel shell, and turtle bone samples. Watt drew from the Horn Shelters, the Aycock Shelter (41BL28), in Bell County and the Clark Midden (41ML39), in McLennan County, to build his Radiocarbon Chronology of Sites in the Central Brazos Valley, adapted here and from Watt's notes as Table 1 (Watt 1978). Two additional sites (41BQ43 &41BQ44) were recorded nearby, on the property of Sleet Dorman, by students of a University of Texas field school conducted in 1973 by Dee Ann Story. Across the Brazos, Dee Ann's students recorded five more (41HI64-68) in Hill County. PaleoIndian materials--points including *Clovis, Plainview, Meserve* and *Angostura* types--were found to be associated with four of these seven sites.

The first systematic investigation of the cultural resources of Bosque County was conducted by Robert L. Stephenson in 1949, with the preliminary results of the archeological survey of the area to be inundated by Lake Whitney published by the River Basin Surveys of the Smithsonian Institution. Sixty-one prehistoric and historic sites were reported, with sixteen considered to be significant. One of these was the Blum Rockshelter in Hill County, where excavations were conducted in 1952 by E.B. Jelks (1953). The archeological investigations at Whitney Reservoir were reported by Stephenson in 1970.

Jelks conducted excavations at the Kyle site, a stratified Hill County rockshelter in 1959 and 1960. Here, Jelks divided the Central Texas Aspect into the Austin Focus, associated with *Scallorn* and *Granbury* arrowpoints and *Godley* dart points followed by the Toyah Focus, with *Perdiz* and *Cliffton* arrowpoints (Jelks 1962).

Salvage archeology at Lake Waco in McLennan County in 1964 was undertaken at two sites by the Texas Archeological Salvage Project. The Baylor site contained a long series of occupations from PaleoIndian to Neo-American, of the Central Texas Aspect. The Britton site contained Late Archaic or transistional Archaic deposits of the Edwards Plateau Aspect, showing integration into the Austin Focus of the Central Texas Aspect (Story and Shafer 1965).

Other sites have been reported as a result of professional investigations by individuals for agencies of government. As part of the park development process of Texas Parks and Wildlife Department, George Kegley located the Bee Ledge Rockshelter(41BQ42) in 1972, while monitoring trail improvements in Meridian State Park. A small, shallow midden within the rockshelter produced a dart point, typed *Ensor*, and a *Scallorn* arrowpoint, indicators of occupation in the Late Archaic, followed by utilization in the Late Prehistoric or NeoAmerican period. The site was revisited and updated

LABORATORY	SITE & ASSOCIATION	APPROXIMATE AGE
SHELL	HORN: LAST OCCUPATION	520 ± 160
UT 1974	HORN 2: FIRST *PERDIZ*	590 ± 60
MAGNOLIA	CLARK: *PERDIZ*-BEAMER	680 ± 150
SHELL	HORN: BURIAL/SINKER	3000 ± 180
UT	HORN 2: FISHHOOK	3470 ± 160
SECONY	HORN: BURIAL	3830 ± 250
SHELL	HORN: Contact of Archaic with Paleoindian	7330 ± 300
AG	HORN: *PLAINVIEW*	9290 ± 300
AG	HORN: *PLAINVIEW*	9500 ± 300
UT	HORN 2: BURIALS & POINTS	9500 ± 200
UT	HORN 2: SCRAPERS	9980 ± 370
AG	HORN: SCRAPERS	10800 ± 300
MAGNOLIA	AYCOCK	11000+

Scale	Period
1950	HISTORIC
1000	LATE PREHISTORIC (NEOAMERICAN)
2000	TRANSISTIONAL ARCHAIC
	LATE ARCHAIC
3000	
4000	MIDDLE ARCHAIC
5000	
6000	EARLY ARCHAIC
7000	
8000	
9000	PALEOINDIAN
10000	
11000	

Table 1. Radiocarbon Chronology of sites in the Central Brazos Valley

in early 1986 by Texas Parks and Wildlife Department archeologist, Ronald W. Ralph.

Construction on Highway 6 in Bosque County led to the discovery of two sites by Daymond Crawford, archeologist with the State Department of Highways and Public Transportation. Recorded in a pre-construction survey, the two sites were given trinomials 41BQ72 & 41BQ73, and are midden-like accumulations of stained soil, burned rock and flint flakes eroding from cuts along the present highway, on opposite sides of the Bosque River. Crawford recommended testing these sites of unknown age before they would be affected by construction in that area.

Site 41BQ75 was recorded by Christopher Jurgens, archeologist for the Texas Department of Water Resources, as part of the planning for the construction of additional treatment units at the Meridian Wastewater Treatment Plant. Jurgens located a hearth about 30 centimeters below the surface as well as two features, mussel shell concentrations exposed in the wall of a backhoe trench, one at 30 centimeters below the surface, the other, about 75 centimeters underground. Jurgens submitted a letter report concerning the site, thought to resemble the Baylor and Britton sites at Lake Waco, with recommendations for management to the Texas Historical Commission in late 1982.

Archeologists for the U.S. Army Corps of Engineers, Fort Worth District, recorded Site 41BQ76 and 41BQ77 as part of the investigations conducted on surplus lands at Lake Whitney, upstream from Kimball Bend. Robert Scott and Daphne Dervin located an open campsite associated with possible hearths, burned rock and chert flakes of Archaic age. Recorded as 41BQ76, the site may be a discrete component of nearby 41BQ77, a large open campsite associated with a burned rock midden containing mussel shell. Artifacts collected from 41BQ77 reveal Middle to Late Archaic components, reflected by *Marshall, Ellis* and *Frio* dart point types. Earlier work had been conducted on Corps of Engineer lands elsewhere at Lake Whitney by Skinner and others from Southern Methodist University in 1971-72, resulting in the recording of a dozen open campsites on ridges or terraces in the Cedron Creek area. These sites were recorded as 41BQ80 to 41BQ92, with recommendations for collecting and/or testing at five sites thought to contain *in-situ* cultural material.

The construction of a Soil Conservation Service floodwater retarding structure on Hog Creek, in Bosque and Coryell Counties, prompted a planning survey of the area generally affected by the project. James Warren, archeologist with the Soil Conservation Service, Temple, located eight sites in Bosque County which required further investigation. These sites, 41BQ57 through 41BQ64, were investigated by archeologists with the Archaeology Research Program, Southern Methodist University and reported by Larson, Peter, Kirby and Skinner (1975). Testing of the sites, including open campsites associated with a lithic scatter (41BQ58) or a midden (41BQ57 and 41BQ61), and rockshelters--41BQ62, 41BQ63, and 41BQ64, resulted in four being recommended for inclusion within the National Register of Historic Places. Analysis of lithic material revealed these sites were occupations during the NeoAmerican or Late Prehistoric period, indicated principally by *Perdiz* and *Scallorn* arrow points. Upstream in the project area, two more shelters and a historic site in Coryell County were also investigated, but not recommended for further investigation. These sites were listed in the National Register of Historic Places as the HOG CREEK ARCHEOLOGICAL DISTRICT, in 1977, a district with eighteen prehistoric sites and one historic site, some of which are located in Coryell County. Additional investigation in the same general area was conducted by Duane Peter of North Texas State University in the late spring of 1977, locating two rockshelters and an open site near the site of the proposed dam of the floodwater retarding structure. Given the trinomials 41BQ66, 41BQ67 and 41BQ68, none of these sites is included within the National Register district.

CULTURAL SEQUENCE AND CHRONOLOGY

Five stages of cultural development are proposed here, stages which are separated through the recognition of new artifact forms and types, altered subsistence strategies, differing technological approaches, changing environment and other indicators. These five stages are the ArchaeAmerican, PaleoIndian, Archaic, Late Prehistoric and Historic.

ARCHAEAMERICAN

This stage is named for the first cultures which inhabited the Americas. The importance of the stage lies in the temporal space it provides to accommodate discoveries of cultural material which is older than is presently considered acceptable for the PaleoIndian stage. It has, therefore, the longest time period of all the cultural stages, at least › 16,000 years, longer in years than all the following stages combined. What this stage is named is relatively unimportant. With minor variations, it is the same stage proposed by Alex D. Krieger (42), who points out that the stage is synonymous with these names used by others, including: Lower Lithic stage, Percussion stage, Protolithic, Paleolithic and Lower Paleolithic (1964: 23-81). Current appellations include Late Pleistocene, and Middle PaleoIndian period (Haynes 1969), and more popularly, the stage has been subsumed within the term, Early Man. In his article, "Early Man in the New World," Krieger remarked:

> Throughout this study, emphasis will be placed on what may be termed a "pre-projectile point" stage of culture, although a better name should be found for it. This is not only because many archeologists(in the United States, at least) find it difficult to believe that there is any general technological stage that precedes the appearance of the first projectile points, but especially because *the question of man's antiquity in the New World cannot be discussed intelligently until the presence or absence of such a stage can be settled.* The writer believes that such a stage does exist, represented by a surprising amount of material in both North and South America (1964: 26).

This writer concurs with Krieger, with reduced emphasis, however, on the presence or absence of projectile points as a determining factor for inclusion. While the majority of sites which fall within this stage do not contain projectile points recognizable either in form or type, most are placed here by virtue of radiocarbon dates, which at the time of Krieger's article, had been in usage for slightly more than a decade. Even then, Krieger was joining others who had proposed the existence of the stage. There are some who remain unconvinced. Michael Waters is skeptical of the majority of sites which fall within this time frame, 27,000 B.P to 11,500 B.P., and all those which purport to be older. Waters reviewed data from 36 sites throughout the Americas, 32 of them fall within this stage. In his opinion, none fulfill the minimum requirements necessary to conclusively demonstrate the presence of early man (Haynes 1969). These essential elements are [1] an artifact assemblage that is definitely man-made or the presence of human skeletal remains, with [2] this material, preferably in primary context and with clear relationships, lying within an undisturbed geological deposit, and [3] suitable for unambiguous determination of age. To Waters, the current evidence does not support the contention that the Americas were occupied prior to about 11,500 B.P. (1985: 125-137). Time will tell.

PALEOINDIAN

Several PaleoIndian sites are known within Bosque County. Generally, sites of this stage range in age from 11,500 to 8,000 B.P. Sites in Bosque County are in rock shelters (Horn Shelters Numbers 1 and 2) and open upland terraces. These sites were occupied during a climatological period which is thought to have been slightly cooler, more moist and less variable than today. Sites are generally recognized by the presence of carefully crafted, generally lanceolate projectile points of chert; types which have been found in Bosque County include *Clovis, Brazos Fishtail* (thought to be a *San Patrice* variant), *Folsom, Plainview, Meserve, Angostura,* and others. Watt and Redder excavated two burials from Horn Shelter Number 2, associated with a 14C date of 9500 ± 200. Excavations of faunal material from sites such as the Horns Shelters reveal that these peoples exploited a wide range of the available foodstuffs--PaleoIndians are no longer considered to be restricted to a hunting economy based on the late Pleistocene megafauna that became extinct during this period. Krieger thought an important adaptation at the end of this period was enough to define what he called the Protoarchaic, a period when rotary grinding, or milling stones document shifting of exploitation strategies away from hunting the dwindling populations of megafauna to one of collecting and processing plant foods (1964: 32-34).

ARCHAIC

This stage begins about 8,000 B.P. and extends to about 1,200 B.P. The Archaic stage is divided into four sequential time periods which reflect ever-increasing cultural adaptation oriented toward exploitation of regional environments. These four time periods, Early, Middle, Late and Transitional Archaic, were initially proposed for the Edwards Plateau Aspect by Johnson, Suhm and Tunnell after they had conducted salvage archeology at Canyon Reservoir (1962). Five additional divisions based on projectile point groupings have been suggested by Weir (1976), further subdivided into eleven phases by Prewitt (1981). As pointed out by Young, Weir's chronology is more applicable in southern Central Texas, Prewitt's in central and north-central Texas (1987:18).

The Early Archaic lasts from about 8,000 B.P. to about 4,300 B.P. and is recognized through the identification of projectile points. Some points still retain their lanceolate forms of the previous period and overlap with types found in the late PaleoIndian stage, but in the Early Archaic, the trend for slightly smaller points--most with stems--is set. Among those hanging on are *Angostura, Golondrina, Meserve* and *Scottsbluff. Hoxie, Gower* and *Wells,* followed by *Bell* or *Andice, Martindale* and *Uvalde* are the dart points common to this period (Turner and Hester 1985:50). Considerable diversification in tool forms and types takes place in the Early Archaic. Elsewhere, but uncommon in Bosque County, burned rock middens are a typical feature of the period, reaching a zenith by the Middle Archaic.

The Middle Archaic period lasts from about 4,300 B.P. to about 3,000 B.P Represented by *Nolan, Travis, Bulverde, Pedernales, Marshall, Williams* and *Lange.* These points are often found at sites associated with burned rock middens in Central and South Texas, but burned rock middens are never common in the Meridian area. Watt reported Middle Archaic deposits at Horn Shelters 1 and 2, which included a burial, *Pedernales* points, and bone fishhooks (See Table 1).

The Late Archaic extends in time from about 3,000 B.P. to about 2,300 B.P. Common projectile points associated with this stage include side and corner notched types, including *Marcos, Montell, Castroville Frio, Fairland, Ensor, Elam* and *Ellis*. Mussel shells are common at these sites, distributed throughout or concentrated into features. Both Skinner and Prewitt (Prykryl and Jackson 1985:23) hypothesize a population peak at the end of this period, a peak which seems consistent with the population of prehistoric sites in the Bosque County area (Biesaart and others 1985:113).

The Transitional Archaic, also called terminal Archaic, dates from about 2,300 B.P. to about 1,250 B.P. The *Darl* (or as Prewitt prefers *Mahomet*), *Godley, Ellis* and perhaps, *Ensor* are the common dart points of this period. Two sites which contain well developed transitional Archaic deposits are the Baylor and Britton Sites excavated at Lake Waco in 1964 by Story and Shafer (1965) of the Texas Archeological Salvage Project.

LATE PREHISTORIC

This is the cultural stage which is also called NeoAmerican. This stage represents a shift away from the use of the spear thrower and dart to the use of the bow and arrow and the manufacture of arrowpoints. Jelks' work at the stratified Kyle site revealed the presence of *Scallorn* and *Granbury* arrowpoints overlain by *Perdiz* and *Cliffton* points--the Austin and Toyah Foci. In addition to arrow points, included within this cultural stage is the introduction of pottery, which appears in sites in the Brazos Valley through affiliation with Caddoan sites in northeast Texas. In the Bosque area, an Archaic lifeway continued despite the northeastern agriculturally-based settlements. Pottery is a fairly rare occurrence in Bosque County; a sherd was recovered from Brawley's Cave and identified by Olds (1965) as similar to ceramics known to occur along the Leon River.

HISTORIC

Historic tribes in the general area of the project includes the Southern Comanche as described by Marcy (1856: 36), as well as *Jenies* and *An-dak-has*, governed by Jose Maria, the chief that led "Bryant's Defeat" (See page 36). Marcy also recorded Caddoes, Wacoes, Towakonis, and Wichitas in the general area, with Delaware and Kickapoos to the northeast. Kichai, Waco and Tawokoni made a Treaty with Terrell and Smith at Torreys' Trading House near Waco in 1845 (Webb 1952 II: 790-791). More information concerning historic natives may be found in the next section, History.

HISTORY

The history of our research area, the valley formed by the confluence of the North and East Bosque Rivers, began in 1685 with the earliest French exploration of the area we now know as Texas. After years of exploration in the northeast for Louis XIV, Rene Robert Cavelier, Sieur de la Salle, sailed down the Mississippi to its mouth in 1682. Claiming the river and its tributaries for France, he returned home to gain support for a French settlement at the mouth of the Mississippi. On his expedition back to the New World, the three ships with more than 200 persons aboard inadvertently missed the Mississippi to land in Texas on the first day of January, 1685. Finally reaching Matagorda Bay, the expedition lost a ship at the entrance of the bay in Caballo Pass. Another ship was lost a few months later, and as one ship had already sailed for France, the settlement was stranded.

La Salle was actively exploring the area during the period of initial settlement, taking an expedition as far west as the Rio Grande to encourage native support for France and to discover the locations of any Spanish outposts which might be there. His second expedition was to the northeast, to find the location of the Mississippi, so with twenty men, La Salle set out in April, 1686. They crossed the Colorado and the Brazos to the Trinity and Neches, where the expedition stalled. After several months of hardship, eight of the original party returned to the settlement near Matagorda Bay (Webb 1952 II: 31-32).

Before he was murdered by his men on a later expedition searching for the Mississippi, La Salle had recorded some of his travels in journals. These journals indicate that the river today named the Brazos may have been the one called *Tokonohono* by the Caddoan speakers of north-central and northeast Texas. La Salle, it is thought, gave the name *Maligne* to the Brazos. As the Caddos and the French must have known, the assignation of names goes to those who remain.

The name *Brazos* was probably first used for the Colorado River and *Colorado* for the Brazos River. In 1716, a Spanish cleric may have called the Brazos, La Trinidad. The name, Brazos, comes from *Brazos de Dios,* Spanish for "arms of God." Irrespective of which legend concerning the River's naming one prefers, all end with its discoverers or those in need of water not perishing, but being saved by this reliable source of water, when all the rest have failed (Webb 1952 I: 211-212).

With the beginning of Spanish hegemony came more exploration. Domingo Cabello, appointed Spanish Governor of Texas in 1778, sent an expedition to explore and map the precise locations of the mouths of the Brazos and Colorado Rivers in April, 1779 (John 1975: 551-52). A few years later, the alienation of these native lands had begun. In 1786, Cabello took advantage of old animosities and turned the Tonkawas, with a war party of Tawakonis, Iscanis and Flechazos, against the Lipans. The result was the expulsion of the Lipans from between the Colorado and Brazos Rivers to the Nueces (John 1975: 699-700).

The first permanent settlement on the Brazos was an Anglo-American one made by John McFarland at the Atascosito Crossing of the Brazos (Webb 1952 I: 211-212), 180 meandering river miles from the Gulf. Called San Felipe de Austin, it became the capital of colonial Texas. As written by Stephen Austin's cousin, Mary Austin Holley:

> The site of this town is exceedingly beautiful. It is a high prairie bluff which strikes the river, at the upper or northern limit of the level region, about forty feet above the level of the stream: an elevation which is unusual in this section. It is the residence of Gen. Austin. The State and municipal officers of the jurisdiction hold their offices here; and this was the capital designated for Texas, when its separation from Coahuila and its reception as an independent State of the Mexican confederacy, should take place. Here, likewise, all the land and judicial business of the colony is transacted. It contains several stores, and present altogether the appearance of a busy and pleasant little village (Holley 1836: 109-110).

Few readers of *Texas* will disagree, Mary Austin Holley's favorite river was the Brazos. She was captivated with the river's changing environments, especially its ability to change from salt to fresh, from red to brown:

> In its course, it receives the waters of many tributary streams, and itself irrigates a region unsurpassed either for the beauty of its scenery, the fertility of its soil, or the salubrity of its climate...The most peculiar feature of the Brazos is found in its westernmost branch, which takes its source in an extensive salt region...The freshet produced in the Brazos by the rise of the Salt Branch, renders the whole river, for a while, brackish; and its waters deposit a fine red clay, as slippery as soap and as sticky as putty, and retaining its saltness, as does the water also, until an inundation from the fresh branches washes it away or covers it up, when the river becomes fresh and potable and continues so until another rise in the Salt Branch (1836: 30-31).

She had visited Texas in the fall of 1831, to gather material for a book and to inspect a league of land, 4,428 acres, which Austin had offered her on the condition she came to claim it. She had sailed from New Orleans to the Brazos Valley, where she attributed the Salt Branch as being the reason:

> that the land of the Brazos has a fertility so truly extraordinary. The freshets of the other branches are much more copius and frequent than those of the Salt Branch. They all rise and flow through very rich land, and their waters go toward the sea charged with fine loam and clay washed into them by the floods. The alternate deposits by these salt and fresh tributaries in time of freshets, form a soil of a light reddish-brown color, slightly impregnated with salt and nitre which it is well known are potent manures. This bright *mulatto* soil as it is called, formed in this manner, is considered the best land in Texas. The whole valley of the Brazos is mostly of this description. On the surface of this alluvion a blackish mould is formed by the decomposition of vegetable matter. The soil, properly speaking, possessing the power of vegetation in all its vigor, extends to an unlimited depth. When brought to the surface from a depth of twenty feet, it will produce as good crops as the surface itself. Where this mulatto soil is found the banks of the rivers and smaller streams are clothed with heavy timber (1836: 49).

One of these freshets heavily clothed with timber was shown on the map included in Holley's book. It is located in the north-central portion of the state, in a green patch marked "Austin and Williams Grant." The river, named by the Spanish for the heavy timber along the stream, is marked, *R*(io) *Bosque*.

The Austin and Williams Grant was one between Stephen F. Austin and his secretary, Samuel M. Williams. It was to settle eight hundred families in western Texas. Their grant was wrested away from Sterling C. Robertson and the Nashville Company during the period that Holley was writing her book.

Sterling C. Robertson came to Texas after organizing a Texas Association which was later called the Nashville Company. Felix Robertson, Sterling's cousin, and Sam Houston were original members of this group. Mexico gave the company a grant in 1825 to settle eight hundred families within six years in the Brazos River Basin, northwest of the grant of Stephen F. Austin. Robertson had settled many families in the area, when the Law of April 6, 1830 halted colonization. Austin's and the Nashville Company's grant were adjoining. Thinking that colonization by the Nashville Company was stopped by law, Austin and Williams secured a contract to the land in the Nashville Company grant. Robertson traveled to Saltillo to plead his case before Mexican authorities. In 1834, the Governor ruled in the favor of Robertson when it was determined that more than one hundred families had been settled by Robertson prior to the enactment of the Law of April 6, 1830. Robertson was made empresario, and his grant became known as the Robertson Colony.

When he was not fulfilling public obligations, Robertson devoted the rest of his life toward establishing the validity of his land claims. He represented the Milam District in the First Congress of the Republic. In 1837, the Texas Congress authorized Robertson to institute judicial proceedings to clarify the claims of the colonists as well as Robertson's claim as empresario. Robertson's claims were finally validated in 1847, more than five years after his death in Nashville, once county seat of Milam County (Webb 1952 I: 488-489).

When Milam County was created in 1836, it comprised one-sixth of Texas' land area (Webb 1952 II: 192). During its heydey, Nashville, or Nashville-on-the-Brazos, as some called it, was home to about 75 families living in cabins of rough or hewn logs. Records of the General Land Office of the Republic as late as 1838 reflect the vague status of the Robertson Colony. The GLO of the Republic published an abstract of Original Titles of Record in that year which included, "A List of Titles issued by William H. Steel, in Robertson, or Austin and Williams' Colony. 1834 & 1835." There are 276 separate grantee listings, which, because some individuals are listed more than once, represent a smaller number of people. One property granted to John Tucker on July 30, 1835 consisted of 25 labors (a labor of land is 177.1 acres) or 4427.5 acres of land. This grant was situated, "W. of Bosque Creek, W. of the Brazos, crosses Bosque repeatedly (1838:168).

Tucker apparently settled his 1835 grant because he was listed by Wilbarger as one who later survived "Bryant's Defeat," an encounter that followed "Morgan's Massacre." The Morgan massacre took place near present-day Morgan's Point. On the first day of January, 1839, several members of the Marlin, Jones and Morgan family were attacked at their homesite, tomahawked, scalped, and after the house was ransacked, were left for dead. A couple of weeks later, the attackers were chased by Captain Benjamin Bryant, with almost 50 men. When the natives, under the leadership of Jose Maria, countered Bryant's charge, the Texans retreated, losing ten men in the onslaught, with another five wounded. Wilbarger noted:

> The Indians lost about as many in this affair as the Texans although the latter were driven from the field. They were greatly elated by their double victory in that neighborhood, and became more daring than ever until checked by a signal defeat near Little River, known as "Bird's Victory (1889: 361-367)."

A battalion of rangers had been raised in Milam County in the fall of 1836 under the leadership of Captain Thomas H. Barron, assisted by Lieutenants Charles Curtis, David W. Campbell and George B. Erath. Erath was promoted to command a second company of rangers in 1839. Captain Erath's staff officers were Richard Ellis, Neil McLennan, William F. Thompson and James Shaw (BCHBC 1986:5). Their main function was the expulsion of the remaining indigines.

Early in the winter of 1839, Erath led a small group of rangers to the headwaters of the Bosque searching for signs of Indians. On their return trip, between present Clifton and Valley Mills, Jacob De Cordova wrote:

> when they reached that noble stream the Bosque, the soldiers being struck with the beauty of the country, soon forgot their military character and in right good earnest turned in to take up lands. These were the first locations made on the Bosque and so valuable were these lands that the party did not leave off surveying until they were forced to do so by famine (BCHBC 1986:6).

Obviously, De Cordova did not know about John Tucker's 25-labor grant recorded four years earlier. Tucker last shows up in the 1850 Census for Robertson County, listed as being 57-years old and from North Carolina. The field notes from De Cordova's journal indicate the surveyors were along this part of the Bosque River from about the 19th through the 22nd of November, 1839.

Shortly after Erath's expedition to the Bosque, a visitor to Austin from Santa Fe, New Mexico, was called on by President Lamar to act as a Commissioner to assist in opening trade. Lamar was hoping to capture a portion of the Santa Fe trade, for Texas needed to expand and open trading opportunities. Lamar failed to get Congressional approval, so under his own initiative, he proposed a trading expedition to Santa Fe. On June 19, 1841, a party of 321 with twenty-one ox drawn wagons with merchandise worth $200,000 left Kenney's Fort on Brushy Creek, in present-day Round Rock, Williamson County, Texas (Webb 1952 II: 729).

The expedition, known as the Santa Fe Pioneers, traveled in a generally north direction. When they were between the South and Middle Bosque Rivers, they saw their first antelope. The expedition crossed the main Bosque, entered what is now Bosque County well east of Valley Mills, and continued northward, crossing Steele Creek about six miles east of Morgan, or about twelve miles east of the project area (BCHBC 1986: 5). The pioneers mistook the Wichita for the Red River. By the time they realized their error, and sent out search parties for the Red, they began to suffer from inadequate provisioning and Indian harrassment. Treachery and lack of water resulted in the expedition surrendering to New Mexican authorities without firing a shot. Most of the survivors, after a march to Mexico City and a stint in Mexican prisons, returned to Texas by the middle of spring, 1842.

The establishment of frontier defenses like those at Fort Graham in 1847 and Fort Gates in early 1849 provided the security necessary for the first families to colonize the area of Bosque County. John W. McKissick built a log house near Steele Creek in 1847, and two years later, returned with his family to settle. About the same time, Ewell Everett and Albert Barton, both with their families, settled and James Frazier began his homestead, but left it for two years, then returned with his family (BCHBC 1986: 5-8).

On February 4, 1854, Bosque County was created from the McClennan territory by an act of the state legislature. A group of men assembled on June 27 that same year in a grove of post oak east of the Bosque River. Close to Meridian Creek, the source of which lies on the ninety-eighth meridian and Meridian Knobs, the future town was named Meridian (Tarpley 1980: 136).

An important source of information concerning the project area comes from one of the earliest settlers in that region, if not the first, James Buckner Barry. On his trip to Texas, Buck, as he was known, got involved in a con game, resulting in his purchase of a watch case for four dollars. He and a group of sailors went to get their money back:

> We walked in. Some of them went straight to the back door and locked it and others at the same time locked the front door. That is, they locked themselves, the auctioneer and me all in together. The spokesman told them to give back the money or he would shed their blood. Some took the money, some paid four dollars more and took good watches. I, for one, took a good watch, brought it to Texas and traded it for the land on the forks of the Bosque, where my farm is now located (Greer 1978:15).

Buck kept a diary of his activities, and because of this record he has left, serves as our local informant about the area in the 1850's. He visited his land on the December 16, 1855, his birthday:

> Sunday, my birthday. 34 years old. Rode out in the forks of the Bosque to look at my land and the mountains. Very few settlers on the Bosque. Stoped all night Meridian with Sqr. that married Widow Maybury(Barry).

Barry stayed on the Brazos until he sold the Brazos property in October, 1856. Barry's wife had slaves and he hired two of them out during the first days of January 1855, Ann to Robert Leetch for forty dollars and Mary to Mr. Snodgrass for twenty-four dollars, taking their personal notes. He hunted and shot domestic and feral hogs, which he sold for five cents a pound. He would haul up logs and burn them, then haul the ashes, make soap and sell it. He kept a cavayard, or remuda, of horses, and had a team of oxen. He raised cattle. He hunted for food, for hides and sport. While on the Brazos, in addition to hogs, he shot deer, turkeys, antelope, ducks, raccoons, and squirrels. He wore buckskin pants and a coat, which he had cut out and made. He went horse hunting or to look for lost livestock and hog and deer hunting, often setting the prairie on fire to get the game moving, thinking nothing of killing five deer or hogs in one day. For crops, he put in potatoes, wheat, peas, corn. His neighbors grew peaches and melons (Barry).

In October 1856, Barry hunted for his bull, but never found him. He gathered the rest of his stock and started for his property at the forks of the Bosque. After he arrived, he built one cabin and bought a house from Mr. Roberson, moved to his property for a horse and fifteen dollars. While he did not consider himself a rancher, Barry once branded thirty colts, and a few days later, he and another branded fifty-three calves. His stock were broke to work and to saddle, and Barry was astride a horse almost every day. Fencing was a big concern and:

> during these earlier years was limited to pens and small pastures for both cattle and horses. Sometimes all hands would turn to and fencing would occupy our time for several days. These fences were made of rails although we sometimes simply used rocks and brush. The rail fences were of rails secured from cedar brakes and other timber along the creeks and even on the mountains. Ordinary rail fences were usually deemed sufficient for cow pens, a horse pasture and the fields, but we had to supplement the rails with planks for our vegetable gardens to keep the rabbits out (Greer 1978: 74-75).

When the ground was moist, Barry found it tillable with his team of oxen. He kept several plows going at once, because as the season progressed and the ground dried, the soil would harden until finally, plowing was abandoned. In the early spring, peach trees would be set out, the corn planted, and oats sowed. Irish potatoes were a favorite. In early fall, a turnip patch would be sowed, followed by wheat in October with rye for the chickens. Like the crops, the Barry family grew and prospered:

> After some two years in log cabins on my Bosque farm, I had a more suitable house built by a very good carpenter, named Short. I was now the father of four children, three of them living, and needed more room. My wife and myself owned a few negroes and they had increased three or four and another cabin was built for them. One of my wife negroes, Soph, had five children. My new house was built of the same materials as the old--logs, but Short did a better job of it. There were two rooms sixteen feet square with a ten foot passage between and a piazza running the full length of one side. To this was added a lean-to room and others could be added as needed. Small windows were provided but there were no panes for two or three years. Nor was this additional house too much room as preachers, travelers, and neighbors sometimes stopped over-

> night with us. On one rainy Sunday night, some twelve persons stayed with us, five of them being ladies. I paid Short eighty dollars in trade for building the house (Greer 1978: 78-79).

Game was there for the taking. Barry listed "bear, panthers, deer, otter, wolves, cats, some buffalo, antelope, turkeys, prairie chickens, ducks, geese and birds too numerous to mention. We seldom wanted for game to eat during several years when the population remained sparse (Greer 1978:8) He found that deer and turkey were not difficult to kill, but that they soon became wary and avoided humans. Describing the hunting to the northeast of his homestead, Barry noted:

> Game was so plentiful that we did not consider the question of sportsmanship, in the latter sense, in methods of killing, if we needed fresh meat for our families and our help. On the East Bosque, one day, I shot several ducks, one pot shot yielding several. Another day I got five ducks at one shot and pot shot fifteen birds at a shot....I had gone up the East Bosque one day to hunt horses. Passing alongside the creek, I saw and killed an otter, several coons, a couple of turkey, and a deer. This was little sport, but I came to a flock of gobblers where there was some open ground and I enjoyed a chase on my pony after one of them. I ran him down and then shot him with my pistol (Greer 1978:86-87).

Buck's luck ran with the seasons. One January, when the weather was cold, several hundred cattle had frozen on the range. By then, bread was already scarce. Food was needed and it came in the form of four turkeys he brought home from a hunting expedition with several men north of Iredell. They had killed twenty-four. He killed a couple of antelope and some other game, and this held the family until the crops came in that season. With the coming of summer and the lower water levels in the Bosque, came fishing. It was a sport, but one which served a real purpose in supplanting their normal food sources:

> I went on one fishing spree in the North Bosque and caught over one hundred by seining with wagon sheets sewn together. We could not "round-up"in the water as with regular seins, but "drug out" on the banks. Most of the fish would thus escape us, but we caught plenty of good-sized ones. Fish frys were held at intervals during the summer, and we always had one on the fourth of July as a part of a holiday festival and celebration (Greer 1978: 88).

Another perspective about life and the rate of development in Bosque County as compared to the rest of the State can be gained from the first Texas Almanac, published by Willard Richardson in January 1857. There was one post office in Bosque County, at the county seat, Meridian (31) Bosque County was listed as containing 16,446 acres of land valued at $26,580.00 ($1.62 per acre), and town lots with a value of $1240. Thirty-four slaves were valued at $17,580.00 or an average of about $517 per slave (52). There were 361 horses valued at $13,760.00, slightly more than $38.00 per head. Cattle numbered 1402, worth $10,740.00, an average of $7.66 per animal. Local banks had $1,100. deposited at interest, with $370. worth of merchandise on hand in local stores (58). In 1857, Bosque County had the lowest taxes in Texas, with miscellaneous property valued at $3113., and an aggregate of taxable property worth $74,483. Of taxes collected, the poll tax was $28.50, the state tax, $112.27, with county taxes totaling $143.12 (Richardson 1857:63).

The coming of the Civil War disrupted the local economy for about a decade. People who had fought alongside one another to win Texas' independence and then defended the State through the days of the Republic and the early days of annexation found themselves at odds over the issue of slavery. Threatened with severe punishment, including death, settlers either swore allegiance to the Confederacy, packed their belongings and left their homesteads, or simply disappeared, only to return after the resolution of the conflict.

Some went to war and never returned, like Alison Nelson, an ex-mayor of Atlanta, Georgia who had purchased land near Meridian in 1856. Nelson was a graduate of the United States Military Academy, but resigned his commission to be a lawyer. He served as Mayor of Atlanta in 1844, after being admitted to the bar and was a member of the Georgia legislature in the early 1850's. Between 1855 and 1858, he served as an Indian Agent under Lawrence Sullivan Ross. Nelson was elected to the Texas legislature in 1860 and the Secession Convention in 1861. He organized a regiment of Confederate infantry, the 10th Texas, and, as a commanding officer, was killed with some of them on October 7, 1862. He was buried in Little Rock, Arkansas, the whereabouts of his grave, unknown (Webb 1952 II:269). Some who were in the War hardly felt its passage, like Buck Barry:

> I served all during the war and never saw a Yankee soldier except three hundred prisoners who were sent to Camp Cooper on the Clear Fork of the Brazos, so that we could feed them cheap on Buffalo meat, until they were exchanged (Greer 1978: 227).

With almost no military conflicts in this part of the State during the Civil War, local attention was focused on dealing with the increase of raids by local Indian groups. Aware that troops were concentrated elsewhere, the Comanches were particularly troublesome. The coming of the end of the War did not reduce native incursions on settlers. From 1864 to 1867, raids by Comanches became commonplace, and included a raid on Buck Barry:

> The spring of 1867 saw the beginning of raids by the Comanches, repeated at every full moon, throughout the summer. In one of these raids they came into Bosque County and stole from me, in day time, thirty-seven head of horses and one strawberry roan stallion. I had turned the horses on the open range, feeling somewhat secure, as no raids had come quite to my vicinity, but the marauders stole past the settlements of the frontier line and raided a portion of my stock. Of course they knew from old experience the physical contours of the country and took advantage of mother nature in getting a good start on their way out (Greer 1978: 207).

Not all experiences with the natives were unfriendly. Tonkawas built their camp on the bank of Steel's Creek in 1865, in front of the house of Ed Nichols (near the town of Morgan). Nichols notes that their "wigwams" were made of cedar poles set in a large circle with the small ends coming together at the top, covered with hide, with an opening on the south side covered with a flap of hide. Bedding was made of prairie grass which was cut and put on the ground. The Tonkawas would assist in tracking the horses stolen by Comanche raiding parties. Apparently, the Tonkawas were camped at Steel's Creek for protection; they stayed there until after the Comanche raids had ceased. Nichols saw the last raiding party of Comanches in 1869 (Cutbirth 1943: 16-17). With the fear of the Indians fading, there was still much civil unrest in the 1870's, brought on by bitterness and reaction to Reconstruction. Vigilante committees were formed by local citizens in Iredell to deal with the lawlessness. South of town, three men were hanged for killing Ame Smith, then, they were buried in unmarked graves (BHBC 1986: 52).

Years later, Nichols noticed that the Santa Fe railroad bridge, built in 1882, crossed Steel's Creek within fifty yards of where the Tonkawas had camped when he was a child (1943:65). Nichols went to school with children who lived along the North Bosque. One year, he went to school in Iredell and boarded with the Loader family. With their son, George, he would go hunting along the River with a flintlock. If they killed a duck or rabbit, they often cooked it on the spot (1943:46-47). Other times, he went to school in Meridian:

> Most of the scholars came from one to three miles up and down the Bosque River to school. Several lived close together--the Hanna, the Gandy, the Gary, the Denis and the Lomax families. Their children walked to school together... I often noticed that Richard Lomax and his red-haired sister Mollie were in the lead. Sometimes their littler brother Johnny (John A. Lomax) came along to spend the day. He was a pretty, fat little fellow four or five years old, and I can see him now as he ran along by their side...On these days when Johnny came to school, the pupils studied something like half the time and watched him the other half. The little rascal was full of mischief (1943: 57).

As a child of four or five, Lomax became interested in the songs which cowboys sang, mostly to restless cattle, and began to write them down. At the age of 28, he attended the University of Texas, showed his collection of songs to a professor of English who declared them unworthy. Lomax burned his cowboy songs that evening. Years later, now a graduate student at Harvard University, Lomax showed a new collection of songs to two professors, who helped him secure three successive fellowships. He traveled to find his songs, writing down the words or making recordings. Lomax published *Cowboy Songs and Other Frontier Ballads* in 1910, with a preface by Theodore Roosevelt. It was the first collection of American folk music, and, the first with the music published with the words (Kamins 1987:40-44).

In 1878, Ed Nichols stretched the first barbed-wire in Bosque County, the same year he claims that Sam Bass and his gang stopped at the Nichols' house for provisions, with each member of the gang tossing him a silver dollar, then riding away(29-30). He thought the coming of the Texas Central Railroad in 1880 had a profound impact on prevailing economics. Greeted by merchants and townspeople, the railroad brought in settlers who bought land, then fenced their fields. Ranchmen began moving farther west to find range for grazing; most horse raisers had left the county by 1883 (Cutbirth 1943:98).

Buck Barry is buried in a family cemetery above the confluence of the East Bosque and North Bosque Rivers, a place which overlooks his beloved valley at the Forks, a few miles west of Walnut Springs, on RM 927. We went to Morgan, Texas, just northeast of Meridian to find Ruby Nichols Cutbirth, Ed Nichols' daughter and biographer of *Ed Nichols Rode a Horse*. We visited the town cemetery just south of Morgan. Here we located the graves of the Nichols family--Ed's parents and siblings and wife were there. Ed was found buried next to his wife, and on his opposite side, his daughter Ruby and her husband. As part of our search for the lineal descendants of the Nichols family in Morgan, we located Mr. Harris. Sterling Harris of Morgan, born in, and a 76-year resident of, Bosque County, knew Ed Nichols (personal communication: 1987). He gave us directions to the old homestead where the Nichols' house still stands. Mr. Harris recalled that Mrs. Nichols ran a dry-goods store in Morgan. Nichols, he said, smoked a big, curved pipe and, "could tell a story that would raise the hair on your neck." Nichols also saw the area transformed from the open range of his childhood, divided into parcels, to look much as it does today.

We inquired about Ruby Nichols Cutbirth. Mr. Harris told us there were no Nichols-Cutbirth heirs. We thanked him for his assistance and shook his hand, a hand that had shaken Ed Nichols', who had shaken Buck Barry's, whose hands had wrested this land from the Natives, then protected his holdings from encroachment by Comanches and others. As we bid goodbye to the community of Morgan and Mr. Harris, we felt a sense of loss, associated with the realization that another local storyteller had related her last tale and because our investigation of the recent history had come to a close.

Throughout the County, the role of individuals and groups and their contribution to local history is recognized and retained as an important aspect of community life. The contributions of Norwegian immigrants is manifest in two National Register Districts: the NORWEGIAN SETTLEMENT OF BOSQUE COUNTY, which contains 32 historic sites, with 14 contributing structures inside of a 2,900 acre rural historic district and the UPPER SETTLEMENT RURAL HISTORIC DISTRICT, with 13 farm structures and Old St. Olaf's Lutheran Church (Robinson, 1984). Many of the families who owned or settled this property have been registered by the Texas Department of Agriculture as part of TEXAS' FAMILY LAND HERITAGE, properties which have remained in family ownership and operation for 100 years, or more (Texas Department of Agriculture: 1974-1984).

Other National Register properties in Meridian include the Bosque County Courthouse, the Bosque County Jail and the First National Bank Building. A remarkable double-octagon pise´, or pied-a-terre, dwelling is located less than two miles southwest of Meridian, and listed in the National Register as the Bridges-Johnson House.

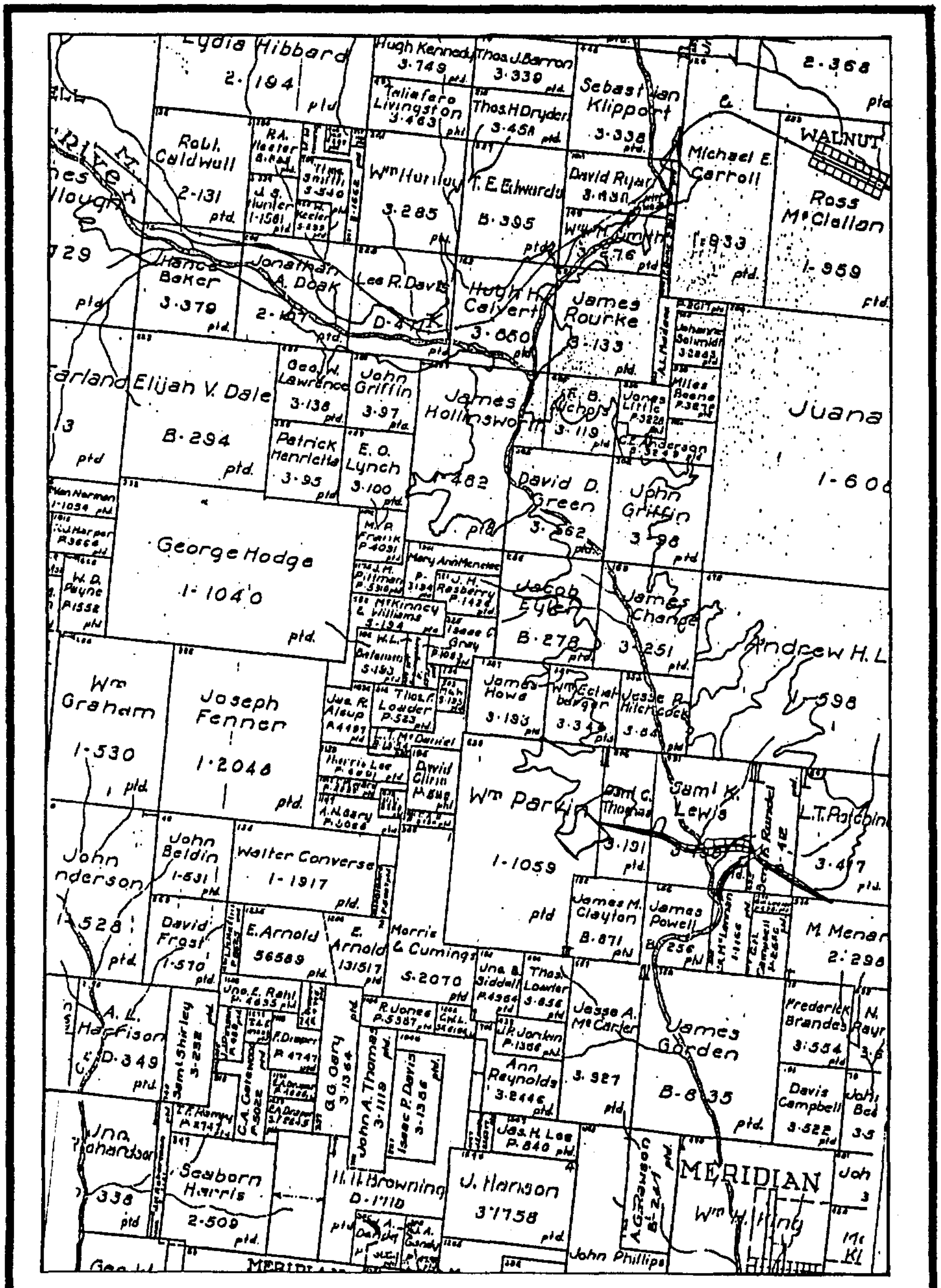

Figure 2. Map of Bosque Dam and Reservoir, showing original land grants

Figure 3. a. Meridian and lower Lake Bosque.

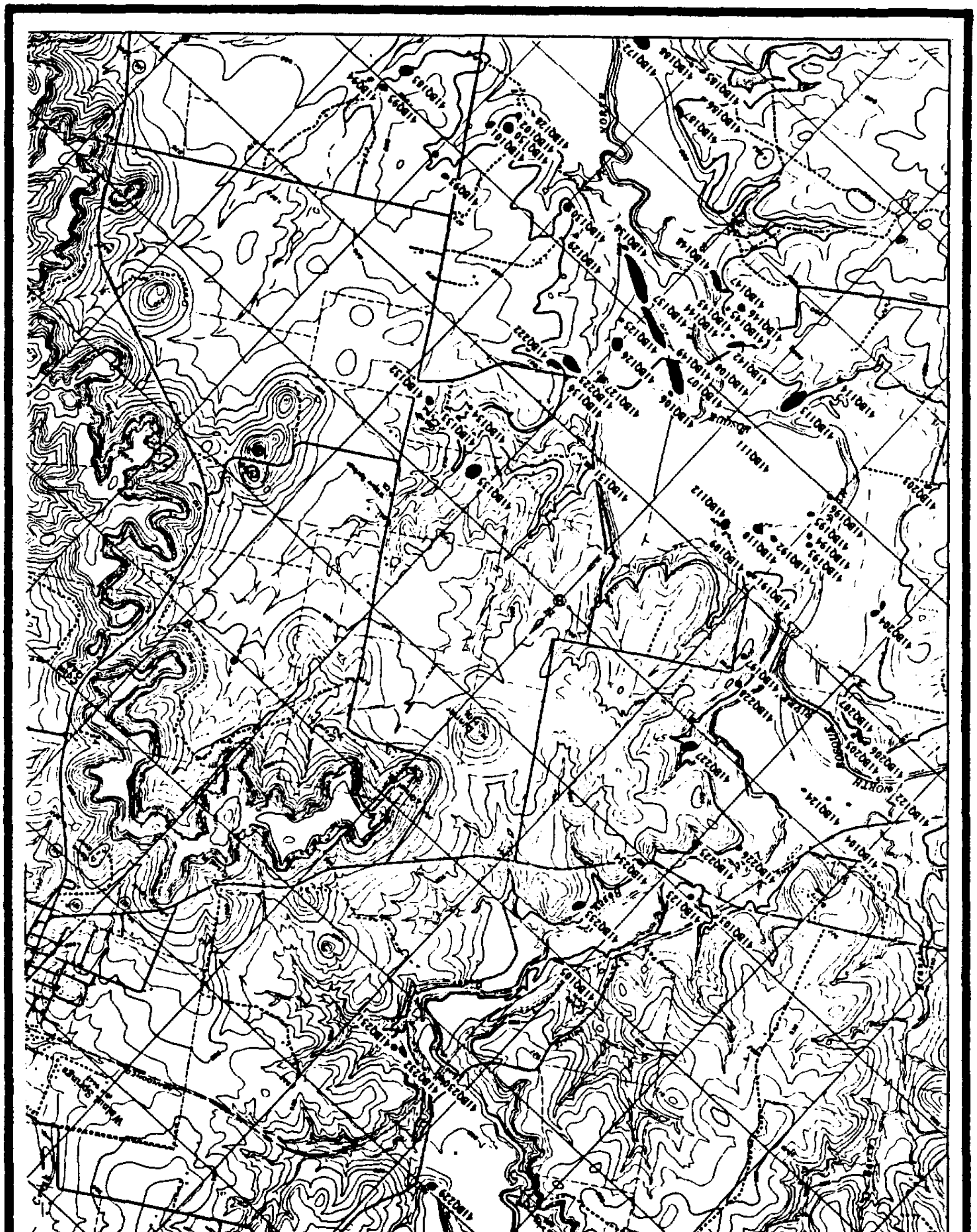

Figure 3. b. Walnut Springs and central Lake Bosque

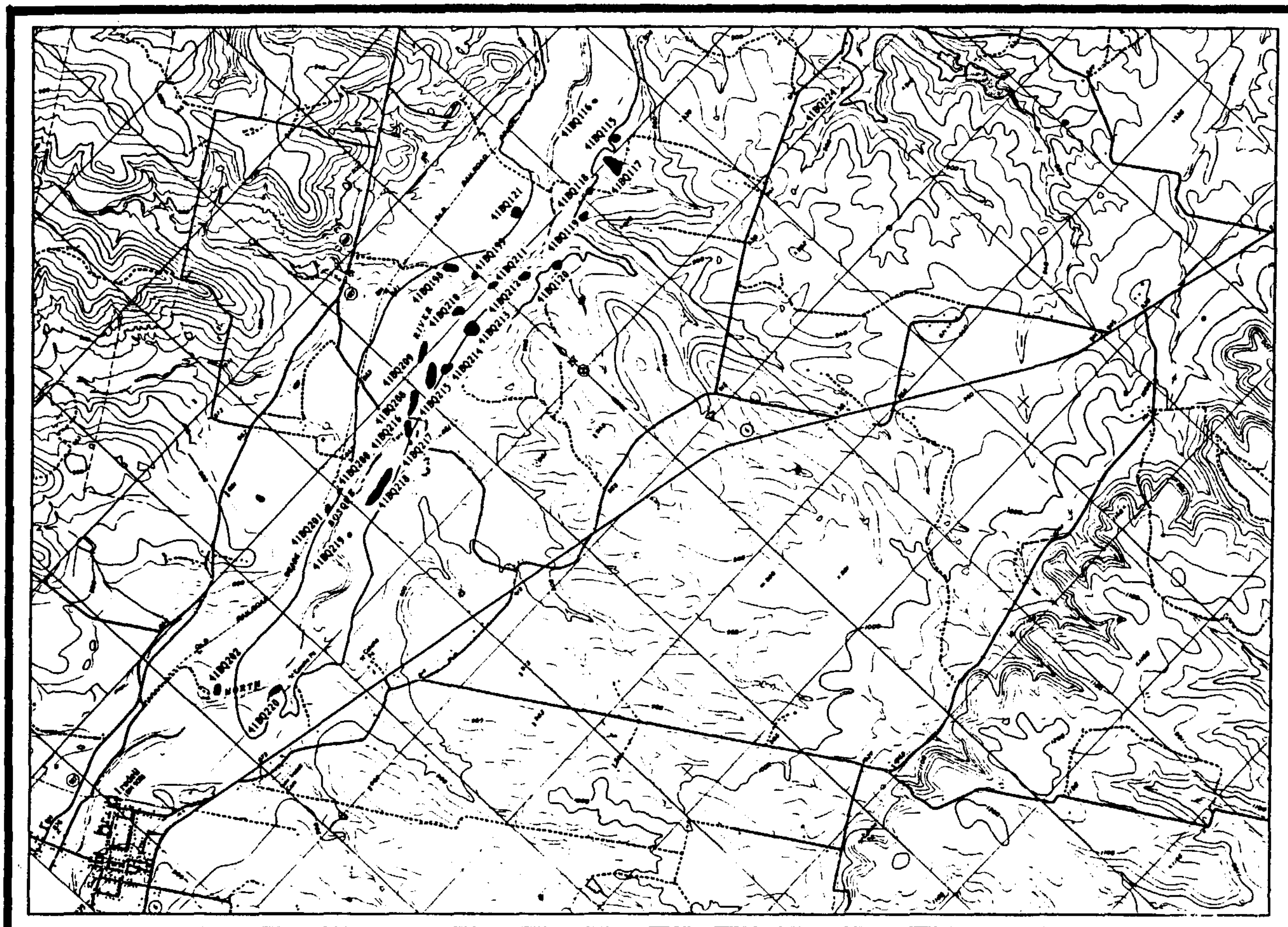

Figure 3. c. Iredell and upper Lake Bosque

SITE DESCRIPTIONS

During the archeological survey of the Bosque Dam and Reservoir, we found 146 areas which were recorded as archeological sites (See Figure 3). Seventy-seven of these were once used by Native Americans and of them, twenty were reused by historic occupants in the 19th century. The remaining 49 areas are historic ones. The following is a description and evaluation of the sites we recorded. The sites which are marked in bold headings are sites which are considered to be important to an understanding of the prehistory or history of the human use of the valley formed by the confluence of the North and East Bosque Rivers.

Site 41BQ93

Overlooking the proposed lake on the northeast, this prehistoric lithic scatter is located on the edge of an upland terrace knoll (See Figure 3.b.). Situated on a flat spot in the normally undulating Purves-Maloterre association of soils, the site is well-drained with water available at a nearby seep or spring-fed tributary to the Bosque, now the location of a stock tank 50 meters to the east. The site appears never to have been in cultivation; the ground surface is a brown gravelly clay sparsely vegetated with short grasses, thistle, juniper and mesquite. The site may have been disturbed by the construction of the stock tank nearby.

The lithic scatter on the site is a light one, with chert flakes, chips, and a biface fragment--probably the mid-section of a dart point--distributed over a roughly circular area about 30 meters in diameter. No diagnostic artifact forms were observed. While the site is badly eroded, probing revealed some 5 centimeters of wind-blown and slope-washed matrix remaining on site.

This eroded prehistoric site may have served as an open campsite or work area where raw lithic material was processed into usable forms. The low frequency of material culture provides little potential for yielding important information concerning the lifeway of Native Americans.

This site is outside of the area directly affected by the construction of the proposed reservoir, located at an elevation estimated at +843 feet mean sea level (m.s.l.). Sites such as this are generally not considered eligible for inclusion within the National Register of Historic Places. This site is not recommended for further investigation.

Site 41BQ94

Expressed as a broad scatter of historic artifacts as well as one chert flake found near a stream crossing, Site 41BQ94 is thought to be the remains of a 19th century ford of the creek, locally known as Nelson Crossing. Situated between two low drains which flow into the stream from the west, the site is located on a slight slope on the bank of the stream (See Figure 3.b.). In Tarpley clay loam which here is a dark grayish-brown, the site was heavily covered with dense grasses to 80 cm., intermixed with prickly pear cactus.

Artifacts discovered at this location included several fragments of ceramics from the latter half of the 19th century, including white ironstone and red transfer underglazes. Also from the same time period was a fragment of an aquamarine bottle which had been altered by fire. Further searching resulted in the discovery of one prehistoric chert specimen, a flake with a prepared platform. No other prehistoric material culture was found.

The presence of the lithic material hints that once in the past, a Native American stopped here and reduced a core, resulting in the loss of this flake. Initially, the historic material was thought to indicate the presence of a structure somewhere in the general area, but our search fail to discover any house or other dwelling remains, especially one that might have burned. Our final interpretation was that this was probably a camping area used by area residents, or travelers in the late nineteenth century. No evidence of a hearth was found. We did not question the local historic attribution of its use as a ford. About 200 meters to the north, we found the small cast concrete bridge which now crosses the stream.

This site is just inside the area directly affected by the reservoir, at an elevation of 840 feet m.s.l. Wave action during periods of maximun inundation of 841.3 feet m.s.l. will erode and destroy this site. The absence of intact features and the scarcity of artifacts offer few opportunities for further interpretation. This site does not appear to fulfill criteria for inclusion within the National Register of Historic Places and is not recommended for further work.

Site 41BQ95

Occupying a small flat hilltop above and between intermittent drains along the east and west which drain into the North Bosque River (See Figure 3.b.), this prehistoric site is a moderate lithic scatter about 35 meters in diameter which will overlook the proposed reservoir from an elevation of about 850 feet m.s.l. On soils of the Purves-Maloterre association, here a dark brown gravelly clay, the site is eroded to bedrock, but as much as 5 cm. of soil depth can be found by probing certain areas. Never in cultivation and used only as range for livestock production, the site appears relatively undisturbed.

With a ground surface visibility of about 30% during time of survey, the short grasses and cacti did not obscure the presence of a large variety of lithic material scattered about the site. Within a few minutes, the team had located a half-dozen biface fragments, several of which were broken projectile points, indicating use of this site during the Late Archaic and a small thick biface (See Figure 4.d). Lithic debris in the form of flakes, chips, and tool fragments; some flakes appear utilized, others marginally trimmed and thinned for use as tools.

This site served as an open campsite and lithic production area for Native Americans here in the Late Archaic. Although somewhat subject to natural disturbance and erosion, there is little to suggest that the site has ever been buried except periodically by wind-blown deposits. The site appears to retain good horizontal distribution and little or no impacts as a result of relic hunting. While not considered to be a single-component site, it appears limited to possible occupation by components restricted to the Late Archaic. The location of the site may indicate a subsistence strategy oriented toward exploitation of the upland prairie rather than the Bosque River valley. Controlled surface collection of lithic material and mapping of any notable features could yield information important in understanding the way in which this site and those of similar age, but along or near the mainstem of the Bosque, differ.

This site is outside the area directly affected by the project, but will likely suffer subsequent indirect impact as a result of greater frequency of human intrusion at the site, either by visitors, or by those who will build on the site because of its commanding view of the proposed project. The site is not a candidate for State Archeological Landmark status, but is recommended as one worthy of nomination to the National Register of Historic Places.

Site 41BQ96

Adjacent to a very large Liveoak on a hilltop overlooking a spring-fed drain to the Bosque, this historic site is located in the undulating soils of Purves-Maloterre association (See Figure 3.a.). The gravelly clay, with a majority of the gravel being fossil *Gryphaea* is here a chocolate brown, intermixed with humus. The ground surface was covered with short to medium grasses, but

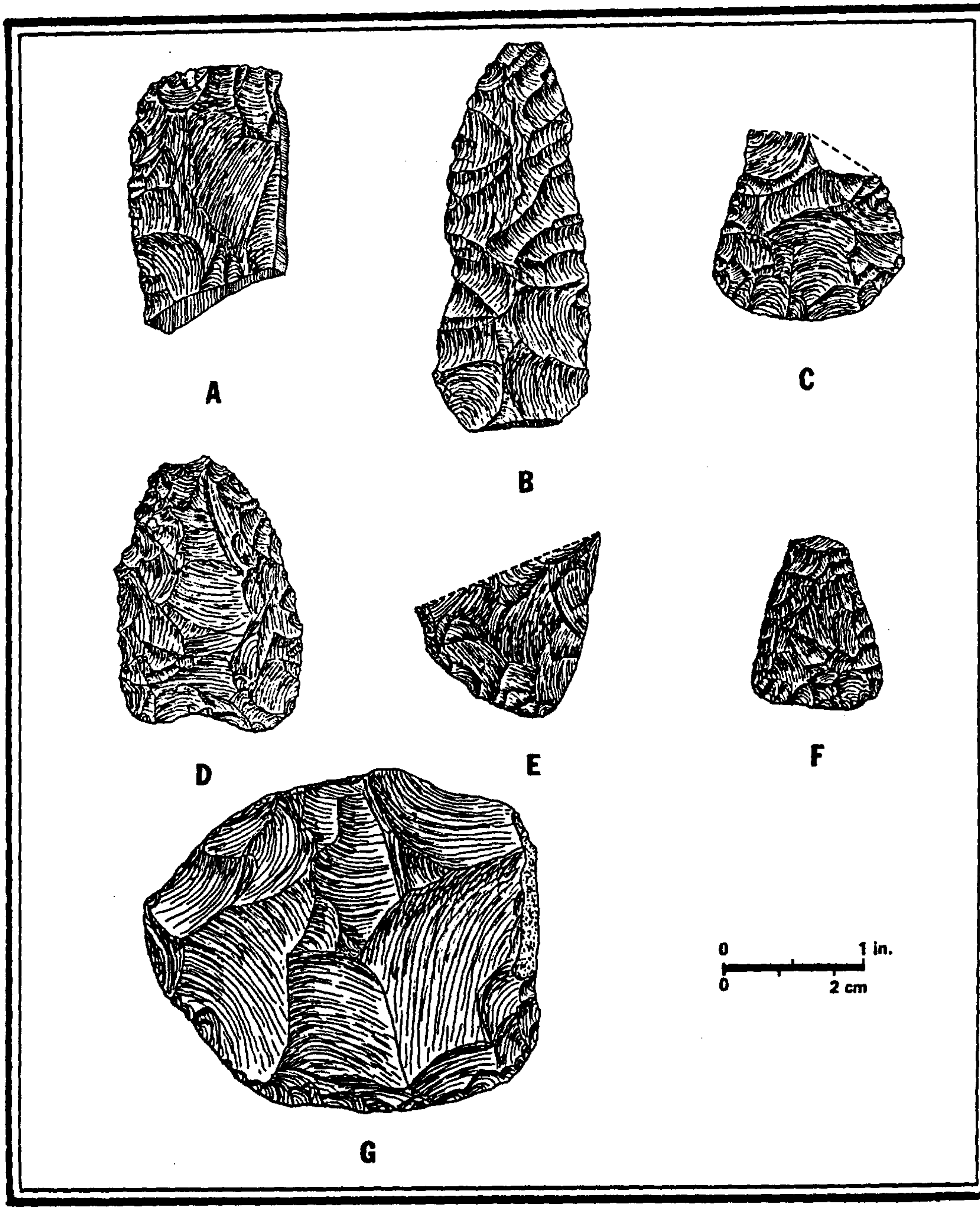

Figure 4. Bifacial tools recovered from the surface during the survey of proposed Lake Bosque

Figure 4. Bifacial tools recovered from the surface during the survey of proposed Lake Bosque.

a. This biface fragment of red and tan chert is from Site 41BQ148.

b. Plucked from an eroded profile about an inch below the surface, this biface blank is from Site 41BQ191.

c. Broken by torsion, this biface came from Site 41BQ121.

d. This small, thick biface has a notch opposite the concave edge and comes from Site 41BQ95.

e. One edge of this biface fragment bears the scars of repeated impacts; it comes from Site 41BQ215.

f. The edges of this small, thin biface from Site 41BQ139 exhibit crushed, shattered platforms.

g. This heavy, thick biface from Site 41BQ121 has crushed and battered edges.

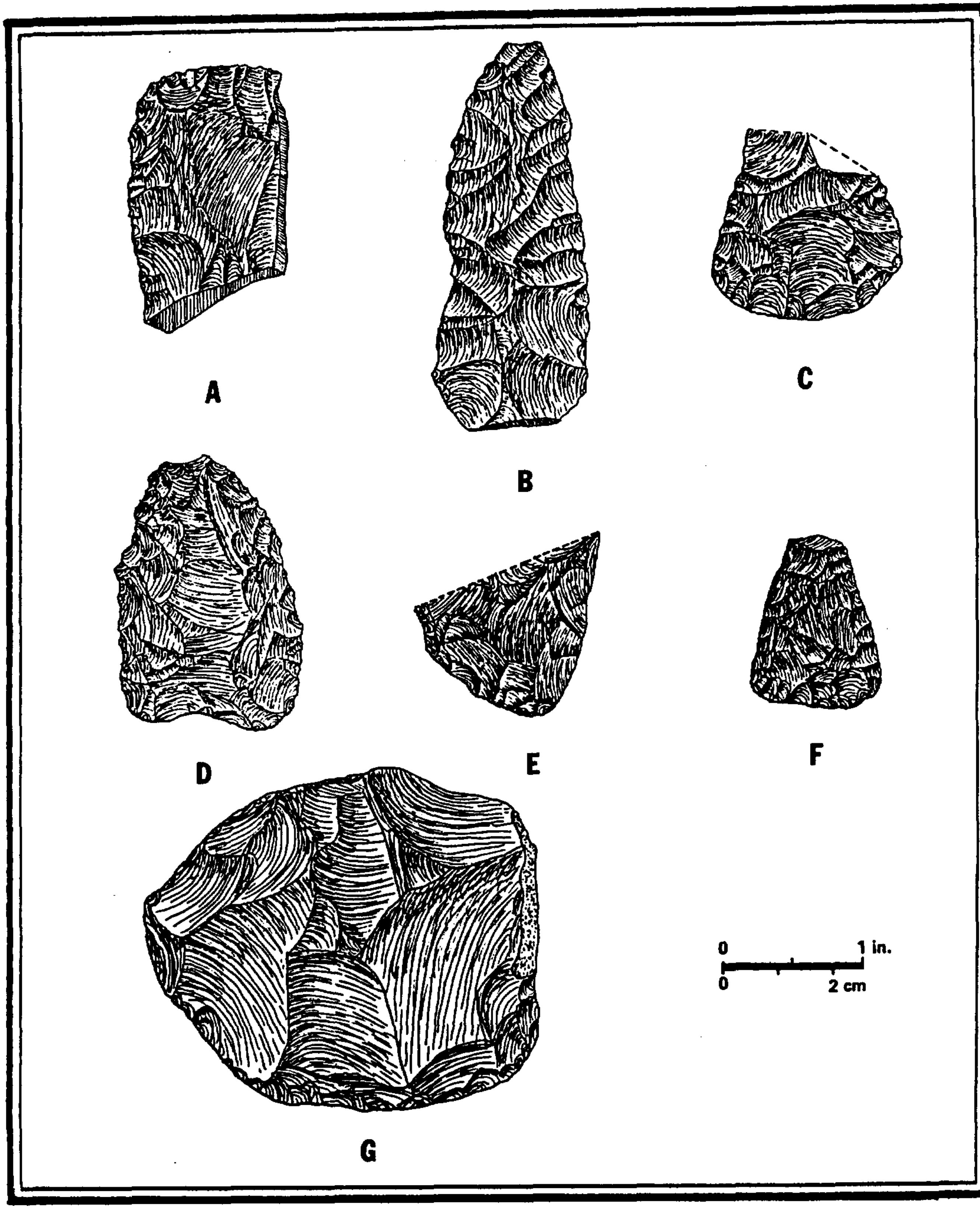

Figure 4. Bifacial tools recovered from the surface during the survey of proposed Lake Bosque

visibility was good. The array of historic artifacts recovered from the area provided a signature we normally associate with a house site. Much subsequent impact from construction and livestock production have altered the site.

The historic artifacts recovered within an almost 100 meter in diameter circle included a variety of ceramic sherds--fragments of white stoneware bowl or churn lid, white ironstone dish, and a brown stoneware food storage jar. Fragments of glass included so-called "black glass"--really an almost opaque dark green, brown, colorless and colorless now photochemically altered to purple. Metal artifacts include a threaded cast iron fitting, probably from a farm wagon, the proximal fragment of a drill bit with tapered pinstock, and cut nails. Collectively, they point to occupation in the late 19th and early 20th century, probably terminating not much later than World War I or from about 1880 to 1920.

Site 41BQ96 is heavily disturbed, thin and scattered, with no noticeable features. Like many historic homesites and earlier aboriginal sites found throughout this investigation, subsequent construction at the site has obscured or disturbed the cultural material in such a fashion as to render it of questionable value for interpretation.

Located at an elevation of about 830 feet m.s.l., the site will be inundated by the conservation pool of the project. Monitoring during clearing activities required for dam construction might reveal the presence of sub-surface features, such as privies, wells, or foundations, and is recommended. If found to contain useful data concerning those who once lived here, such features should be recovered by controlled excavation.

Too broad an area to sample without surficial clues, Site 41BQ96 is not presently considered for State Archeological Landmark status nor a determination of eligibility for inclusion within the National Register of Historic Places.

Site 41BQ97

Our pre-entry interview established from the lessee that chert and projectile points had been recovered at this prehistoric site. On an oval mount that drains to a well-watered tributary a few hundred feet northwest, the site is in soils of the Purves-Maloterre association, here eroded to a bedrock of fossiliferous gravels (See Figure 3.a.). The ground surface is lightly covered with short grasses, a few prickly pear and other cacti and yucca, and appears to have always been used for range. Disturbance resulting from the county

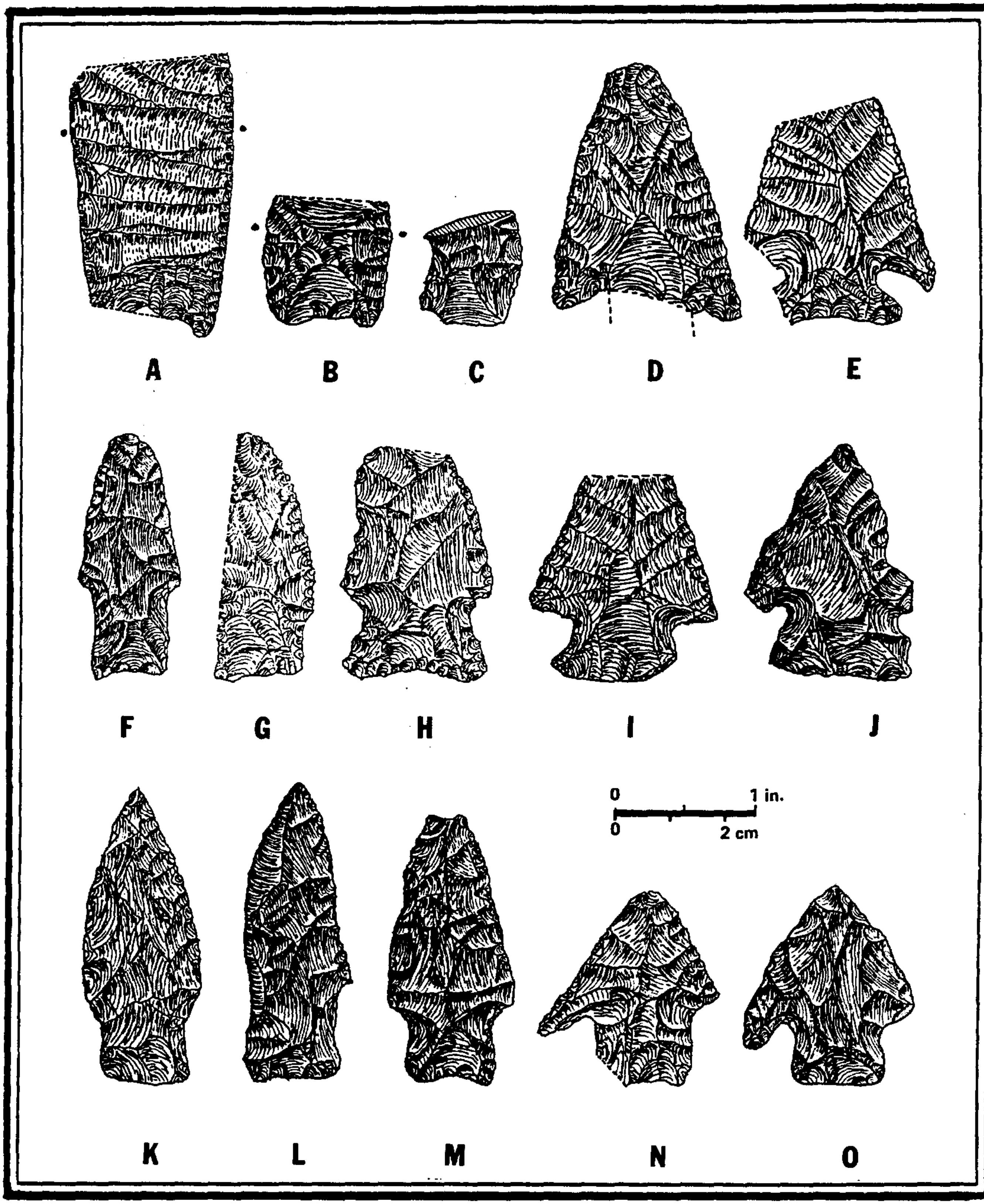

Figure 5. Projectile points recovered from the surface during the investigation of Lake Bosque

Figure 5. Projectile points recovered from the surface during the survey of proposed Lake Bosque.

a. Site 41BQ215

b. Site 41BQ227

c. Site 41BQ194

d. Site 41BQ227

e. Site 41BQ149

f. Site 41BQ206

g. Site 41BQ97

h. Site 41BQ151

i. Site 41BQ208

j. Site 41BQ215

k. Site 41BQ218

l. Site 41BQ151

m. Site 41BQ206

n. Site 41BQ195

o. Site 41BQ206

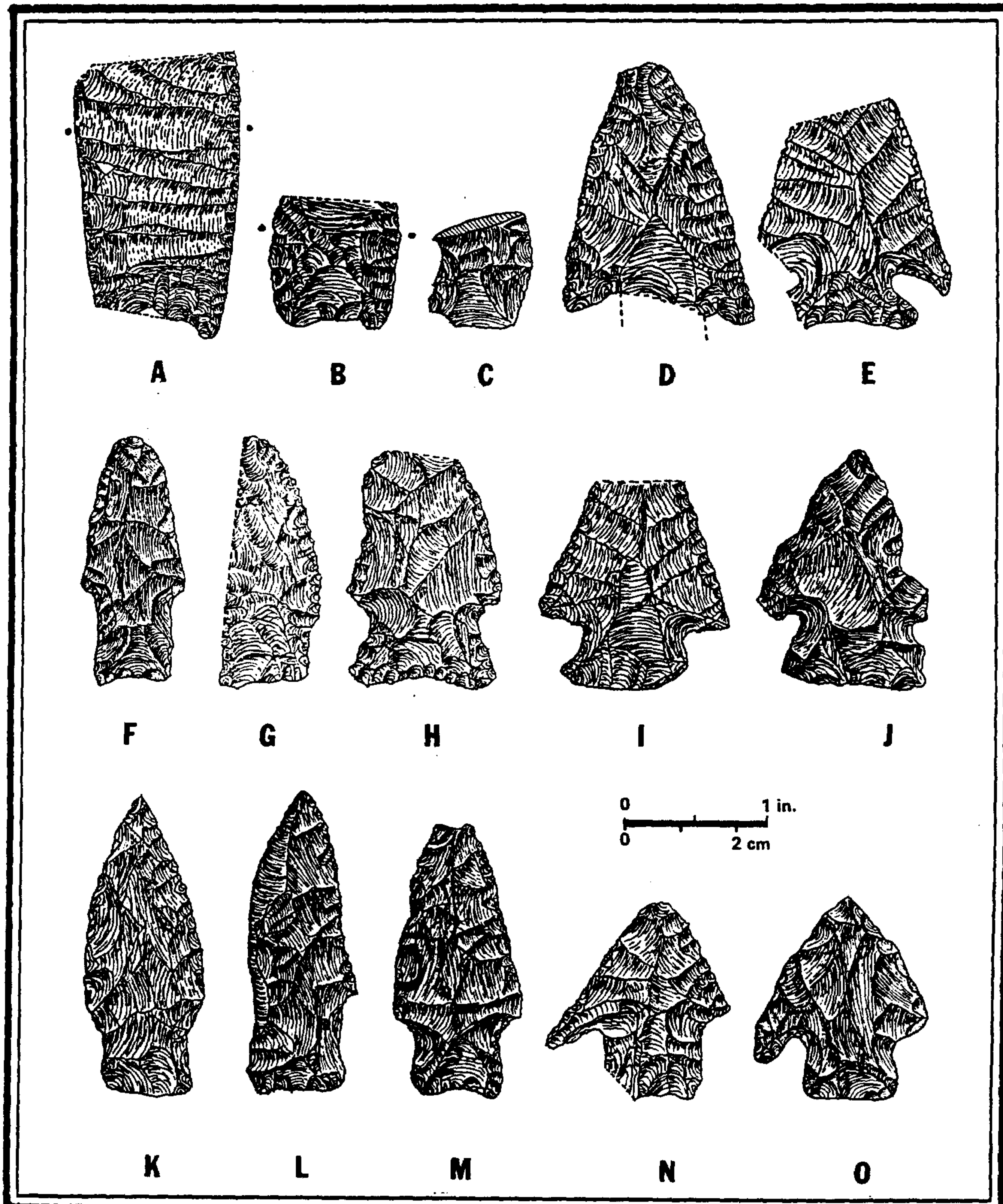

Figure 5. Projectile points recovered from the surface during the investigation of Lake Bosque

road which flanks the site and the unimproved road which circles the site include grading and other earth moving as well as improved access to the site. This has resulted in the area being subject to artifact collecting and the dumping of waste stone and other materials.

The lithic scatter on the ground surface is a moderate one. Flakes, chips, tools, and fragments of large and small bifaces of chert and an occasional manuport of red quartzitic sandstone are indicators that a number of activities, from food preparation to lithic reduction and tool production. Fragments of four large thinned aformal bifaces and two dart points (See Figures 5.g. & 6.a.) and a broken drill or arrowpoint preform broken in the process of reduction yield little useful information in determining the age of the site, but it is presumed to be Archaic. Accordingly, perhaps the most interesting artifact found at the site is a small thick biface, the edges of which have been battered so repeatedly as to form a flat surface, with the opposite edge revealing similar alteration.

This site is located at an elevation of about 840 feet m.s.l. and will be subject to periodic inundation and wave action. As the fossiliferous bedrock on which the site rests is not a thoroughly welded deposit, some erosion may continue. This site is similar in many respects to 41BQ95. Controlled surface collecting within selected portions of the site might help us better understand lithic reduction in the uplands and perhaps provide clues to subsistence strategies utilized by the occupants of the site. This site appears to fulfill criteria for inclusion within the National Register of Historic Places. Candidacy for State Archeological Landmark status is dependent on land ownership subsequent to development of the project.

Site 41BQ98

Marked by a few foundation rocks apparently in place on a low terrace, Site 41BQ98 was once a house. Located just across the spring-fed branch to the North Bosque (See Figure 3.a.), and opposite Site 41BQ97, the house may have been a log one--an assumption based on the scarcity of nails. Whatever the type of construction, little of the structure remains at the site, indicating the house may have been moved elsewhere. Today, the site is obscured by grasses of medium height, mesquite and juniper.

The few historic artifacts found at the site included fragments of whiteware, brown glass and fragments of sheet iron, probably the remnants of food cannisters or "tin cans." None of this material is considered to be diagnostically restricted to any particular period and accordingly, was not

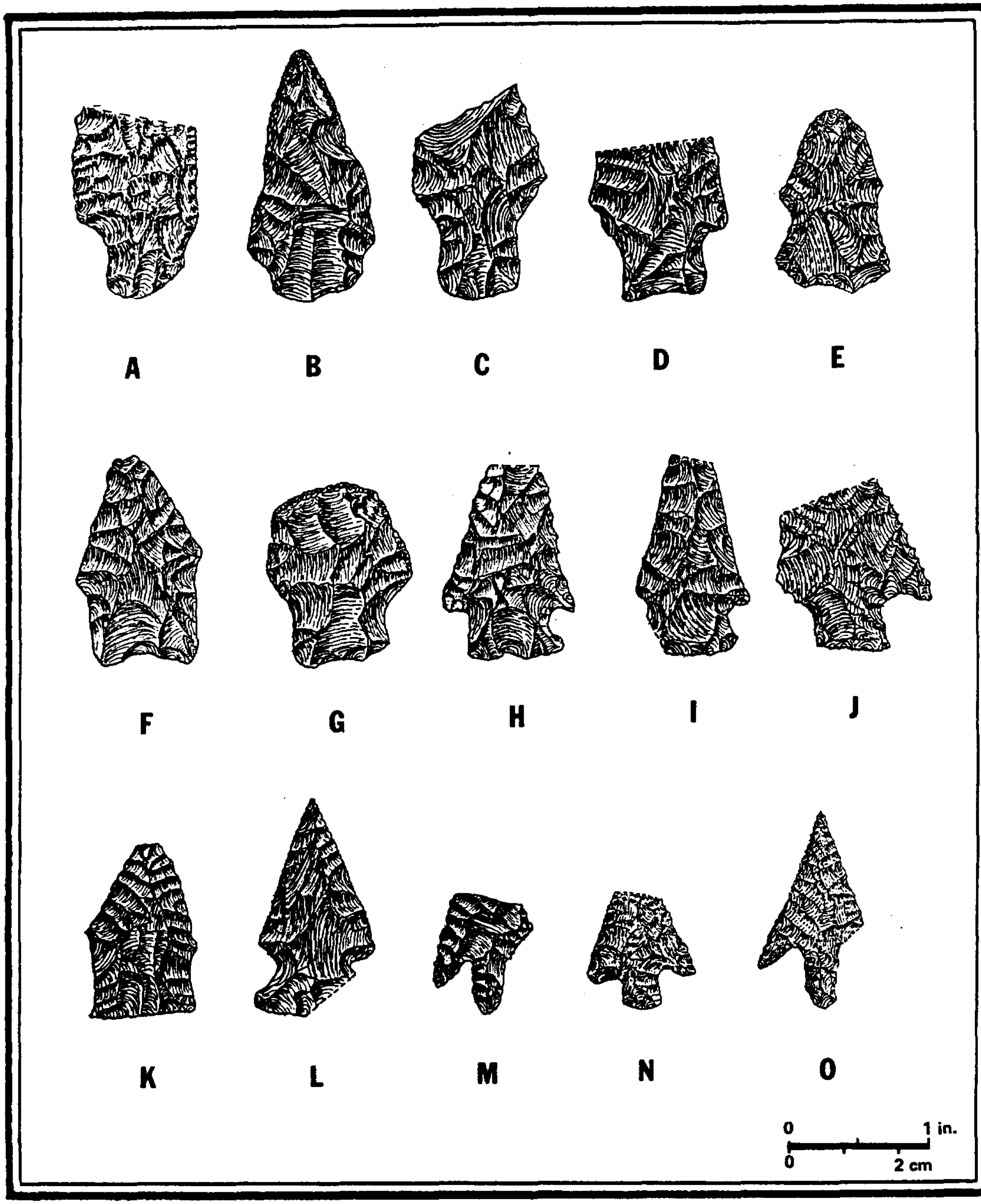

Figure 6. Projectile points recovered from the surface during the investigation of Lake Bosque

collected. The lack of 20th century artifacts, however, leads us to the suspicion that Site 41BQ98 was occupied to the late 1890's.

Notwithstanding the few foundation rocks apparent at the site, little in the way of cultural material remains for interpretation. Additional work here would be restricted to a careful mapping of the site, and selected controlled surface collection oriented toward determining the age of the site. Archival research may reveal whether this site represents the homesite of an original settler, or perhaps a tenant house.

Located at an elevation of 805 feet m.s.l., this site will be inundated by the normal pool elevation of 830 feet m.s.l. Interpretation of this site could enhance our understanding of the early settlement of this portion of the project area and accordingly, Site 41BQ98 is thought to fulfill criteria for inclusion within the National Register of Historic Places and is a candidate for State Archeological Landmark status.

Site 41BQ99

Located on a terrace overlooking the floodplain of the Bosque, Site 41BQ99 is the site of a house that was built in the late 19th century and only recently razed, perhaps within the last decade. Situated adjacent to the present road and linked by a primitive road which travels to what is now State Highway 144, remaining features include a windmill, pens, and a house foundation of rock (See Figure 3.a.). Sheet metal and debris resulting from demolition are still in evidence, although most have been removed. The medium brown Cranfill gravelly clay loam is vegetated in medium to tall grasses and is shaded and surrounded by liveoak and hackberry trees.

Artifacts on the surface include a wide range of fragmentary glass which extends from the 1890's until the present. Metal artifacts include cut nails, broken cast iron, sections of galvanized guttering and pipe, plumbing fittings, etc. The long time period of use here has resulted in a diffuse and intermixed scatter of artifacts, the majority of which are post World War I to the 1940's.

At an elevation of 805 feet m.s.l., Site 41BQ99 will be inundated by the reservoir at a pool level of 830. Because of the mixing of different aged material, the majority of which is quite late, this site is not recommended for further work. Given our present understanding of the site, it is not recommended for inclusion within the National Register of Historic Places.

Site 41BQ100

The location of a dart point discovered during our survey, Site 41BQ100 pinpoints its occurrence (See Figure 3.a.). At an elevation of 812 feet m.s.l., the point was found on an open hillside, above and to the west of an active seep. The fragmentary projectile point is similar in outline to the ***Marshall*** type but smaller(See Figure 6.j.). The projectile may have been lost or discarded here by a hunter during the Late Archaic for a search of the surrounding area revealed no other cultural material or features.

This site is not recommended for further work and is not considered worthy of nomination to the National Register of Historic Places.

Site 41BQ101

This site consists of the foundation of a house established here after 1870 and which may have survived to just after the turn of the century. No structural remains of the house are visible above ground surface although a few of the foundation stones can be seen in the grass. It probably faced to the northeast, toward a small, springfed tributary which drains from the north (See Figure 3.b.). In the Cranfill gravelly clay loam, a large number of artifacts were found among the short grass and cacti, the vegetation which dominate the site.

Ceramics including fragmentary earthenware, broken stoneware (ironstone dishes and a furniture caster), porcelain and core of an early battery are mixed with metallic artifacts like a saw blade, cut nails, a cast iron stove top, portion of a hole-in-top can and an aeolina, or mouth-harmonica frame (See Figure 7.c.). Glass in considerable variety is scattered around the structure.

This site appears to contain a wide variety of artifacts in appropriate and interpretable context. It appears to be related to Site 41BQ102, a complex foundation to the south-southwest of this house foundation.

At an elevation of 825 feet m.s.l., this site will be inundated at normal pool elevation of 830 feet. Thought to be important in understanding late 19th century development of this part of the project area, Site 41BQ101 is considered potentially eligible for inclusion within the National Register of Historic Places. and is a candidate for State Archeological Landmark status.

Figure 7. Concertina and aeolina, or mouth-harmonica, reed plates.

a. A fragment thought to have come from a concertina, this plate from 41BQ196 is made of whitemetal, and has widely-spaced reeds. It measures 35mm x 25mm x 1mm, and weighs 4.8 grams.

b. From a site thought to have included a log cabin, this aeolina plate is from 41BQ134. Made of brass, it measures 99 x 25.5 x 1 mm and weighs 16.6 grams. This is thought to be the earliest plate found.

c. The site where this plate was found was active in the 1880's. From Site 41BQ101, it is made of brass and measures 101 x 25 x 1mm and weighs 18.2 grams.

d. From Site 41BQ229 on the FlatTop Ranch, this brass plate is from a housesite occupied at the turn of the century. It measures 107.5 x 29 x 1mm and weighs 21.8 grams.

e. From Site 41BQ152, a housesite occupied until the 1940's, comes this iron reed plate which measures 100 x 25 x 1 mm and weighs 12.6 grams.

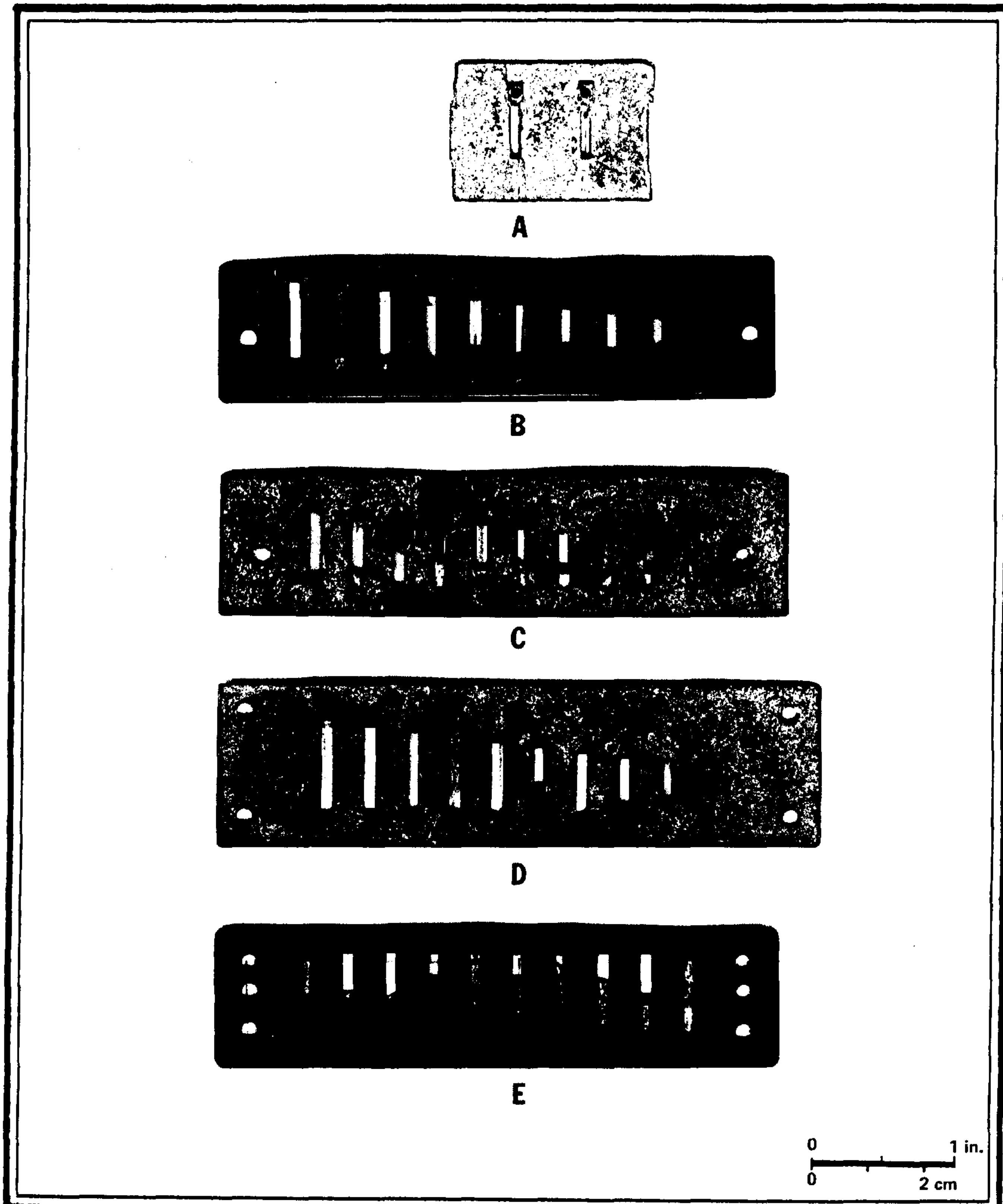

Figure 7. Concertina and aeolina, or mouth-harmonica, reed plates

Site 41BQ102

This foundation is thought to be the remains of a barn partially dug into the edge of a ridge to take optimal advantage of natural warming from the sun and protection in winter from prevailing northerly winds. Of large locally available stone, the structure is a subgrade foundation which now extends to 4 feet below adjacent ground surface, but with probing, we estimate it once extended to as deep as 5.5 feet. With external dimensions of more than 60 feet long and 20 feet wide, it is the largest 19th century structure found in the project area.

Outside the structure to the north and west are irregular outlines of rock, some rectangular, others square, with fences and gates. Its overall pattern is one that is designed for the movement and management of livestock. storage of materials, plus other unknown functions. It is possible that whatever was being constructed here was never completed, but was at least finished to a point where the site became functional. Artifacts are uncommon in the area directly adjacent to the foundation and once away from the site, are those normally associated with a late 19th century and early 20th century homesite, perhaps with Site 41BQ120, just across the fence to the west-southwest. The structure is thought, however, to be related to Site 41BQ101 because it is located on the same terrace, is on the same side of a property line and is strategically located for livestock, between the house and the fields, close to water, but downstream from the possible domestic water source and downwind (See Figure 3.b.).

Additional mapping and limited excavation might reveal further insights into the nature and function of this interesting structure. At an elevation of 825 feet m.s.l., this site will be flooded by normal pool elevation of 830 feet m.s.l. This site is considered to be one which is potentially eligible for inclusion within the National Register of Historic Places and a candidate for State Archeological Landmark status.

Site 41BQ103

Marked by a standing chimney alongside the unimproved road which leads to Fulton Cemetery, Site 41BQ103 includes a foundation, the chimney, the remainder of a porch slab and subsurface feature, probably a storm cellar. Located in Sunev clay loam, here reddish brown, the housesite is situated in an open meadow above and northeast of a small tributary which drains to the East Bosque River (See Figure 3.b.). Dense short grasses cover the ground, and the site is shaded and surrounded on the north by small oaks and hackberry.

The structure is located adjacent to a road which ran east-west, now replaced by R.M. 944. This road also ran to the north and in front of 41BQ123, a house built in 1881. When this road was abandoned is unknown, for it could have been deserted when the railroad was constructed through this area, changing local roadways, or later, with the construction of R.M. 944 during this century.

Earthenware fragments in the form of crockery and stoneware, impressed whiteware, ironstone (See Figure 8.m.) and one decorated by polychrome decalcomanias, was mixed with a variety of colorless glass, including canning jars associated with zinc lid fragments. Also found was a fragment of a divided plate as might be used to serve children, made of colorless glass and impressed from the rear with a figure of "'Little Bo-Peep" and running sheep, and the words "(y)ou Going," intaglio.

All artifacts found on the surface of this site suggest a settlement beginning as late as post-1920. This late structure seems to reflect almost urban patterns of artifact selection, perhaps a result of one of the family members working in the city, but living in the country, a common mid-20th century lifeway in rural Texas.

Located at an elevation of 835 feet m.s.l., this site will be subject to periodic inundation during times of flooding to an elevation of 841.3 and during filling and drawdown, will be subject to washing and wave erosion. At our present level of understanding of this site, it is not considered eligible for inclusion within the National Register of Historic Places.

Site 41BQ104

Located along the northern boundary of proposed Lake Bosque, usually inside the normal pool elevation of 830 feet m.s.l., this site is the remains of the Texas Central Railroad, built here in 1881 (See Figure 3.b.). The Texas Central Railroad began to decrease its trackage as early as 1893, when 52 miles of trackage were sold to Texas Midland Railroad (Zlatkovich 1981:88). Crews working out of Walnut Springs extended the line, which included a depot at the S.M. Swenson Cattle Company, to Stamford by 1900. World War One brought a period of growth to the railroad and the communities which the rail served. The end of the War resulted in a general economic downturn, not to be improved by the coming of the Great Depression. As noted in *Bosque County: Land and People*,

Figure 8. Ceramic sherds with maker's marks recovered during the investigation of Lake Bosque.

a. Site 41BQ130
b. Site 41BQ196
c. Site 41BQ228
d. Site 41BQ107
e. Site 41BQ107
f. Site 41BQ236
g. Site 41BQ138
h. Site 41BQ107
i. Site 41BQ229
j. Site 41BQ234
k. Site 41BQ229
l. Site 41BQ228
m. Site 41BQ103
n. Site 41BQ149
o. Site 41BQ118

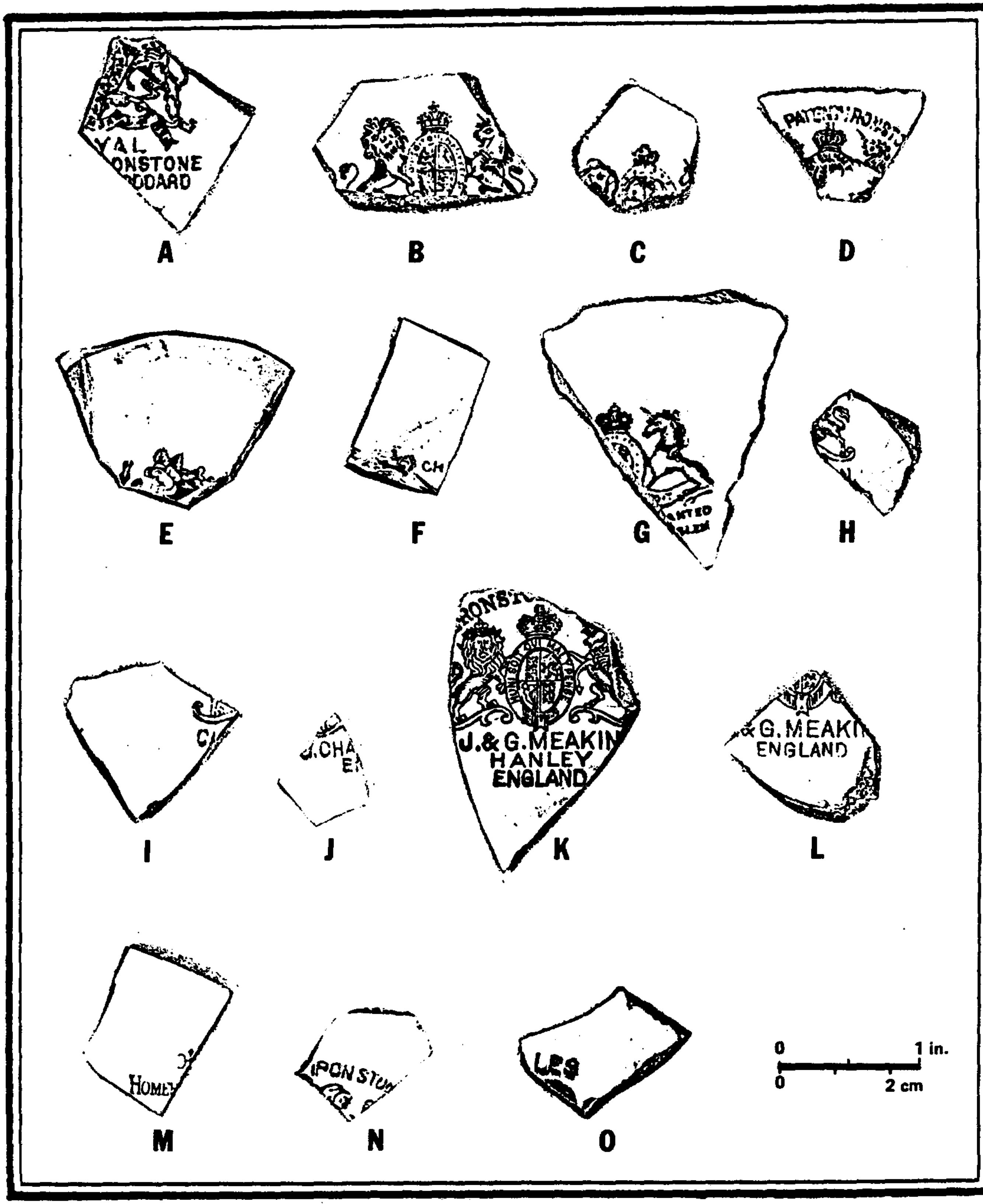

Figure 8. Ceramic sherds with maker's marks recovered during the investigation of Lake Bosque

> People lost their jobs, banks closed, drought came, railroad employees were laid off, and all of this spelled doom for the proud little Texas Central and the town that it helped to build. Finally, only a Diesel motor car brought the mail although freight service continued during the years of construction of Whitney Dam. Today the old right-of-way, covered, as it is, by grass, wild flowers and old cross ties, remains to mark the path of the old railroad line that Henry McHarg envisioned and planned to extend as far west as Artesia, New Mexico (Bosque County Historical Book Commission [BCHBC] 1986: 96).

We found not only the cross ties, but also remnants of the old telegraph system which used to parallel the trackage, including coils of the heavy gauge wire, discarded to the side of the right-of-way during rail removal. We collected a spike and several insulators from the debris left by abandonment in the drainage easement adjacent to the railroad grade. Only a small fraction of the abandoned line will be covered by the reservoir, as it extends for miles in either direction outside the project area.

We looked adjacent to the abutments, especially on the eastern side to find any traces of construction camps which might have been active in the building of the railroad in the early 1880's, but no features or artifacts which might have been associated with this labor were discovered. Perhaps construction crews lived in nearby Walnut Springs or were housed in rolling crew cars during construction here. Site 41BQ104 is not recommended for further work.

Site 41BQ105

This prehistoric site of unknown age was found atop an eroded and cultivated flood plain rise of the East Bosque River, the channel of which is 70 meters to the east of the site (See Figure 3.b.). Marked by a very light scatter, a reduced core and fragments of mussel shell, the site is located at an elevation of 834-839 feet m.s.l. and will be subjected to infrequent flooding by the proposed lake.

Our observations led us to believe that the majority of the site is exposed, and derived from its original context. The site was recorded because of its importance in understanding the overall settlement plan for the area affected by the project. At our present level of knowledge concerning Site 41BQ105, it is not recommended for a determination of eligibility for inclusion within the National Registor of Historic Places nor is it a candidate for further investigation.

Site 41BQ106

Located on the slope of what is thought to be a pleistocene levee of the Bosque River, the Pearce Cemetery is adjacent to the Pearce Homestead, Site 41BQ107, below (See Figure 3.b.). Surrounded by a cast iron cemetery fence manufactured by the Stewart Iron Works, Cincinnati, Ohio, the plot contains at least two, and perhaps as many as five, interments, the latter three external to the fence. The west face of the gravestone is marked:

A. C. PEARCE	ANN M. Wife of A. C. PEARCE
SEPT. 17 1823 NOV. 3 1878	April 1 1827 April 4 1871

Gone but not forgotten

FATHER	MOTHER

Outside of the fence, on the northwest corner is found a rectangular stone which appears to be unmarked. A variety of stories have been encountered from local residents concerning the possibility of interments outside of the fence. These included that the stone found outside is one of a kinsman who was convicted of killing a freed slave and was buried contrary to the others, the orientation of his grave running north-south! Others told us that two persons, freed slaves once belonging to the Pearce family, were also to be found outside the fence.

This site lies at an elevation of +805-806 feet m.s.l. and will be flooded by normal pool operation at +830 feet m.s.l. While this site is, as are most cemeteries, not considered as a candidate for nomination to the National Register of Historic Places, it is eligible for designation as a State Archeological Landmark. Careful excavation and total relocation are recommended for this cemetery.

Site 41BQ107

This site is thought to be the homesite once occupied by Ann M. Pearce and her husband, A.C. Pearce. Situated on the northern tip of the red clay levee (See Figure 3.b.), the site is superposed atop a prehistoric one of Archaic age. Portions of the house foundation appear to remain, but they are scattered as is the entire site.

A review of maps on file in the Bosque County Tax Assessor-Collectors files in Meridian reveal that as late as 1971, the site and adjacent cemetery were located in a thicket of woods. Change in ownership resulted in new management practices with conversion, through clearing and sodding in coastal bermudagrass, to range. This may have included the use of heavy machinery, including dozers, to remove vegetation. It also included the removal of foundation stones, which were carried to the edge of drains where they were cast into eroded areas to serve as catchments for slopewashed topsoil. This proved to be a typical effect on historic homesites found throughout this property. We are not able to determine whether the burned artifacts found at the site are the result of a fire which might have consumed the house or from brush which might have been piled here and burned during the 1970's. Among the artifacts we recovered were several sherds of whiteware impressed with marks indicating British manufacture (See Figure 8, d., e. & h.).

Despite its disturbed condition, this site is thought to be an important one in understanding the early history of the project area and this area of Bosque County. The site is considered to be eligible for inclusion within the National Register of Historic Places and for designation as a State Archeological Landmark. It is therefore worthy of further investigation, including mapping, controlled surface collecting and the search for sub-surface features. Little remains of the prehistoric site outside of a broad lithic scatter, and it is not recommended for further investigation except as it is encountered through the investigation of the historic homestead.

Site 41BQ108

This site is the Austin Bridge, found at Jackson Crossing, the only highwater crossing of the Bosque River in the project area. Located near the Pearce Homestead and Cemetery, the bridge was once the site of a ford which had its beginning just north of the eastern footing of the present bridge (See Figure 3.b.). Here can still be seen the old cut which descended to the river channel, apparently ran upstream for approximately 50 to 60 yards and then crossed over the low bank to the opposite side , just north of the bluff atop which is found the western footing of the present bridge. The bridge trusses on either end measure about 50 feet, with the central truss measuring about 100 feet for a total bridge span of 200 feet. Each truss has the markings of the manufacturer on brass plates, attached by screws, which read:

Built By
AUSTIN BRIDGE COMPANY
DALLAS, TEXAS
Date 9-38 Contr. No. [ ]
Built for [ ]

Three trusses make up the structure, two modified Pratt through trusses, with diagonals in tension, and verticals in compression, and with *no* hip verticals adjacent to the inclined end posts (Comp 1977: Diagram 12). The central truss is a modified Parker, a Pratt with a polygonal top chord, in this case, with 6 slopes and flat center top chord. According to Comp,

> Many trusses retain the Pratt configuration of compression and tension members, while alternating the shape of the top and bottom chords. The Parker truss (diagram 14) is clearly a Pratt with polygonal top chord. Because of its arched top chord, the bridge is stronger than a regular Pratt truss, while it uses the same amount of material. However, the sizes of members in a Parker truss are not as uniform as they are in a Pratt, and consequently, they were often more expensive to construct(1977:3-5).

This engineering site is almost 49 years old at the present writing, but before the project is completed, will achieve the age of 50 years, making it eligible for consideration as a State Archeological Landmark or for the National Register of Historic Places. The structure is limited in its ability to bear loads, but the bridge is still considered suitable to carry traffic. The Bosque County Commissioners plan to relocate this bridge for reuse.

Site 41BQ109

This eroded open campsite on the northeast edge of a terrace which slopes to the southwest, adjacent to a drain (See Figure 3.b.), was located because of the fired-cracked rock scattered downslope by wash and erosion. Not found to be concentrated into a recognizable feature, the burned and discolored rock points to probable food preparation here, although no organic remains were noticed. Among the stones was found one chert flake, devoid of cortex.

This site is not one of those we consider to be of further interest. It is not considered to be eligible for inclusion within the National Register of Historic Places at this time.

Site 41BQ110

This multiple component site is located on a sand covered, clay terrace overlooking the bottomlands of the Bosque (See Figure 3.b.). The site is altered by earth moving machinery which have been used to dam the small tributary gouge to the west. Fed by runoff and seeps in the uplands, this site was attractive to prehistoric inhabitants as is evinced by the so-called "biscuit" mano recovered from the surface (See Figure 9.a.). While historic artifacts are abundant on the surface eroded to clay, there is an extreme paucity of other prehistoric items.

The site has been subjected to relic hunters searching for historic materials with the aid of a metal detector, and we found the accumulations of metal artifacts which reflected this form of disturbance in two or three areas on the site. Conversations later held with the landowner indicated our assessment was correct and that he had permitted such activity, but only with persons who could demonstrate an interest in the early history of Bosque County. Some disturbance has also resulted from the utilization of a nearby old and unused trench silo for garbage disposal. Despite this disturbance, we believe that the historic component of Site 41BQ110 merits further investigation.

Strangely isolated in the center of the site, with disturbance all around it, was found the remains of a hand-dug rock-lined well, filled to within 30 inches of the surface.

Of unknown depth, this well could contain deposits of cultural material thrown into it after it no longer produced water or was replaced by another water system. If present, these deposits would be stratified, the earliest on the bottom, the most recent, on top. Two such wells were encountered during monitoring of construction at 301 Congress Avenue, in Austin, Texas during late 1984 and early 1985. Called "tube middens" by archeologists working on the project, these wells produced thousands of artifacts and fragments when dug to a depth of between 25 to 30 feet below ground surface (Briggs, forthcoming). Well preserved perishable items, including food bone and bone tools, leather and leather shoes, and non-perishables like dishes, glassware, liquor and other bottles, buttons, children's toys, corroded tools and parts of tools, plus a number of bucket bails, were found in abundance. One well produced one of the earliest dated historic artifacts discovered in Austin, a latch plate for a lock patented by Carpenter in 1830 and produced during the reign of William IV of England, between 1830-1837. The well at 41BQ110 might be similar to those just discussed or be empty. Only deep archeological testing using heavy machinery will provide

Figure 9. Manos or grinding tools recovered during the survey of proposed Lake Bosque.

a. This grinding stone is made from indurated, sedimentary sandstone. Apparently a function of its use, the lateral edges were pecked and ground until they were flattened. The resulting edges resemble a layered biscuit, hence the term, "biscuit mano." Of the many types of manos collected or observed throughout the investigation, these are the most common. The consistent size and shape of "biscuit manos" suggests that most of these multi-purpose food processors are worn past utility, and were rejected by their users. Our experiments indicate that palmar and digital abrasion would be a result of continued use. This one comes from Site 41BQ110.

b. A side of this quartzite grinding stone still resembles the original, unaltered pebble, but the other has the uniformly ground surface associated with a mano. The trace of scratches which mark the direction of use are still visible on this face. One edge has been flattened by crushing and grinding. This type of mano, generally made from a pebble of hard rock and retaining many rounded surfaces, is the other common one found in the project area. This one comes from Site 41BQ139.

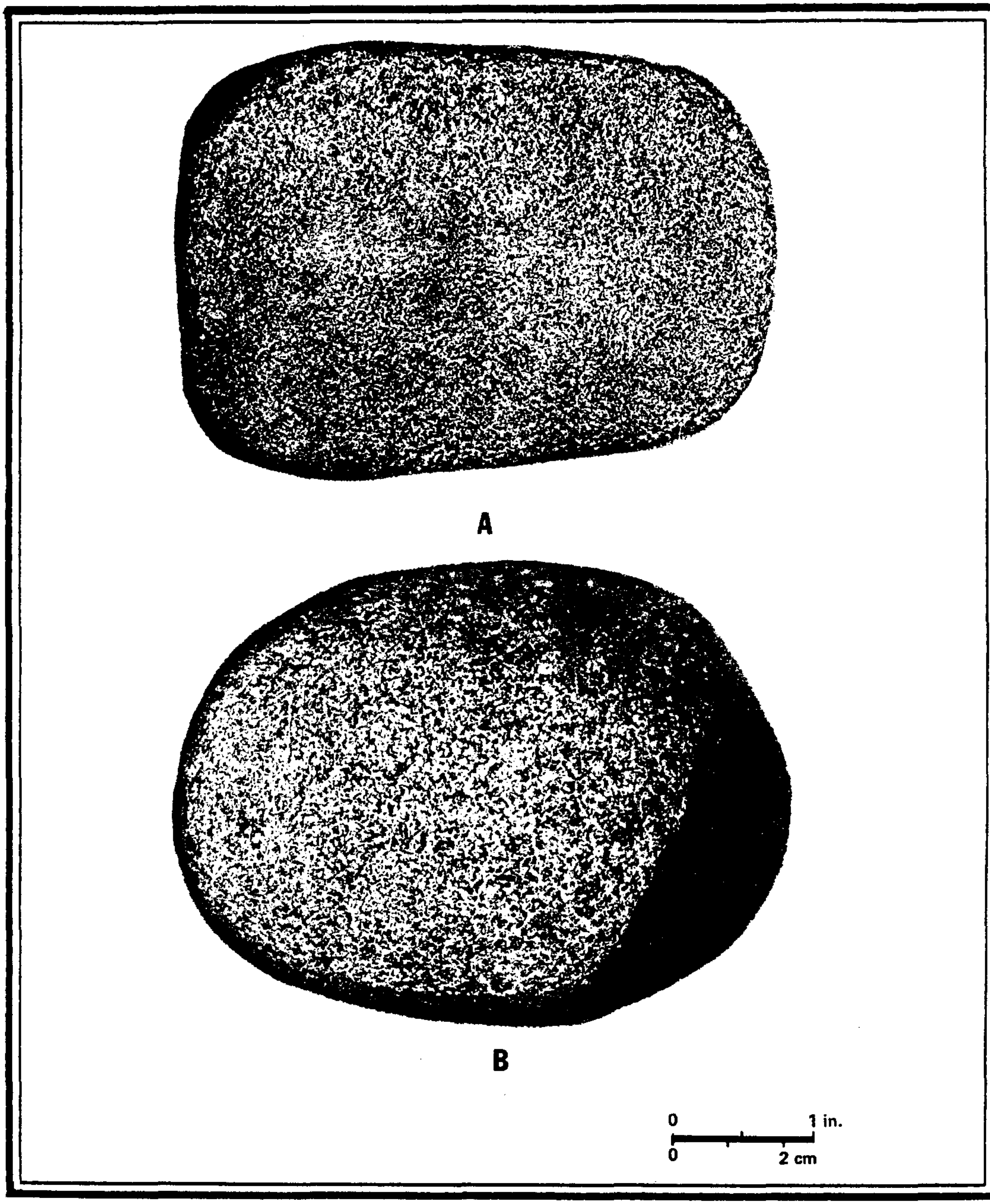

Figure 9. Manos or grinding tools recovered during the survey of proposed Lake Bosque

an answer. Our probes struck nothing when we passed them through the uppermost fill of the well.

Eligible for designation as a State Archeological Landmark, and considered to be potentially eligible for inclusion within the National Register of Historic Places, Site 41BQ110 is recommended for further work prior to inundation by Lake Bosque.

Site 41BQ111

This prehistoric site is located on a very slight floodplain rise adjacent to an ephemeral drain from the uplands (See Figure 3.b.). Discovered in an area devoted to feed production, the site was recently plowed. Scattered in the recent alluvium by tillage, a few large pieces of burned limestone marked the presence of a hearth in the general area; close inspection revealed the fragments of mussel shell, the remains of food which had once been prepared here.

While little of the site remains, its presence on a flood plain rise is similar to other sites found during this investigation, which, when exposed in profile, contain stratified deposits of food remains. Presently in production, this site is recommended for deep testing to determine the presence of such cultural deposits and to gain a better understanding of the sedimentary regimes of the Bosque River in this area. Site 41BQ111 is considered potentially eligible for inclusion within the National Register of Historic Places and for designation as a State Archeological Landmark.

Site 41BQ112

Located on a high secondary terrace of the Bosque River, some twenty feet above the floodplain (See Figure 3.b.), this site is presently occupied by a very large pole barn used for the storage of hay. An examination of the periphery of the ground surrounding the structure, especially under the dripline of the roof, revealed the presence of fragmentary historic artifacts, such as ceramics, glass and iron. No historic features were noted.

After we recorded this site, an interview with the landowner resulted in gaining important information about the site. This included a photograph, circa 1900, which identified the area as the site of the barn of the Ramsey Cox Farm. The photograph was labeled," The M.T. Westmoreland Family at Headquarters of the Ramsey Cox Farm, Walnut Springs, Bosque County (personal communication: Alfred McKnight, Jr.)." An interview with a descendant of Joe Westmoreland told us of a slave burial near an oak tree just north of the present structure (personal communication: Tom Hill).

This site is a candidate for further archeological investigation subsequent to the removal of current standing structures. Archival research should tell us more about the Cox Farm and the Westmoreland family. Serious efforts should be devoted to searching for the grave reported near the old oak and if discovered, recovered prior to inundation by the normal pool of the proposed Lake. At our current level of knowledge, Site 41BQ112 seems to fulfill criteria for potential eligibility for inclusion within the National Register of Historic Places and State Archeological Landmark status.

Site 41BQ113

Located atop a ridge which will overlook proposed Lake Bosque as a peninsula(See Figure 3.b.), this eroded site exhibits a very large scatter of chert, burned rocks and mussel shell fragments eroded to bedrock. Scattered by the road, vehicular traffic and clearing, the site appears to retain little, if any, in-place material culture. The site area covers the ridgetop and extends along it for more than 100 meters! While little of the site remains in original context, it serves to remind us of the potential size that sites may attain, especially those which we found buried in the recent alluvium adjacent to the channel of the Bosque River.

At an elevation from 845 to 860 feet above m.s.l., Site 41BQ113 will not be directly affected by Lake Bosque. At our present level of understanding, Site 41BQ113 does not appear to qualify for a determination of eligibility for inclusion within the National Register of Historic Places, and is not recommended for further investigation at this time.

Site 41BQ114

Found just west-northwest of the previous site and located on the edge and slope of the same ridge is the historic dump numbered 41BQ114 (See Figure 3.b.). Having cascaded down the slope where it was dropped, the dump contains a few late 19th century bottle fragments and much early 20th century material. The point of origin--that is, the location of the homesite, the occupation of which generated this material--is unknown.

A reflection of an archeologically well-documented period of our history, little of this site remains useful for interpretation, although its study might reveal the selection of certain brands, marketing processes and the availability of products in the project area during the turn of the century.

We believe we will find better information in tighter and more reliable, contexts elsewhere in the project area. This site is not recommended for a determination of eligiblity for inclusion within the National Register of Historic Places.

Site 41BQ115

This site is the eroded remains of a prehistoric campsite. Almost no cultural material was found here, but the site's location is within an environment chosen frequently by Native Americans, a high knoll adjacent to the flood plain (See Figure 3.c.). This destroyed site is located at an elevation of 842-848 and outside the direct effects of the proposed Lake. It is not considered a candidate for inclusion within the National Register of Historic Places nor is it one that is recommended for further investigation.

Site 41BQ116

The location of a dart point discovered during our survey, Site 41BQ116 pinpoints its occurrence (See Figure 3.c.). At an elevation of 815-820 feet m.s.l., the point was found on a floodplain rise. The projectile point is similar in outline to no common type, probably because of the extensive retouching which it has undergone (See Figure 6.e.). Because the stem exhibits grinding along its lateral and basal edges, it may be one associated with the Early Archaic, and is somewhat like the *Gower* or *Hoxie* type (Turner and Hester 1985:105-106). The projectile may have been lost or discarded here by a hunter during the Early Archaic or later era for a search of the surrounding area revealed no other cultural material or features.

This site is not recommended for further work and is not considered worthy of nomination to the National Register of Historic Places.

Site 41BQ117

Below a knoll on a sloping surface above the flood plain of the Bosque, this multiple component site is one where cattle gather for feeding, resulting in erosion and the churning of cultural material. The site is located in an area which will be flooded very infrequently, at 840 feet above m.s.l. and higher (See Figure 3.c.).

The prehistoric remains of this upland site include a fragment of a unifacial tool, a fragmentary biface, battered chunks of chert, and chert flakes which indicate that lithic reduction and tool making were Native American activities here. Historic artifacts include a fragment of a cast-iron kettle, marked "2 Gall/," fragments of colorless glass, photochemically altered to purple, indicating the presence of manganese and probably predating World War I, a few pieces of colorless glass, perhaps dating to after World War I, and fragments of dishes--a blue glass bowl, an ironstone saucer, and a pearlware plate. Also found were fragments of crockery, one of which was identified as part of a lid.

Little of this site remains in evidence, with none thought to remain *in situ* Accordingly, this site is not recommended for further work. At our present level of understanding, 41BQ117 is not recommended for a determination of eligibility for inclusion within the National Register of Historic Places.

Site 41BQ118

This multiple component site is thought to be a prehistoric campsite as well as the remains of a homestead built here in the late 19th century, astradle the road which leads to the ford that crosses the Bosque River (See Figure 3.c.). Located above possible flooding on the second terrace, the site overlooks the broad alluvial floodplain which was probably farmed by the site's inhabitants. If the historic site was not located on both sides of the road, then the unimproved one of the present has bisected it, leaving a residue of disturbed foundation remains on the eastern side of the road, with the majority of historic artifacts found on the western side.

Historic artifacts included a couple of broken ironstone coffee cups, another thought to be made of pearlware, and fragments of two ironstone plates, the bottom of one having a partial mark which includes the letters "ILES," probably British (See Figure 8.o.). An abundance of wheel-thrown crockery fragments, thought to represent a minimum of six specimens, cut nails, fragments of bottle glass in colors of green and brown, and fragments of a cast-iron stove with a floral motif, including a leg with leaf design, marked "O," were also found on the surface. Prehistoric material culture was also found here, including a plow-struck mano, a fragment of metate, a chunk and interior flake of chert. This prehistoric material was traced upslope to Site 41BQ119, discussed below.

This site is one we would like to know more about. It could be quite early, with the first historic occupation here shortly after the Civil War. The use of remote sensing here might reveal the presence of sub-surface features which could then be the subject of archeological investigation. While feasible for this site, such measures are presently considered to be of low priority, given the needs at other sites which will be more directly impacted by the

Lake. At present, Site 41BQ118 is not recommended for inclusion within the National Register of Historic Places.

Site 41BQ119

This high, flat ridgetop located at an elevation of 860 feet above m.s.l., has a commanding view of the river bottom from the west to the northeast (See Figure 3.c.). Almost nothing remains of the prehistoric campsite which was here before the terrace was scraped by heavy machinery, probably a bulldozer. But here and there, one spies the crushed remains of a manuport, perhaps once recognizable as a hammerstone, flakes of lithic reduction and tool manufacture, or a fragment of clamshell.

Recorded because of its importance in understanding the general prehistoric settlement pattern in the project area, Site 41BQ119 is not recommended for a determination of eligibility for inclusion within the National Register of Historic Places. Site 41BQ119 is not recommended for further investigation.

Site 41BQ120

Located above and adjacent to a flowing creek which pools here, then cascades over a waterfall, this site is a multiple component one which includes the remnants of a prehistoric site, atop which is built a late 19th century or early 20th century house (See Figure 3.c.). Outbuildings are found to the northwest and to the north, the remains of an underground chamber--presumably a storm cellar dug into the side of the hill, covered with timber and then, with soil--can be seen. In the dripline under the roof of the house were found several prehistoric chert flakes resulting from the manufacture of tools here. Historic artifacts were abundant, but collection was limited to those thought diagnostic. Fragments of glass were the only historic materials recovered from the site. One basal fragment of a cylindrical brown bottle is marked, "/HILA," the other is of colorless glass, thought to date to after World War I.

Located at an elevation of 853 to 856 feet above m.s.l., Site 41BQ120 will not be directly effected by the creation of Lake Bosque. The pre-entry interview with the current landowner indicated that the house was an old one on the property when it was purchased in 1928 (personal communication, Homer E. Woody). While of no particular architectural merit, the site is old enough to be considered as one potentially eligible for inclusion within the National Register of Historic Places. As regards the prehistoric component here, it may be in better condition under the structure than elsewhere and may contain in-place cultural deposits, a rarity at upland sites in the project area. This site is not presently recommended for further investigation.

We crossed the waterfall for a second time when we left the site area. On the edge of the falls, the writer in new boots, slipped, turned a somersault and landed seven feet below at the bottom of the falls, uninjured. Throughout the remainder of the investigation, crew members referred to the area as "Alton Falls."

Site 41BQ121

On the north side of the North Bosque River, Site 41BQ121 is a prehistoric one located atop a rise on the edge of the second terrace, or fossil floodplain, above the river (See Figure 3.c.). From the top of the rise at an elevation of 850 feet m.s.l., this site extends down the slopes to an elevation of 838 feet. Like most of the sites on this property, the site has been cleared with heavy machinery, has been sprigged with coastal bermudagrass and converted to range for cattle production.

Artifacts found on the eroded slopes include the fragment of a bifacial tool, perhaps a large perforator/drill missing the distal portion (See Figure 4.c.), fragments of three unidentifiable bifaces, a so-called "biscuit" mano of sandstone and a fragment of another mano, this one of quartzite with a flat ground surface. Also recovered was a pebble bifacially reduced on one end with cortex left on the remainder; As is indicated by the heavily battered edge, it may have served as a chopping tool (See Figure 4.g.). A variety of flakes, chips and chunks of chert were collected.

Displaced by machinery and eroded by the elements and livestock, none of this site is thought to remain in a context useful for further archeological investigation. Site 41BQ121 is not recommended for inclusion within the National Register of Historic Places.

Site 41BQ122

Located just downstream, and east of the confluence of Barry Creek and the North Bosque River, this site is a multiple component one (See Figure 3.b.). Situated on top of a low bluff overlooking the North Bosque, the site is dominated by a recent oak log cabin. According to our informant, the structure is built on the foundation of a 19th century cabin occupied by a family with the surname of Parson(personal communication, R. L. McCoy). Archival research has not revealed additional information on this family.

No 19th century historic artifacts were found on the surface surrounding the present log structure, but this is an area which floods periodically. Such deposits of cultural material could be covered with a blanket of recent alluvium. In the eroded bank of the North Bosque, about 1.3 meters below present ground surface, we cleaned the profile and took a sample of buried mussel from a profile which was otherwise undifferentiated. We removed 33 grams of clamshell, a sample barely large enough to use for radiocarbon dating. The sample was been submitted to the Radiocarbon Laboratory at Balcones Research Center, the University of Texas at Austin. The date of sample TX-5794 was 2300 $\pm$ 70 years before the present (See Table 1.).

Intact deposits of subsistence materials in a datable context are a target of this survey. Because the results of our sampling prove promising, this site is recommended for further investigation. At present, this site is one considered to be potentially eligible for inclusion within the National Register of Historic Places and a candidate for designation as a State Archeological Landmark.

Site 41BQ123

This historic house stands much as it did when it was first constructed in 1881 (See Figure 3.b.), although our observations indicate the structure was expanded sometime after its initial construction (personal communication, John R. Thompson). Facing to the north and a now deserted roadway, which served this structure and the one to the west, the Half Chimney House Site, 41BQ103, the structure has been recently repainted and efforts made toward its stabilization. Foundation remnants of outbuildings are found to the south of the structure and the omnipresent root-storm cellar to the west. We have been told that this was once the domicile of James Buckner Barry; research concerning Colonel Buck Barry, Texas Ranger and this old structure continues.

This structure will not be in the area impacted by the construction and operation of Lake Bosque. Notwithstanding the structure's proximity to the present highway and the East Bosque River on Ranch-to-Market 927, it will not be affected by highway or bridge relocation. This structure is considered to be potentially eligible for inclusion within the National Register of Historic Places because of architectural merit.

Site 41BQ124

These three prehistoric localities are found on the floodplain in a field that is in tillage (See Figure 3.b.). On ephemeral floodplain rises of recent alluvium which are separated by subtle drains, each area produces a few fragments of clamshell. In small quantity and the only material found on site, the shell marks areas where machine testing at depth is recommended to learn more about the deposit of shell and to attempt dating the recent alluvial regimes of the North and East Bosque Rivers.

Because of the information this locality is thought to contain, it is considered to be eligible for inclusion within the National Register of Historic Places. It is considered eligible for designation as a State Archeological Landmark.

Site 41BQ125

This prehistoric site is located on the eastern edge of an old eroded terrace (See Figure 3.b.). Material culture is found in a thin deposit of wind-blown sand and sandy loam, generally less than 20 centimeters in depth, in a field which is plowed several times each year. Portions of the site appear to be relatively intact to the southeast in the next property, across the fence. Here, the site is devoted to range, subject to erosion accelerated by the hooves of livestock in their passage from the terrace to Willow Springs Creek. The fragment of a mano, chert flakes and clamshell found at the site reveal that Native Americans prepared food here as well as reduced lithic material and produced stone tools.

This site is recommended for further work, especially the search for in-place deposits of food remains or radiocarbon to date the site and age the upper geological surface of the terrace deposits. It is one thought to be potentially eligible for designation as a State Archeological Landmark and for inclusion within the National Register of Historic Places.

Site 41BQ126

This prehistoric site is located along the same terrace as the one just discussed (41BQ125), on a slightly flatter and higher elevation (See Figure 3.b.). Situated more central to the ridge, this campsite is well drained and habitable when 41BQ125 to the southeast may be covered with several inches of water. Water from rainfall and seeps which collects there is now diverted to a great extent by drains placed there recently. Site 41BQ126 is now marked by the presence of a windmill in the middle of a field which is plowed on an annual schedule.

Native Americans probably obtained their water from the nearby tributary today called Willow Springs Creek, but the mussel shell found at the site hints at a subsistence relationship based on trips to the channel of the North Bosque River. The lithic scatter and metate fragment found on the eroded surface indicate that lithic reduction, stone tool production and food processing were some of the activites carried out at this site during its occupation.

Based on our observations, Site 41BQ126 may have always been entrapped in shallow colluvial deposits which are now disturbed by erosion, well digging,windmill construction and operation, plowing and grazing. This site is not recommended for further investigation. Site 41BQ126 is not presently considered a candidate for recommendation to the National Register of Historic Places. It is not recommended for designation as a State Archeological Landmark.

Site 41BQ127

An historic house built during the late 19th century once stood on this spot (See Figure 3.b.) identified by the presence of window pane fragments, broken crockery and dishes, and cut nails. Our interview with the landowner revealed that the structure had been here until the recent past(personal communication, Jack Gilleland). The structure was initially slated for restoration and preservation. As the structure was being disassembled, it became evident that the foundation had long ago given way. The entire structure had settled, slumping down and inward, and slowly, the boards of the house had adopted a new set. As the floor was being leveled, it became obvious that perpendicular surfaces would never again be achieved inside the structure and it was disassembled for materials.

Little remains at the site of this structure. Its location within an area now devoted to the management and feeding of livestock has further obscured its presence. Site 41BQ127 is not recommended for further work. It is not presently considered a site to be recomended for a determination of eligibility for inclusion within the National Register nor is it one meriting designation as a State Archeological Landmark.

Site 41BQ128

Site 41BQ128 is a small historic dump directly north of and opposite the property line of a house that was occupied after World War II (See Figure

3.b.). Items found here include a stoneware fragment of crockery and an ironstone saucer and a variety of colored bottle glass.

Our search of the ground surface surrounding the structure across the fence does not indicate that it is one built atop a site occupied during the period of the dump. There is a possibility that Site 41BQ128 is associated with the house and barn foundations recorded as 41BQ101 and 41BQ102. If our present dating of these two sites is correct, they cease to be occupied at about the time we believe the dump was first used. Unless investigations at 41BQ101 and 41BQ102 indicate otherwise, no further work is warranted at this site.

Site 41BQ128 is not presently recommended for designation as a State Archeological Landmark nor considered a candidate for inclusion within the National Register of Historic Places.

Site 41BQ129

An early 20th century house was once located on the terrace overlooking Willow Springs Creek as is revealed by a disarray of foundation materials and artifacts in a grassy, rolling meadow (See Figure 3.b.). The site has been cleared and pushed by heavy machinery, probably a bulldozer; erosion and grass cover have softened the scars of this site's disturbance. Artifacts found here include fragments of glass dishes, bowls and bottles, which are thought, based on finishes and color, to be from the late-19th century until the First World War. Stoneware found includes an abundance of wheel-thrown crockery and ironstone, a plate, saucer and bowl. A cast iron wrench was also recovered.

Too disturbed and scattered to be useful for further research, Site 41BQ129 is not recommended for designation as a State Archeological Landmark, nor for inclusion within the National Register of Historic Places.

Site 41BQ130

Centrally located on a ridge which overlooks the valley of the North Bosque River to the southwest, this historic site marks an early settler in the area, probably before 1870, possibly before the Civil War. With the lake at maximum flood pool, the site will remain above water at the tip of a peninsula (See Figure 3.b.). Already naturally eroded and cleared by heavy machinery on the slopes which surround it, the house site may still retain some foundation rock in place although a few stones may have been robbed for construction elsewhere. Artifacts recovered from the surface consisted of crockery, including some thought to be identifiable as to maker, a whiteware cup fragment with blue underglaze transfer print, thought to be mid-19th century in age, and an ironstone plate fragment (See Figure 8.a.), marked with the characters, "RO\YAL// IR\ONSTONE//G\ODDARD."

This site is one of the earlier historic sites discovered in the uplands of the project area. It, with Site 41BQ138, is considered likely to be the homesite of General Alison Nelson, with 41BQ138 the present favorite. Because it may prove important to an understanding of the early history of the area, Site 41BQ130 is considered to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ131

This historic structure was built to the northwest of the modern house which replaced it (See Figure 3.b.). Other than a disturbed scatter of historic artifacts in a field sprigged with coastal bermuda, nothing appears to remain of the house once located here. The structure was demolished in the recent past. Now in an area of heavy livestock traffic, the site is subject to the churning feet of cattle. Aside from artifacts which can be used for the relative dating of the site, sometime in the late 19th-century, probably after 1880, little remains for interpretive purposes.

Demolished by the owner and altered through landuse, Site 41BQ131 is not recommended for further investigation. It is not considered to be a candidate for designation as a State Archeological Landmark or recommended for a determination of eligibility for inclusion within the National Register of Historic Places.

Site 41BQ132

Located outside the impact of Lake Bosque at an elevation of 870 feet m.s.l., this historic housesite is one demolished in the recent past by the present landowner. It is situated on the edge of the upland terrace to the northwest of Willow Springs Creek (See Figure 3.b.). Part of the drive, the drilled well and the landscaping of the general site remain. The ground is littered with artifact scatters around the site of the house and the foundations of outbuildings.

Earthenware pottery, stoneware crockery and porcelain are among the ceramic fragments found near the house. Bottles, canning jars, and plate glass and a mother-of-pearl button as well as a hinge of mussel shell were found nearby. Metal artifacts are particlarly common. One, a 31 millimeter in diameter brass make-up case cover, is marked:

DEAR MADAM:
DON'T EXPECT BEST
RESULTS FROM LADY ESTHER
ROUGE UNLESS YOU CAREFULLY
FOLLOW DIRECTIONS SHOWN
IN "MY ROUGE GUIDE"
CORDIALLY
LADY ESTHER
SHADE № 7
Made in U.S.A.

We recovered another lid, this one of copper, marked "MELBA," a suspender snap cover marked "BOY BLUE," and a child's tableknife fragment, which when cleaned by electrochemical means, revealed a small boy holding a frog, his dog sitting at his feet, marked "BUSTER BROWN," a popular cartoon character before 1910. A United States one-cent coin with little wear but oxidized from long exposure to the elements, was found in the drive near the house; made at the Denver Mint, the coin bears the date, 1941.

Well outside the area to be affected by Lake Bosque, Site 41BQ132 is not recommended at this time for further work or inclusion within the National Register of Historic Places.

Site 41BQ133

The site of a hand-dug, limestone-lined well, Site 41BQ133 (See Figure 3.b.) may be associated with the house site, 41BQ134, or the site just discussed above. No artifacts were found surrounding the well, although its method of construction is consistent with other wells we have found in the project area which we are quite certain were dug in the 19th century. Adjacent to an unimproved road, the well is relatively close to ten large, flat-lying limestone rocks also near the roadway. If once a part of a foundation, few, if any, of these stones, are still in place.

Not recommended for further investigation, Site 41BQ133 is not considered eligible for inclusion within the National Register of Historic Places.

Site 41BQ134

Marked by a scattered limestone foundation and fragments of 19th century artifacts, Site 41BQ134 is thought to be the location of a homestead, the foundation, the remains of a log cabin. Located in a motte of Liveoaks, the site is on a slight slope above Willow Springs Creek (See Figure 3.b.). Opposite an unimproved road which once served the site is a small oval area dug into the ground; this feature may have served as a storm cellar for the residents. Stoneware fragments included a drawer pull, four types of crockery and ironstone, in creamer, plate, and saucer forms. A porcelain cup and fragments of white milk glass, probably a canning jar lid, as well as other glass in a variety of colors and forms, including jars, bottles and a dish or bowl were found. Metal artifacts recovered include part of a stove, a cast iron vent cover, and the brass frame of an aeolina, more commonly called a mouth-harmonica (See Figure 7.b.).

Outside of the area to be affected by Lake Bosque, Site 41BQ134 is not recommended for further work. Site 41BQ134 is not presently considered eligible for inclusion within the National Register of Historic Places.

Site 41BQ135

On a high, sloping hillside overlooking Willow Springs Creek from the northwest (See Figure 3.b.), Site 41BQ135 is a prehistoric campsite eroded to bedrock. Broken projectile points and other bifaces, thick bifaces which may have served at different times as cores and tools, and chunks, flakes and chips of chert were recovered. A small quartzite mano ground on two surfaces and fragments of clamshell were also collected.

At too high an elevation, between 858-870 feet m.s.l., to be affected by Lake Bosque, Site 41BQ135 is not recommended for further work, nor is it presently considered to be one eligible for inclusion within the Naitonal Register of Historic Places.

Site 41BQ136

This historic site marks the location of a late 19th and early 20th century house which has been cleared and disturbed with the aid of heavy machinery (See Figure 3.b.). No artifacts were collected from this destroyed site, but we observed fragments of ironstone, porcelain and photochemically weathered purple glass.

Above an elevation of 830 feet m.s.l., this site will periodically be flooded by Lake Bosque. It is not recommended for further investigation. It is not presently considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ137

Covering much of the southeastern portion of Pearce Ridge, the name we gave to the red, pleistocene levee deposit northeast of Jackson Crossing, this large prehistoric site is thought to be Late Archaic in age (See Figure 3.b.). Although only fragmentary projectile points were found at the site, their general size, and one which is side notched (See Figure 6.l.), lead us to this tentative assignment of age of occupation. The cultural material, which includes in additon to chert artifacts, a quartzite mano with a pit in the center of the grinding surface, a metate fragment, and clamshell, seems to be resting on an eroded surface, presently held in position by a thin blanket of fine sandy loam. No in-place deposits were noted in this moderately heavy scatter of artifacts and shell, but as this site is the only one on Pearce Ridge that does not appear to have been heavily disturbed by agriculture, and may contain hidden deposits of value, we recommend further work. Extensive machine trenching perpendicular to and along the axis of the ridge would reveal such buried deposits.

This site will be inundated at normal pool elevation. This site is eligible for designation as a State Archeological Landmark and potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ138

This multiple component site not only contains a buried prehistoric site which is revealed by the presence of chert and clamshell, it also is one of the earliest historic sites located during our investigation (See Figure 3.b.). The site is disturbed, with some machine pushing in the area once thought to be the site of the structure, thought to have been a house. An inspection of this same area revealed the presence of the prehistoric material in the alluvial fill upon which the structure was built. Historic artifacts are abundant and generally appear to be from the early pioneer period of the mid-19th century. They include fragments of four different stoneware crockery containers, another of earthenware, two ironstone chamber pots, a flown-blue underglaze, edgeware plate, and several ironstone plates and a saucer (See Figure 8.g.). Several fragments of glass items were found, most were bottles in shades of brown, dark and emerald green and aquamarine. One fragment of a tumbler, a fragment of white glass thought to be a bottle and one sherd of colorless glass were also recovered. Iron artifacts included cut nails and fragment of cast iron stove leg.

Undisturbed prehistoric deposits appear to lie underneath the disturbed historic foundation at Site 41BQ138. This site is thought to be the early domicile of General Alison Nelson, and if so, occupied directly before the "Great Breakup" and the Civil War. It lies within lands owned by Nelson during this time period. Recommended for further investigation, Site 41BQ138 is considered to be potentially eligible for inclusion within the National Register of Historic Places and a candidate for designation as a State Archeological Landmark.

Site 41BQ139

Located on the edge of the valley along an eroded, sloping terrace between Gibson Branch and the North Bosque River (See Figure 3.a.), Site 41BQ139 is a prehistoric one first discovered in a primitive road which runs along the terrace. Derived chert tools (See Figure 1.f.), flakes, cores, and a quartzite mano, ground on one face and side (See Figure 9.b.), were found in the loose sand which overlays the red clay that makes up the subsoil of this site. Our probes and search along the margin of the site failed to reveal any *in-situ* deposits. While each site discovered throughout this investigation is considered to be unique, and this site is no exception, we believe that 41BQ139 is similar in many respects to Site 41BQ235, which is up Gibson Branch in an area more conducive toward its preservation, than is found at Site 41BQ139.

Site 41BQ139 is not recommended for further investigation. It is not considered eligible for inclusion within the National Register of Historic Places nor for designation as a State Archeological Landmark.

Site 41BQ140

This is a historic housesite, demolished probably within the last decade by the current owner. The foundation of puddled cement with one standing wall of stone are all that remain of the small structure, shown on the 1955 Meridian, Texas, 7.5 minute U.S.G.S. topographic map as still standing, but no longer occupied (See Figure 3.a.). The artifacts surrounding the structure were few and mixed with recent trash, presumably the residue of campers who trespass here. Our observations based on this artifact scatter led us to conclude that this structure was occupied in this century until shortly after World War II. In usual circumstances, we would have been given additional information concerning this structure by the property owner. This is one of the few sites that we visited without the benefit of our pre-entry interview. Repeated telephone efforts to contact the landowner failing, we mailed letters, without response.

Site 41BQ140 is not a site we recommend for further investigation. Given the present level of knowledge concerning this site, it is not one considered eligible for inclusion within the National Register of Historic Places.

Site 41BQ141

The artifacts found at this spot provided a signature we usually recognize as that of a house (See Figure 3.a.). They included domestic ceramics, one an ironstone plate, pressed glass, bottle glass in several colors, especially purple and brown, and the broken cast iron leg of a stove. A search of the meadow in which they were found indicated that heavy machinery had been at work here, with a few residue piles still remaining visible in the margins of the clearing. None of these piles contained the foundation material we expected to find. Our final analysis of this site is that it is dumped household trash, probably from 41BQ140, the demolished housesite to the northwest.

This 20th century dump is too scattered to be of further value. It is not recommended for designation as a State Archeological Landmark, nor for inclusion within the National Register of Historic Places.

Site 41BQ142

A heavily eroded southeastern slope exposed to the indurated Paluxy sand (See Figure 3.b.), this site is a prehistoric one which, because of the erosion, exhibits a wide scatter of lithic items. A projectile point (See Figure 6.f.) and three manos, two of them fragmentary, were recovered. Chert flakes, bifaces fragments and a hinge of clamshell were also collected from this site. Lithic material is found from the uppermost slope to the centerline of the drain which carries surface water to the North Bosque. Our mine probes failed to reveal any undisturbed deposits of cultural material that were usable for archeological purposes other than site identification.

Site 41BQ142 is not a site recommended for further investigation. It is not recommended for inclusion within the National Register of Historic Places or considered one to be designated as a State Archeological Landmark.

Site 41BQ143

Found in the profile exposed by the drain which runs from the eroded slopes of the previous site, Site 41BQ143 is a prehistoric one which contains both clamshell and small quantities of chert debris exposed in the sidewall of a drain which cuts through the site (See Figure 3.b.). On a sloping terrace covered with vegetation, no other cultural material was noted. While there is sufficient depth for a site to be buried here, the paucity of artifacts reduces our interest.

This site is recommended for sampling in conjunction with work needed at nearby sites 41BQ147 and 41BQ148. It is not considered a likely candidate for designation as a State Archeological Landmark or worthy of nomination to the National Register of Historic Places.

Site 41BQ144

Part of the old roadway which descended to the ford replaced by the Austin Bridge (41BQ108) at Jackson Crossing, Site 41BQ144 is two rock abutments which once supported a wooden bridge (See Figure 3.b.). Only the dry-stacked limestone masonry remains; the wooden trestle has long since rotted or was taken away for use elsewhere. After crossing the drain which has eroded Sites 41BQ142 and 41BQ143, the road ran toward the North Bosque River, then turned toward the northwest, where it can be followed to the present road, crossing it just southwest of the bridge at Jackson Crossing, through a gate and into the pasture beyond. Just upstream of the abutments, a few feet to the west is found another crossing, this one either used after the bridge gave way, to cross with loads heavier or wider than the bridge could sustain, or as a dry weather alternative.

Recorded to document part of the transportation system that was replaced by the current bridge and roadway, Site 41BQ144 is not recommended for further work. It is not considered a likely candidate for designation as a State Archeological Landmark nor it is considered to be one for inclusion within the National Register of Historic Places.

Site 41BQ145

This small prehistoric site perched on the edge of the high, upland terraces overlooking the proposed Lake is considered to be an important one (See Figure 3.b.). Located at an elevation between 856-862, this site consists on a hearth of limestone rocks in a roughly circular outline. In and around the hearth are fragments of mussel shell and flakes of chert. We avoided disturbing this hearth; moving well away from the center of the site, we tied our flagging tape in four trees, the intersection of these points falls directly over the hearth and it may be found with ease. Two chips of chert, both thought to be the residue of bifacial reduction and three fragments of shell were recovered. Three grams of shell were recovered (less than ten percent of the sample weight required for radiocarbon dating) without digging into the feature. The hearth appears to be isolated from other features, with good integrity.

Site 41BQ145 is outside the area directly affected by the Lake, but is recommended for further investigation, perhaps total recovery. This site, and another hearth, Site 41BQ167, are thought to contain data which offer the opportunity to further evaluate the inorganic carbonate problem associated with the utilization of river shell for radiocarbon dating purposes. Because this is a major area of concern in dating the sites in the reservoir area which are to be affected by inundation, Site 41BQ145 is considered to be a site which is eligible for inclusion within the National Register of Historic Places.

Site 41BQ146

Located on the next terrace, above and to the southwest of the hearth site, 41BQ145, this site is a large prehistoric one which covers the eroded upland crown and terrace edge at an elevation between 860-870 feet m.s.l. (See Figure 3.b.). This site has been cleared with heavy machinery, the surface of the site still exhibiting eroding piles of earth and brush from this activity. Among the debris are scatters of burned limestone, chert debris and mussel shell, the remains, we believe, of hearths like the one recognized at 41BQ145.

No further investigation is warranted at this destroyed site. Site 41BQ146 is not recomended for inclusion within the National Register of Historic Places.

Site 41BQ147

Originally thought to be a deep site which ran along and was contained within the ridge of a crevass splay, or alternatively, a relict sandbar of the North Bosque River, Site 41BQ147 is a prehistoric one which contains burned rock, lithic debris and clamshell (See Figure 3.b.). Sampling revealed the deposit to be thin, averaging less than 50 centimeters, to the bedrock of the Paluxy sandstone. One of the few sites which exhibits surficial staining, presumably particulate carbon and organic residue, of the soil, Site 41BQ147 contains tools and projectile points associated with the Late Archaic (See Figure 10.a.&b.). Preliminary data indicate this site may be one useful in interpreting the multimodal exploitation strategy used by the prehistoric occupants of the North Bosque River valley. Of the material recovered during sampling, 48.3 grams of mussel shell was committed as a carbon-14 sample to the Radiocarbon Laboratory, Balcones Research Center, the University of Texas at Austin(See Table 1), with a resuting date of 3010 $\pm$ 50 years before the present (TX-5795).

This site is recommended for further investigation. It is considered to be one eligible for inclusion within the National Register of Historic Places and a candidate for designation as a State Archeological Landmark.

Site 41BQ148

This large prehistoric site was first noted as a light lithic scatter; it was traced to the edge of the floodplain on the channel of the North Bosque River where large quantities of chert (See Figure 4.a.) and mussel shell were found eroding onto the bedrock Paluxy sandstone formation, and thence, into the River (See Figure 3.b.). The only site we discovered during the investigation which provided a clearly differentiated profile on the basis of color, the result of cultural activity which had stained the light tan to brown sandy loam to a uniform dark gray to almost black, the site was scheduled for additional sampling. When we returned to the site to perform this additional work, we were shocked to discover that the rains which had seriously hampered our field efforts in late June and early July, had resulted in floodwaters which eroded the underpinning of the site, causing it to collapse into the North Bosque River, scattering site and contents downstream. Notwithstanding the loss, we located another area to perform limited sampling.

Our findings indicate that much of this site remains intact. It is buried and apparently, much of it undisturbed. The site is more than one meter in depth and contains well-developed Late Archaic components (See Figure 10.c.- k.). The deposits dip toward the channel of the creek, indicating a sloping surface at time of occupation. This slope is maintained through time, marked by two apparent pavements of hearth stone, one at about 35 centimeters in depth, the lower one at a depth of about 60 centimeters. The distribution of these rocks may only reflect concentrations of a generally consistent behavior through time, but they document the slope on which the site was building, which here dips toward the river, about 7.5 centimeters vertically for every horizontal meter. Of the material recovered during sampling, 96.7 grams of mussel shell was committed as a carbon-14 sample to the Radiocarbon Laboratory, Balcones Research Center, the University of Texas at Austin(See Table 1), with a resulting date of 3830 $\pm$ 70 years before the present.

Thought to be important to an understanding of the lifeway of the native inhabitants of the general area, Site 41BQ148 is considered eligible for inclusion within the National Register of Historic Places and is a candidate for designation as a State Archeological Landmark.

Figure 10. Artifacts recovered from sub-surface sampling at Sites 41BQ147 & 41BQ148.

a. From **41BQ147**, 0 to 10 centimeters, this dart point in the *Ensor-Ellis* tradition is made of bluish-gray chert.

b. From 41BQ147, 10 to 20 cm, this unstemmed biface used as a cutting tool is made of medium brown chert.

c. From **41BQ148**, as are the rest, below, this projectile point, from 20 to 40 cm, is of grayish-brown chert.

d. From a depth of 40 to 60 cm., this projectile point is of purplish gray chert.

e. From 40 to 60 cm., this biface fragment has serrated edges and barbs.

f. From 40 to 60 cm., this projectile point has beveled lateral edges.

g. This fragmentary projectile came from 60 to 80 cm.

h. This base and mid-section fragment is from 60 to 80 cm.

i. This stem fragment is from 60 to 80 centimeters.

j. Perhaps also used as a perforator, this point came from 60 to 80 centimeters below the surface.

k. This unifacial tool is modified opposite the bulbar end by trimming the opposite end and the lateral edges. It comes from 60 to 80 centimeters below the surface.

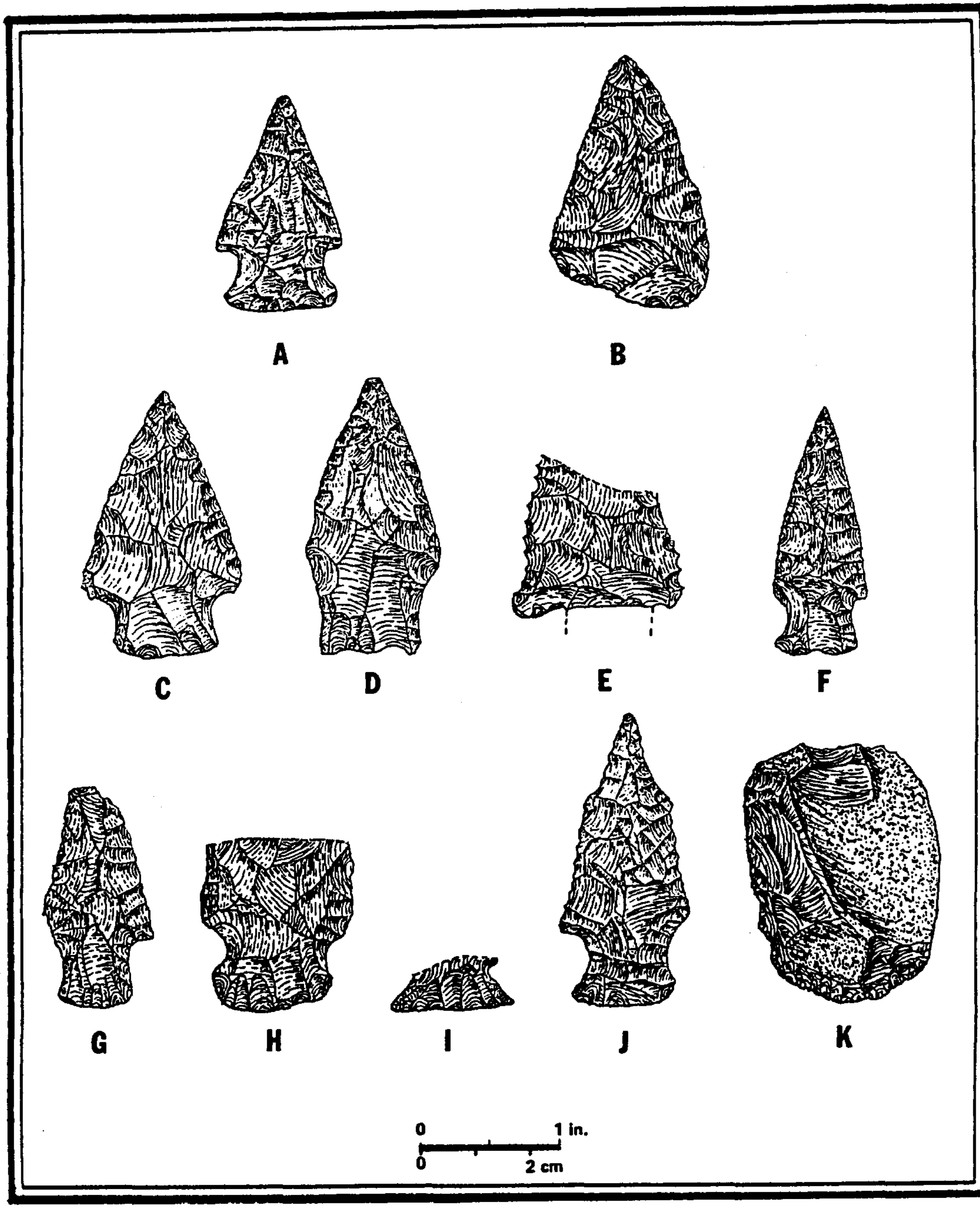

Figure 10. Artifacts recovered from sub-surface sampling at Site 41BQ147 & 41BQ148

Site 41BQ149

Probably the largest surface exposure of artifacts found throughout the project, Site 41BQ149 is a multiple component one centrally located in the middle of Pearce Ridge (See Figure 3.b.). The majority of the site has been affected by a variety of natural and mechanical agents. Along the southern lower margin, the site has been disturbed by plowing, fencing and the removal of trees, probably as nursery stock. The central portion of Pearce Ridge has been cleared by machinery and in areas, soil has been mined from the surface.

Prehistoric artifacts are fairly common throughout the area; most are what would be considered to be lithic debris, although a few broken projectile points (See Figures 5.e. & 6.g. & h.), biface and unifaces (See Figure 11.c. & d.), and a mano fragment were recovered. Also collected were 28 grams of mussel shell. Historic material is concentrated near the top of the ridge, not far from the location of the present house. While much of the historic area has recently been disturbed by a garden plow, the foundation of the original structure is in place. In the garden, we found fragments of two types of earthenware, three types of stoneware crockery, ironstone plates and saucers (See Figure 8.n.), "Blue Willow" underglaze whiteware, other decorated ware, and a porcelain bowl and saucer. Bottle glass in light purple, colorless, light green, aquamarine, amber and brown were recovered as well as part of the glass chimney of an oil lamp. Also found was an unidentified piece of ceramic fineware, a scroll, perhaps part of a cup, a blue and white ceramic "crock" marble, and one brass dome button, with a 19 millimeter diameter.

While the majority of both the components of this site have been disturbed, we know that the foundation of the historic house remains in place, Likewise, there are probably areas of prehistoric material culture in the site which are less disturbed than elsewhere. Our survey did not locate them during our visits. Additional sampling for prehistoric components during investigation of the historic features is recommended. The site area is extensive and more information concerning prehistoric usage of the Pearce Ridge area is critical to an understanding of adjacent areas where prehistoric sites have been virtually destroyed by clearing, cultivation and conversion to grasslands for livestock production.

Figure 11. Unifaces recovered during the survey of proposed Lake Bosque.

a. Resembling an exhausted unifacial core, this nubbin from Site 41BQ206 is the remains of a tool thought to have been used in the production of wood artifacts.

b. Exhibiting formal bilateral symmetry, this nubbin from Site 41BQ218 is otherwise similar to **a**., above.

c. This tool from Site 41BQ149 may be morphologically similar to the original configuration of **a**. & **b**., above.

d. Thinner and wider than the unifaces above, this tool from Site 41BQ149, exhibits a pattern of damage that suggests it was used in a fashion similar to all those above.

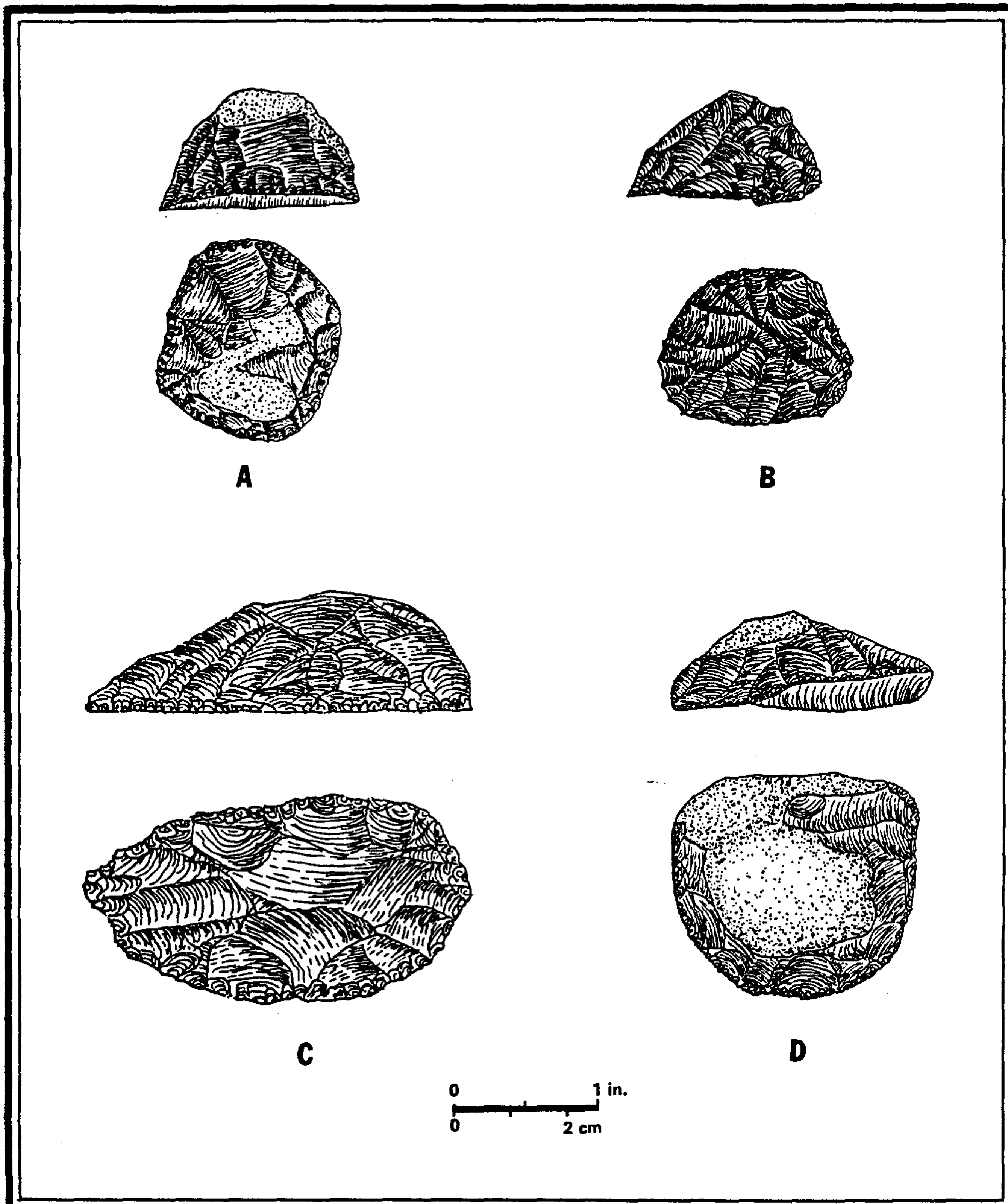

Figure 11. Unifaces recovered during the survey of Lake Bosque

Site 41BQ150

On an eroded mount of *Gryphaea* which will remain a peninsula when Lake Bosque is at floodstage (See Figure 3.b.), this prehistoric site is very thin and scattered. We recovered a dart point, a few chert flakes and a fragment of clamshell from amid the fossil shell which here is the major constituent of the soil.

Not recommended for further investigation, Site 41BQ150 does not merit inclusion within the National Register of Historic Places.

Site 41BQ151

This large prehistoric site is, like 41BQ150, on an eroded bed of *Gryphaea* (See Figure 3.a.). Short grasses and a thin soil contributed by the upland slopes and the wind serve to stabilize the cultural deposits. Some of the surface has been disturbed by the clearing and digging which occurred there during the installation of a 66 KV transmission line through the site. This disturbance is probably the reason we were able to find some of the five fragmentary projectile points (See Figure 5.h. & l.). Biface fragments, a couple of unifaces, flakes of chert, some the result of lithic reduction, others, the residue of tool production, were also recovered from among the scattered fire-cracked rock on the surface. We collected 23.7 grams of clamshell, too small a sample for dating purposes. The systematic use of mine probes indicates the soil on this Middle to Late Archaic site is rarely more than 20 centimeters in thickness.

With a shallow deposit and no apparent intact features, Site 41BQ151 is still considered to be a potentially important one. Upland sites not exposed to bedrock are uncommon, and this is one. Additonal sampling is warranted, especially in areas directly affected by the construction of the dam and spillway. Site 41BQ151 may prove eligible for inclusion within the National Register of Historic Places and one for designation as a State Archeological Landmark.

Site 41BQ152

This historic site is located on the edge of the upland terrace (See Figure 3.a.). Although the family who lived here probably left by the end of World War II, the grape hyacinth and iris which were planted northeast of the house still bloom. The rock foundation of the house retains good integrity, with the concrete doorstep in position on the southwest. Southwest of the foundation is the root and/or storm cellar. The crockery, glass, bottles, dishes--all the fragments and specimens--have characteristics of early 20th century manufacture. The mouth-harmonica frame we found here was a rusted one of sheet iron, in response, perhaps, to a brass shortage during the war (See Figure 7.e.). No materials recognized as post World War II were recovered. Relatively undisturbed and apparently uncontaminated by more recent artifacts, Site 41BQ152 is considered to be a good example of a 20th century occupation.

To be affected by construction of the dam and spillway, Site 41BQ152 is recommended for further investigation and archival research. The site is considered eligible for inclusion within the National Register of Historic Places and is a candidate for State Archeological Landmark status.

Site 41BQ153

This site is located on the lower terrace, at the toe of the slope, slightly above and fairly close to the floodplain and channel of the North Bosque River (See Figure 3.a.). We found the remnants of a presumed log cabin, almost buried under colluvium and juniper needles at the end of a rockwall--called a drift fence, according to Roy V. Nichols, to keep one's cattle from drifting to a neighbor's property (personal communication), something the fences probably accomplished. We found them to be synonymous with old property lines.

We looked for cut nails, but found none on the thick humus. Other items, however, were well represented. Bottle forms included fragments of a picnic flask, four mold-blown bottles with brandy, double-bead and florida water finishes (Wilson 1981). Weathered purple glass, a fragment of a milk glass mug, an ironstone cup, wheel-thrown crockery and a ceramic cannister fragment were found. Metallic artifacts include a "tin" can and a harness buckle. Timewise, the artifacts seem to be restricted to the late 19th century, from after 1880.

This site may be affected by construction of the dam, spillway or haul roads. The placement of this site near the horticultural terrace and close to water marks it as an early settlement. Site 41BQ153 is considered to be a candidate for State Archeological Landmark status and potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ154

This prehistoric site is a very light lithic scatter in an eroded open meadow above an upland drain (See Figure 3.a.). In the short grasses, we found a fragment of a unifacial tool and a half-dozen flakes distributed over a very broad area. Presumably the residue of a short term encampment, little of Site 41BQ154 remains.

Site 41BQ154 may be affected by the construction of the dam, service spillway and haul road. Given our current understanding of the site, it is not recommended for further investigation or for National Register inclusion.

Site 41BQ155

This prehistoric open campsite is situated on a hilltop above two intermittent seeps or springs feeding a tributary of the North Bosque River (See Figure 3.a.). The site has been scattered by clearing with heavy machinery, probably by the owner, as well as operations associated with the construction of a 66 KV transmission line through the site. Probing revealed that in most areas, the site is less than 5 centimeters, or two inches, thick. Artifacts found here consisted of lithic debris and several fragmentary bifaces, including two projectile points (See Figure 6.k.).

Little remains of Site 41BQ155 that is useful for further investigation. The cultural material found at the site is altered and derived--no longer in original position-- from interpretable context. This site is not recommended for the National Register of Historic Places.

Site 41BQ156

This historic site is associated with the early transportation system put in place by the local residents, as well as with early property lines (See Figure 3.a.). Throughout our investigation, we found few present property fences to be congruent with old property lines. In most cases, we find the old rock fences inside the property, with the current property expanded by later surveys. This site is no exception.

The site is the road, ford and rock wall which come together to cross at a spring fed tributary. We gave the tributary the name of Beaver Creek because of all the signs of *Castor canadensis* in the neighborhood, including a dam, fallen timber and curiously cut short logs, generally measuring less than 40 centimeters in length, with tapered ends. To descend from the hilltop to Beaver Creek, the builder had to cut and fill along the edge of the terrace, cutting through bedrock much of the way. The resulting limestone rubble was utilized for fence construction and to fill the creek with a loose jumble of rock which allowed the passage of water but provided a firm footing for wagons or other traffic. This road was probably replaced by the current one which crosses the creek about 350 meters upstream.

No artifacts were found to be associated with the features described above. Not recommended for further work, Site 41BQ156 is not considered eligible for inclusion within the National Register of Historic Places nor is it a likely candidate for State Archeological Landmark status.

Site 41BQ157

This is the location of an early 20th century house which has been cleared with heavy machinery and a modern house built on the original site (See Figure 3.a.). Only a few artifacts were recovered to document this house site. Metal items included the bilateral half of a toy cap pistol, and a fragment of a tire pressure gauge which very much resembles a brass shotgun cartridge case, marked, "SCHRADER-UNIVERSAL, BROOKLYN, N.Y., patented July 6, 1909-Mar 28, 1916-Feb 14, 1922." Fragments of ironstone and crockery were recovered as was the neck and finish of a light green bottle.

Site 41BQ157 was recorded to document the historic settlement pattern of the project area. It is not recommended for further work. It is not considered to be eligible for inclusion within the National Register of Historic Places nor one to be designated as a State Archeological Landmark.

Site 41BQ158

This site is a deeply buried one, presently outside the reach of conventional equipment, on the channel of the North Bosque River (See Figure 3.a.). Only mussel shell is found in a layer in dark loam, in a shear bank on the northern side of the channel. The site is due south and directly adjacent to the present property line. The site cannot be approached from below without scaffolding, nor from above without rappeling, the latter not considered to be a viable alternative when one considers the on-going sloughing of the bank here. Given our experience with dating shell at Site 41BQ216-41BQ217, this mussel shell should be subjected to radiocarbon testing and the results compared with the other sites undergoing similar evaluation before any efforts are made to strip away overburden, here an extremely expensive proposition.

Nevertheless, we consider it a likelihood that this site is a buried prehistoric open camp and an important one in understanding the lifeway of the Native American inhabitants of the general area. Until sampling or deep machine coring proves the site to be of no value, Site 41BQ158 is considered to be one potentially eligible for inclusion within the National Register of Historic Places and a candidate for designation as a State Archeological Landmark.

Site 41BQ159

We discovered an ephemeral scatter of historic artifacts on a slightly sloping upland terrace, and traced the artifacts across the barbed wire property fence to find what is probably the largest complex of historic foundations discovered during our investigations (See Figure 3.a.). Among the juniper, hackberry and liveoaks, we counted at least five foundation remains, including a carefully constructed storm or root cellar lined with limestone with radiused corners, an unusual building method. At the moment of its discovery, the cellar was filled almost to capacity by water; we could not determine if this was the result of surface runoff or groundwater infiltration.

The site appears to have escaped the notice of relic hunters and to be relatively undisturbed. We were surprised to find such a large historic site not revealed to us by the pre-entry interviews with the surrounding owners. Artifacts observed or recovered from the site include fragments of early Mason aquamarine canning jars, panel bottles in a variety of colors, including colorless and light green, and a whiskey bottle turned purple from photochemical weathering. Whiteware included fragments of an Ironstone bowl and saucer. Other ceramics included dishes decorated with green underglazes and gilt-edged, and two forms of crockery. Metal recovered was all cast iron, most identifiable as parts of a kitchen stove.

We went to the neighbors and asked if they might provide us with some additional information concerning the site, its original occupants, etc. Jeffie Hanna remembered the place, recalling that he had seen a board house, delapidated and unoccupied, when he left the area to join the service in 1938 (personal communication).

Above the normal pool of Lake Bosque, and to be periodically affected by flooding above 833, Site 41BQ159 is recommended for further investigation. In addition to archival research, the site is recommended for clearing of vegetation before any further mapping is attempted. This site is thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ160

This prehistoric site is just northwest of a small peninsula on the upstream side of the dam (See Figure 3.a.). The eroded, sloping surface of the site showed many fragments of mussel shell; we collected a fairly large sample of shell, 83 grams, for later radiocarbon testing. Our examination of the site revealed chert flakes, a biface fragment, a broken uniface, and a fragment of a sandstone mano. Probing revealed the site to be very thin, the deposit concentrated between 0 to 10 centimeters, or about 4 inches.

This site is not recommended for further investigation. It is not considered to be a candidate for State Archeological Landmark status or inclusion within the National Register of Historic Places.

Site 41BQ161

On a terrace edge above an intermittent tributary of the North Bosque River (See Figure 3.a.), this eroded prehistoric site is a very light lithic scatter, associated with mussel shell. Clearing of juniper in the uplands has accelerated erosion, destroying the site and exposing bedrock. Probing revealed that no areas of the site possess appreciable depth.

Outside of being a good example of a site destroyed by indirect impact, Site 41BQ161 is considered to be of no further value. Given our current understanding of the site, it is not eligible for inclusion within the National Register of Historic Places.

Site 41BQ162

This prehistoric site is located at the toe of the slope, on the flooodplain of the North Bosque River (See Figure 3.a.). This site was brought to our attention by Edward Moorman, property owner, and an archeologist who worked with the River Basin Surveys, Smithsonian Institution. He had found this site many years ago but kept its location secret; shortly after he disclosed its whereabouts, he found it was being looted. The signs of this disturbance remain mute testament to the work of the relic hunters, but it also marks the location of the site, and because of the overgrown condition of the floodplain, it was otherwise virtually obscured. We found no time-diagnostic artifacts in the backdirt or on the surface, but we could look at the matrix and tell that these were burned rock midden-like deposits, intermixed with some chert and considerable amounts of mussel shell. Barely exposed at the surface, we presume that the site is a relatively recent one, with some depth and considerable horizontal extention. We collected 105.7 grams of mussel shell, enough for a radiocarbon sample.

This site is one recommended for further investigation. It is thought to have in-place deposits relatively undisturbed. In a geological context with potential for relatively uniform deposition and good separation, Site 41BQ162 is considered to be potentially eligible for nomination to the National Register of Historic Places. It is one considered to be a candidate for designation as a State Archeological Landmark.

Site 41BQ163

A large flat area on a hilltop overlooking the North Bosque is the setting for this large, light lithic scatter (See Figure 3.a.). Perhaps the most intriguing aspect of this site is the virtual absence of mussel shell throughout the surface, heavily eroded in areas from the feet of cattle, plowing and vehicular traffic. With a ground visibility of forty to fifty percent, with much surficial downcutting by livestock directly into the red clay which is the bedrock of this site, we were only able to recover one small fragment of clamshell, a sample weighing .2 gram.

Unless some unknown agent is mechanically or chemically removing the shell, the occupants of this site did not avail themselves of this food resource. Tests of the soil's chemistry to determine if it is acid or alkaline in character would seem a useful starting point in evaluating this speculation. Data resultant from sampling in Site 41BQ147 suggest the possibility of a hiatus in the utilization of freshwater clams, or at least a periodic reduction, somewhere in the neighborhood of 90 percent.

According to Paulsen, using measurements taken with a staff gauge near Clifton, there are times when the Bosque flows 39,000 second-feet, with a gauge height of 23.2 feet (4-22-1945) with a greater flow in a unmeasured flood on May 9, 1922, with a reported gauge height of 25 feet (1948:113). Using records available from 1923-1948, the 25 year average discharge was 228 second-feet. From October,1947 to September 1948, records indicate a *low* flow of .7 second feet in late August, which lasted only three days, followed by a heavy rain which brought the North Bosque River back to levels it had been flowing in late July. From 1923 to 1948, although the report does not list the year or the duration of the events, the minimum discharge was, "no flow at times."

We do not know enough about freshwater mussels to speculate about their viability or survival rates under stressful environmental conditions. An extended period of "no flow at times" might, notwithstanding the fundamental organic water requirement, have a considerable impact on the economy of a human population accustomed to the utilization of the shellfish as a reliable food supply. To the other extreme, floods on the North Bosque are known to better than double the maximum flows discussed above, causing such severe scouring of the river channel as to potentially endanger the molluscan population (personal communication, Paul Price).

Aside from sampling of the soils at 41BQ163, we recommend no further investigation. It is not one recommended for inclusion within the National Register of Historic Places, nor considered a potential designate as a State Archeological Landmark.

Site 41BQ164

Outside the project area on a flat terrace is historic Site 41BQ164, initially identified as a homesite (See Figure 3.a.). Our post-discovery interview with Jeffie Hanna revealed we had found the site of the local school. In the 19th century, the school was originally located elsewhere, on property donated by Jordon. Then it was known as the Jordan School. Sometime in the late 19th century, the school was moved to this site near Loader Springs, named perhaps for Thomas T. Loader, the second postmaster of Iredell. He was one of the founders of Iredell, having purchased a lot at the settlement in 1871.

> Joining Lot #1 on the north, Lot #2, Block 1 of the new town was sold to Thomas T. Loader and on it he and Andrew Downing established the first store in the new townsite. Mr. Loader was appointed postmaster in 1872, and the post office was located in his store. He was born and reared in England and his wife was a cousin and lady-in-waiting to Queen Victoria. Because it was unheard of that he, a commoner, should marry royalty, the young lovers eloped...with the help of friends, to the United States and Iredell (BCHBC 1986:51).

Since that time, it was known as the Loader Springs-Jordan School. Classes were last held here in 1936 (personal communication, Jeffie Hanna).

The terminal date for the school was not consistent with our analysis of the artifacts recovered and observed. Searching through the partial foundation remains of the structure, we found cast iron and bottle glass which led us to an estimated age of occupation from the early twentieth century to 1950. Interestingly, one artifact recovered supported a misreading of the site as a domicile and threw off our terminal date by more than a decade, to the middle of the 20th century--it was a fragment of a brown glass PUREX bleach bottle, marked to indicate its year of manufacture, 1949. The site's proximity to the roadway has resulted in trash being dumped near the school, masking the artifacts of interest and in general, contaminating the deposit. There is a good possibility, however, that this contamination is confined to the surface, and while perhaps shallow, interpretable intact deposits may remain.

School houses are a favorite target of the historic archeologist. Some have privies segregated on the basis of sex, providing opportunities to observe behavioral differences. The array of artifacts, oriented toward learning, but accompanied by toys, clothing fasteners, food remains and whatever else the children or teacher brought from home and left there, yields general information concerning the lifeway of local inhabitants, the availability of goods and local economics. Most importantly, such sites offer opportunities to observe the past behavior of children in a setting rarely obtainable elsewhere, that is, children interacting with same-age children.

This site is not to be affected by Lake Bosque. This site is considered to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ165

Site 41BQ165A is an early 20th century historic site that includes a foundation of disturbed limestone and a few bricks and a nearby excavation assumed to be the root or storm cellar (See Figure 3.a.). Colorless glass, whiteware and crockery, and fragmentary sheet iron, some from "tin" cans, was found in the grassy clearing surrounding the foundation remains. We presume from the artifacts observed here that this was once a house, albeit a modest one. Additional interviews with adjacent landowners may reveal new information which would be contrary to our finding that the site merits no further work.

Site 41BQ165A is not recommended for inclusion within the National Register of Historic Places, nor it is considered to be a candidate for further work.

Site 41BQ165B is the house that was moved from the foundation remains we found near the edge of the channel to its present location, midway along the upland terrace (See Figure 3.a.). The structure we find here is larger than the foundation at 41BQ165A, leading us to the conclusion that with the relocation, the movers rehabilitated the house, adding perhaps two rooms.

Ed Moorman told us this structure was always called the "rent house," and had been at the new location since before 1950 (personal communication). Analysis of data gathered at this site provided a tentative span of occupation from after World War I to the middle of the 20th century. We do not recommend this portion of Site 41BQ165 for further investigation.

Site 41BQ166

This site is located on an upland terrace, above an intermittent drain to the North Bosque River (See Figure 3.a.). It is a multiple component one, with a very light lithic scatter on the surface mixed with historic materials. The biface thinning flakes found at the site told us that tools were probably once manufactured here by Native Americans. Historic materials include a limestone foundation pad of native fieldstone associated with thin, sheet iron strapping about 1/4 inch in width, thought to be recent and associated with perforated sheet metal, the residue of oil filters for gasoline or diesel engines, certainly from the 20th century. The absence of domestic artifacts like ceramics, glass, etc., makes it unlikely this was a homesite; the lithic scatter is ephemeral considering the terrace is eroded almost to bedrock and the short grasses afford good surface visibility.

Site 41BQ166 is not recommended for further investigation. It is not considered to be one eligible for inclusion within the National Register of Historic Places. It is not a candidate for designation as a State Archeological Landmark.

Site 41BQ167

Probably the smallest site we discovered within the general area of the project outside of those individual artifacts recorded as sites, this prehistoric hearth associated with chert and food remains measures less than 3 meters in diameter (See Figure 3.a.). For its size, it is potentially one of the more important sites. With mussel shell associated with burned rock, this site is rarely more than 10 centimeters in depth. The site is extremely localized and is thought to represent a single component campsite. We collected a sample of the shell to be used for radiocarbon testing. The resulting date was 2600 ± 80 years before the present (See Table 1, TX-5789).

Sites like 41BQ167 can yield important insights into the variability to be expected between radiocarbon dates taken from burned wood, soil, and mussel shell. Thought to be critical to the interpretation of prehistoric sites throughout the upper North Bosque watershed, this site is recommended for complete recovery through excavation. Site 41BQ167 is considered to be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ168

On a slowly sloping floodplain on the west side of the North Bosque River (See Figure 3.a.), this prehistoric campsite was given the name, Beaver Skull

Site, because there we found this irrefutable indicator of *Castor*. In the eroded margins of the site along the slope, we found mussel shell, two biface fragments--one, *Pedernales* -like, the other unidentified--and scattered flakes and chips. The subtle scars of machine reshaping are discernable across the site.

Our probes did not help us estimate the thickness of the cultural deposit here and this site is recommended for further sampling. It is one which should be considered to be potentially eligible for inclusion within the National Register of Historic Places and status of a State Archeological Landmark.

Site 41BQ169

Found on the surface of the current floodplain of the North Bosque River, this site was evinced as a scatter of burned rock, chert and mussel shell amid a carbon-stained zone of the sandy loam (See Figure 3.a.). We traced the various cultural materials over a broad area of the field, currently cultivated several times annually, depending upon the crop; at the time of our investigation, the choice was grain sorghum. Thought to be the location of a disturbed hearth, we measured the feature from a tree marked with flagging tape.

The surface of the site is extremely disturbed, but underneath the plow zone, cultural deposits may remain intact. The location is one which would have been attractive to Native Americans. On the basis of the surface exposure of the site and its close proximity to the North Bosque, hence subject to periodic flooding and deposition of alluvial overburden, Site 41BQ169 was thought to be a late prehistoric campsite, probably of the Neo-American period. The radiocarbon date of the mussel shell we recovered from the site proved otherwise. The sample yielded a date of 3020 ± 50 years before the present (See Table 1, TX-5792), the second oldest ^{14}C date in the project area. Additional sampling after harvest is recommended.

Although plowed and slightly eroded by wind and water, Site 41BQ169 is still considered to contain data potentially important toward gaining a better understanding of prehistoric life near the River. Accordingly, this site is considered to be potentially eligible for inclusion within the National Register and a potential candidate for State Archeological Landmark status.

Site 41BQ170

This prehistoric campsite is located on a small terrace above the floodplain of the North Bosque River (See Figure 3.a.). Situated on a sloping surface, erosion has contributed to the destruction of the site, coupled subsequently with heavy machine scraping, the range production method generally used throughout the uplands of this property. We recovered only a lithic specimen, a chert sample, from the site, but we observed the normal indicators of Native American activities here in the past, associated with food processing, lithic tool production and subsistence--these were thermally fractured and discolored limestone fragments, a scatter of chert flakes and mussel shell.

The combined effects of time, slope and machinery have reduced this site to one of limited value. It remains useful in helping plot areas of prehistoric settlement in the general area of the project, but it is not one recommended for further investigation. Accordingly, Site 41BQ170 is not recommended for a determination of eligibility for inclusion within the National Register of Historic Places, or designation as a State Archeological Landmark.

Site 41BQ171

Located on a hilltop and draping down the slope was the cultural material of a late 19th or early 20th century housesite (See Figure 3.a.). As we approached the top of the hill, we discovered dozer piles with historic materials protruding from the masses of earth and trash. These included a number of cast iron and iron frames and headboards of beds and lightning rods and fasteners. There was little to salvage that was usable for our purposes, especially for the dating of the structure. We gathered only what we could from the piles, in this case a lightning rod bracket which once guided the rod along the side of the structure, as well as the threaded male brass connector which once was pinched onto one end of the twisted, galvanized rod, and which allowed the rods to be joined. Our assessment of this site led us to the conclusion that a house which retained its contents had been razed by machine.

Sometime before this demolition, perhaps in the late 1930's or early 40's, the residents built a dugout structure into the side of the hill with rock and mortar. It has the appearance of never having been completed, although almost so. We measured the small structure for our notes and wondered concerning its use and history. Our interviews with the current landowner revealed no additional information.

Significant disturbance results in the loss of interpretable data, and this is the circumstance at this site. Not recommended for further investigation, Site 41BQ171 is not a candidate for a determination of eligibility for inclusion within the National Register of Historic Places.

Site 41BQ172

This site is located atop a hill which will be an island when Lake Bosque is operating at an elevation of +830 feet m.s.l (See Figure 3.b.). The prehistoric material we found here was out of place. Through the use of heavy machinery, almost the entire hilltop has been scraped to bedrock. Piles of pushed soil, rock and roots are the current matrix in which we observed mussel shell, and flakes and chips of chert.

A site had been predicted here, not remarkable when considering that as each new site was plotted, we reexamined the aboriginal and historical settlement pattern and made new projections concerning site locations. This site, it was predicted, might be like a few of the others on high mounts near water, undisturbed but eroded. This prediction had failed to include consideration of another pattern which was emerging from our data gathered in the project area; many of the prehistoric and historic sites which had not been rendered uninterpretable by time and the elements had been destroyed by human action.

Site 41BQ172 is not recommended for further investigaton. It is not one thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ173

A slight rise in the floodplain near the edge of a field in cultivation marks the location of this prehistoric campsite (See Figure 3.a.). Within a rough circle 15 meters in diameter, Site 41BQ173 was revealed as a light scatter of mussel shell in the freshly plowed alluvium. We observed, but did not collect the flakes of chert, present but rare on the surface. A few thermally fractured and discolored stones mark the probable location of a derived hearth.

Certain the site is disturbed through the plowzone, we recommend that additional sampling be performed here after harvest. Site 41BQ173 should be considered one that is potentially eligible for inclusion within the National Register of Historic Places and one that might merit designation as a State Archeological Landmark.

Site 41BQ174

Site 41BQ174 was given the appelation, Horned Toad Site, because of the number of Texas Horned Lizards, *Phrynosoma cornutum,* (Ransom 1985:418) which reside here. The site contains an apparent breeding population of these small lizards, so abundant they scampered onto our recovery tools to be retrieved for closer inspection before we placed them back in the site. We found them to be distributed among the prickly pear and other cacti, in the short grasses, sedum and other low forbs which cover the site. Site 41BQ174 is a prehistoric one located on an eroded mount on a terrace ridge between two drains, a common uplands configuration normally used by Native Americans, and one frequently avoided by later historic occupants of the North Bosque River valley (See Figure 3.a.).

This fairly large, very light lithic scatter included the fragment of a large, thin biface, a fragment of a tool made from a unifacially reduced flake, and flakes which reflect lithic reduction and tool production. These we collected. Our mine probes revealed this site to have a depth of as much as 5 centimeters, or 2 inches, in places, but the majority of the site is exposed to the bedrock.

This site is not recommended for further investigation. It is not a candidate for State Archeological Landmark status or for inclusion within the National Register of Historic Places.

Site 41BQ175

This is not an archeological site, but one recorded to document a geological occurrence. Throughout the project, one of the goals was to determine the presence of any autochthonous chert, that is, formed or occurring in the place where found. Site 41BQ175 is the location of an eroded outcrop of gray coarse-grained, fire-cracked chert (See Figure 3.a.). Although we initially thought them to be the result of aboriginal lithic procurement, our search of the site revealed that all of the chert specimens were heat modified, but none was altered by direct human action. We collected fifteen (15) fragments of these thermally-altered specimens.

We were surprised to discover *any* local sources of chert within the project area; our review of the area's geology had not prepared us for its occurrence. Furman Grimm, a geophysicist who once owned these or lands directly adjacent to this site was also surprised at our discovery. He had examined a number of post holes on his property and had contracted excavations for stock ponds in the same area without finding this locality.

This geological locality is not recommended for further investigation. It is not one for inclusion within the National Register of Historic Places nor a designee for State Archeological Landmark status.

Site 41BQ176

Located above and outside the area directly affected by the creation of Lake Bosque is this multiple component site on a hilltop (See Figure 3.a.). Surrounded by large liveoaks, the site consists of a housesite adjacent to a prehistoric campsite. The majority of the prehistoric site was centrally located on the hill, in an eroded area now used for cattle feeding and for the passage of vehicular traffic. The ground surface revealed a small mano, a biface fragment, and several interior flakes resulting from the reduction of decorticated cores.

Historic materials from the site were those normally associated with a house. and are closer to the road than the prehistoric site. They included fragments of glass bottles, one of which was a panel bottle, both with hand-finished necks. Stoneware included fragments of ironstone, including a piece of a bowl. Metallic artifacts included cut nails in a variety of sizes and a "U" shaped handle of wrought iron, once affixed to a container with two rivets at each end, probably from the edge of a pot. The fragments of a cast-iron stove were broadly distributed over the area. We collected them and found they were marked, **BEACH & \/ IRON CLAD / LOW COPPER / RESERVOIR / FEB 14TH 1871 / PAT DEC 5 \/ FEB 8, 1870 / REASSIGNED JUNE 3 **.

Little remains of either component that would benefit from excavation. Surface collection of prehistoric and historic material in the deflated central portion of the hill would yield an interesting variety of artifacts, usable for determining the kinds and nature of items used by the Native and later populations. The site is thought to no longer contain in-place deposits. The site is not thought to be eligible for inclusion within the National Register of Historic Places, nor considered a candidate for designation as a State Archeological Landmark.

Site 41BQ177

This eroded lithic scatter is exposed on the surface of a high mount at an elevation of +860 feet m.s.l. (See Figure 3.a.). Field probing revealed the site has no depth. A remnant of a prehistoric open campsite, the scatter included a chert cobble which probably served as a mano, for it is ground on one side. A few chunks of grey chert and some flakes, both with and without cortex, are what remains of the site.

Site 41BQ177 is not recommended for further investigation. It is not one which merits inclusion within the National Register of Historic Places.

Site 41BQ178

Microenvironmentally similar to Site 41BQ174, this site is at the slightly higher elevation of +840 to 843 feet m.s.l (See Figure 3.a.). On-site probing reveals the depth of the site not to exceed 4 cm., or < 2 inches. A very light lithic scatter is the cultural material found here. Included were two points, one a fragmentary one of crystal, the other, essentially complete (See Figure 6.b.), which make us suspect this site was occupied in the Middle to Late Archaic.

Little remains of Site 41BQ178 for further recovery, and it is not recommended for further investigation. Site 41BQ178 is not considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ179

Now the location of a modern house, this prehistoric lithic scatter represents the remains of an open campsite on the top of a hill overlooking Beaver Creek, associated with the early 20th century remains of a housesite (See Figure 3.a.). The prehistoric material included a flake from the manufacture of a chert biface and a chunk of dark gray, speckled chert. Observed but not collected were a post World War I deposit of glass, ceramics and food cans. The prehistoric occupation is of unknown age but the historic one is estimated to span from around 1920 to the 1940's. Machine clearing of the general surface and the introduction of rock materials from outside the project area have resulted in a deposit which is disturbed beyond archeological utility.

At an elevation of +845 feet m.s.l., Site 41BQ179 is above the area to be affected by Lake Bosque. It is not recommended for further investigation. Site 41BQ179 is not thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ180

Located on the tip of a secondary terrace overlooking Beaver Creek (See Figure 3.a.), this site is a prehistoric one eroded to fossiliferous bedrock. This extremely light lithic scatter is also found on the lower terrace. Almost nothing remains of this site. We were able to find three flakes, seven chips, and a chunk of gray chert, along with a fragment of aged, colorless glass decorated with an embossed pattern. The glass fragment is thought to have come from Site 41BQ98, a few dozen meters to the south.

This site is not recommended for further investigation. Site 41BQ180 is not considered to be eligible for the National Register of Historic Places.

Site 41BQ181

This prehistoric lithic scatter is another eroded open campsite on a well-drained circular mount about 30 meters in diameter (See Figure 3.a.). No diagnostic forms were observed, although we did recover a couple of biface fragments along with five flakes and an equal number of chips of chert, as well as four chunks of gray chert. We found a small fragment of mussel shell which we did not collect. The occupation or activity areas of this and many other of these eroded lithic scatters on mounts appear to be constrained to the mesa-like, flat portions of the terraces.

With no appreciable depth and little cultural material, Site 41BQ181 is not recommended for further work. It is not a candidate for State Archeological Landmark status or considered to be eligbile for inclusion within the National Register of Historic Places.

Site 41BQ182

This historic site is located in the middle of an upland terrace above and to the east of a drain which periodically feeds Beaver Creek (See Figure 3.a.). According to the present owner, Leland Pridemore, the site has been affected by clearing and filling(personal communication). We found the scatter of a limestone foundation and a few sherds of bottle glass, but little of this site remains.

The cultural material and house foundation are displaced and mixed, providing little opportunity for discovering activity areas or in-place features. Site 41BQ182 is not recommended for further investigation. It is not thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ183

Located in late April, this prehistoric lithic scatter, presumed to once have been an open campsite, was called the Killdeer site (See Figure 3.b.). Two nesting pairs of this common plover, *Charadrius vociferus*, feigned injury, ran and voiced their noisy and persistent call and finally took to the air (Ramsey 1985:82). We continued our sweep of the terrace, which produced a few flakes, some chunks of chert, a small uniface, a chipped fragment of crystal and a fragment of a projectile point. As we walked away from their nests, the killdeer returned, leading us to their nesting scrapes and two almost invisible eggs camouflaged by blotches of brown on a buff background. Almost nothing remains of this chert scatter which covers a broad area about 50 meters in diameter.

Recorded because of its presence and importance in the general prehistoric settlement pattern in the project area, Site 41BQ183 is not recommended for further work. It is not one considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ184

This prehistoric site is an extremely light lithic scatter which covers a terrace edge above a creek, an area approximately 50 meters wide by 180 meters long (See Figure 3.a.). We found no diagnostic tool forms to offer clues to the age of Site 41BQ184. Perhaps the most remarkable aspect was the frequent use of the locally available coarse-grained gray chert, representing 75 percent of the sample recovered. It hardly seems suitable for tool production. The tool fragment and a flake, thought to be the result of biface reduction, we recovered are of a finer-grained, dark gray chert.

Eroded and perhaps affected by machine clearing, little of Site 41BQ184 remains. It is outside of the project area and is not recommended for further investigation. Site 41BQ184 is not considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ185

On the 20th of January, 1987, we interviewed Roy L. Nickels about any interesting sites he knew of on his property. He reported a "slave burial" on the south end of his property, across the North Bosque River in a motte of oaks. While he had looked for it alone, and with others, it had not been found.

In this inaccessible portion of his property during late April, at an elevation of about 800 feet m.s.l. (See Figure 3.b.), we located a rectangular limestone feature set with lime mortor in the configuration of a grave. Near one end of the rectangle was a heavy wrought iron grate on the ground. Away from the feature, but in general proximity, we found some red brick impressed with the mark, GROSBECK. The liveoak motte we were within provided a shade for a lush cover of medium grasses; the feature itself was covered with a profusion of poison ivy, *Toxicodenron radicans*, which we did not disturb (Vines 1960: 638). While we consider this site to be the most likely candidate to conform with Nickels' description, this feature is dimensionally similar to a firebox which could be used as a sorghum cooker, to reduce the sap expressed from cane to syrup (Briggs 1981:29-32).

Our inspection of the surrounding area revealed no artifacts to be found on the surface. To be sampled, the site must be cleared of the growth of harmful plants in such a manner that the rootlets are also killed. The roots must be allowed sufficient time to decay before hand excavation may be attempted. If testing results are positive, and the site has been used as a cemetery, relocation of any corporal remains is recommended. Sites such as this are generally not considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ186

This historic housesite is located on the edge of a terrace above the flood-plain of the stream adjacent to the suspected gravesite, Site 41BQ185 (See Figure 3.b.). A chip of gray chert and a small fragment of mussel shell may point to the presence of a prehistoric campsite in the area as well. Aside from some foundation rock disturbed by machinery or a plow, we found a sherd of colorless flat bottle glass, 5 fragments of colorless and light green glass and two fragments of stoneware, an ironstone cup and plate.

The artifacts may be misleading in that they seem to point to a fairly late occupation in the early 20th century, but the foundation and scatter resemble a late 19th century one. The site is likely related to 41BQ185, but at present, the nature of this relationship is not understood. They may be related not only by proximity, but in time and culture. A candidate for further archival research and possible sampling, Site 41BQ186 is considered to be a site potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ187

This prehistoric open campsite will be adjacent to the edge of the proposed Lake at the maximum flood pool of +841.3 feet m.s.l. It will then be one of the easternmost points on the west side of the lower portion of Lake Bosque (See Figure 3.b.). The site is not a deep one because it is located on the upland terrace edge, an area which is generally eroding and rarely receives colluvial or wind-borne soils. The fragment of a chert dart point thought to be Late Archaic in age was recovered amid a light scatter of burned rock, a broad, light lithic scatter and mussel shell, enough sample for radiocarbon dating. We also found one fragment of brown bottle glass.

This site is a large one, measuring over 100 meters along the edge of the terrace. There may be buried, undisturbed portions away from the exposed bedrock along the margin of the site, missed by our probing. We saw few signs of recent human activity in the area other than annual deer hunting and periodic bird shooting and noticed no machine damage here. This site is not recommended for further investigation at this time. This site may be one to be considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ188

This historic housesite is located on a slight rise above a stream terrace of Otter Creek (See Figure 3.b.), the name we gave this tributary because we found a mud-stained trail from the water over the dam of a small lake to a long slide down to the creek, possibly the result of activity by river otters, *Lutra canadensis* (Ransom 1985:377-378). The house site is marked by the walkway that led from the drive to the house, with flower beds boxed in with limestone on either side. Limestone foundation remains of the house are still to be seen and we found the root and storm cellar and the water supply, a drilled well.

The artifacts we found here suggest a late occupation, from the 1930's to 1940's--they included a variety of late Automatic Bottle Machine (ABM) bottles, a TEXAS 1936 CENTENNIAL license plate, and a later-dated *Coca-Cola* bottle from 1948.

This late historic site is not recommended for further investigation. It is not considered to be a candidate for State Archeological Landmark status or thought to be one for inclusion within the National Register of Historic Places.

Site 41BQ189

This large prehistoric site is located on the eastern side of the North Bosque, on an upland terrace overlooking a drain (See Figure 3.a.). The site appears to contain at least two small rises of burned rock, with no signs of disturbance. Covering an area along the terrace edge greater than 50 meters, the site contains mussel shell, chert flakes and thermally-altered rock, presumably the residue of hearths and cooking. Probing here revealed depths exceeding 20 centimeters, with potentially greater depth because of the obstructions provided by the burned rock and other materials in the soil matrix. Our examination of the surface yielded no time-diagnostic forms, but we collected some chert samples in the form of flakes and collected almost 100 grams of shell, a sample of which we submitted for radiocarbon dating. The sample of shell yielded a date of 1140 $\pm$ 60 years before the present (See Table 1.1, TX-5788). This date is the youngest of those mussel shell samples recovered from archeological sites during this investigation which makes it a candidate for our latest Native American site.

We did not dig here or conduct sampling, but we would have if we could have gotten permission. This site appears to be undamaged by machine action although it is quite possibly eroded to bedrock, covered with colluvial and eolian deposits and then stirred for a thousand years by disturbance from the succession of intrusions by roots and burrows.

This site is recommended for further sampling. It is thought to be one potentially eligible for inclusion within the National Register of Historic Places and to be a candidate for designation as a State Archeological Landmark.

Site 41BQ190

This historic site is located on the same terrace and is just northwest of Site 41BQ189 (See Figure 3.a.). Situated on a flat terrace edge adjacent to a stone fence, the house foundation can be found in a clearing surrounded with junipers and liveoaks. We found a biface fragment here; whether the site is prehistoric or whether the historic residents collected the artifact elsewhere and dropped it here remains unknown to us. Stoneware in the form of fragmentary crockery, broken whiteware dishes, and the wheel from a furniture caster was found. Glass sherds collected represented a packing jar and panel bottle. The material we observed and gathered appears to represent a late 19th and early 20th century occupation.

We were unable to obtain permission to perform sampling at this site, but we believe it merits such additional investigation. Archival research in the title office at the Bosque County Court House would probably clarify the date of occupation and help orient further investigaton. Site 41BQ190 is considered to be one potentially eligible for inclusion within the National Register of Historic Places and a candidate for status as a State Archeological Landmark.

Site 41BQ191

This shallow prehistoric campsite on a slowly sloping upland terrace (See Figure 3.b.) appears to be buried under about 3 centimeters of recent colluvium. This is the result of a range management change in the neighboring property upslope, where the soil has been cleared, tilled and sprigged with coastal bermudagrass. A biface blank, or preform, was pulled from an eroded sidewall, slightly more than 2 centimeters below the surface (See Figure 4, b). In the zones where the pinkish tan sand covering the site was blown or washed away, we saw flakes of chert and scattered burned rock.

We think this site is eroded to a bedrock clay and scattered, then covered by recent fill. It may have been cleared by machinery in the past. Perhaps 20 percent of the site remains buried. We recovered no time-diagnostic artifacts from the site, but geologically, it is situated in an area which we believe has been relativley stable since the late pleistocene. The best method of demonstrating if this site has any in-place deposits is through sampling. The site is therefore recommended for further investigation. This site may be one potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ192

This open prehistoric campsite is similar to the previous one, Site 41BQ191, eroded, with pinkish-tan sand overlaying red clay, but 41BQ192 is located on a midlands terrace edge (See Figure 3.b.). We found the distal tip of a biface, probably a projectile point, and several flakes of chert, one thought to be the residue of bifacial thinning. This site has been subject to clearing for pasture and range production at some time in the past.

Site 41BQ192 is not one recommended for further investigation. It is not thought to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ193

This historic site provides the signature for a housesite, one we did not locate, we think, because it was burned and subsequently churned by machine clearing (See Figure 3.b.). While we were on site, a sherd of light purple panel bottle was moved more than 2 feet by a cooperating team of red, harvester ants. We collected the specimen and later, returned to the lab to measure the sherd. It had a maximum length of 20 mm, a maximum width of15mm, was 2.5 mm thick and weighed 1.1 grams. During the survey, we have always included stops at harvester ants nests to help us discover small pressure flakes of chert, clues to the discovery of a buried prehistoric site in the area, but we had not realized their potential for disturbing artifact patterns in a horizontal manner. We found several ceramic fragments of a saucer, also a plate and a bowl; we found two chunks of burned, melted bottle glass and fire-discolored whiteware. In addition to the mixture of burned and unburned material, we found a hand-forged ax head that weighed 3 3/4 pounds and spent the remainder of the day passing it from crew member to crew member.

This site is of little value for archeological inquiry. More information can probably be gained from archival work, but the site itself is not recommended for further work. Site 41BQ193 is not thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ194

This prehistoric site runs along the edge of an midlands terrace overlooking the bottomland of the North Bosque (See Figure 3.b.). It is another one let down on red clay thought to be late pleistocene in age, then covered with reddish blow sands. The chert first discovered in an exposed area was traced along an old roadway, but the character of the site did not change. A fragment of a projectile point, a barb from a point like a *Bell* or *Andice* (See Figure 5.c.) is thought to be Early Archaic in age (Turner and Hester 1985: 64-65 & 72). No other time-diagnostic tool forms or datable samples were recovered. Eroded and once disturbed by traffic through it, we found few indications that this site had any material culture in place. One sherd of stoneware crockery found here may come from Site 41BQ193, to the north-northwest.

Not recommended for further investigation, Site 41BQ194 is not presently thought to be a candidate for nomination to the National Register of Historic Places.

Site 41BQ195

This moderately eroded open prehistoric campsite on a slightly sloping upland terrace is shaded by juniper and mesquite (See Figure 3.b.). It displays lithic material lightly scattered down the slope. Burned rock was observed in a light and very wide scatter. We recovered a projectile point, apparently barbed on one side (See Figure 5. n.), a unifacially trimmed flake, a couple of sandstone mano fragments, flakes of chert and a sample of fragmentary clamshell. Also at this site, but thought to have been dumped here from the historic site, 41BQ196, were fragments of stoneware--ironstone plates and a cup. A neck of a bottle finished by hand, a couple of fragments of cut nails and a piece of cast iron stove were found nearby.

Extensively eroded, this site is of limited value for archeological investigation. Areas may be found near the upper margin of the site which are not derived as a result of the slope and, hence, usable for interpretation. Limited sampling of 41BQ195 is recommended. It is possible that this site might qualify for inclusion within the National Register of Historic Places.

Site 41BQ196

A long abandoned, heavily eroded roadway led us through a derived artifact scatter of prehistoric and historic materials (See Figure 3.b.). By the time we had reached the top of this ridge above the North Bosque, we had found a fragment of a biface, a quartzite mano fragment, one of the small chert "chisel" bifaces we had been finding at various prehistoric sites, several varieties of flakes and slightly more than 30 grams of clamshell. Historic materials included crockery of four different forms, including one of which was identifiable as the shoulder fragment of a "Glasgow" ale bottle. Fragments of a pearlware plate, a British marked ironstone plate fragment (See Figure 8.b.), as well as piece of a coffee cup were found. Glass fragments included colors in light purple, aquamarine, amber, brown and the so-called "black," actually very dark green. Metal artifacts included a horseshoe nail, a broken cut nail and a fragment thought to come from a concertina or melodian, an accordion-like instrument invented by Sir Charles Wheatstone in 1829 (See Figure 7.a.) or perhaps from a foot-pumped keyboard organ.

With this scatter of artifacts, it seemed extremely likely that a house was in the vicinity. We established transects and passed over the hill without discovering any foundation remains in the waist-high grasses. We turned and passed over again, changing places but covering the same general area, again without result. On our fourth try, we found traces of foundation material and followed them to a fairly large, complex limestone rock outline, covered by tall grasses and prickly tasajillo, *Opuntia leptocaulis*, a common break-apart stick or stem cactus in the area (Weniger 1984: 337-340).

The prehistoric campsite at the top of this hill may be eroded, but the historic site still retains considerable integrity. The historic site may have inadvertently preserved portions of the prehistoric site intact under the foundation and structure on the hilltop. We think this is a site which merits additional archival and archeological inquiry. This site is considered to be one potentially eligible for inclusion within the National Register of Historic Places and a candidate for designation as a State Archeological Landmark.

Site 41BQ197

On the crest of an upland knoll at an elevation greater than +900 feet m.s.l. this prehistoric campsite is completely eroded to bedrock and exhibits a very light, broadly distributed chert scatter (See Figure 3.b.). We observed flakes and at least one core. The lack of time-diagnostic tool forms prevented estimating a time of occupation.

Recorded because of its importance as data in the general prehistoric settlement pattern of the project area, and not because of the site's potential for further investigation, Site 41BQ197 is not recommended for inclusion within the National Register of Historic Places.

Site 41BQ198

This is a multiple component site which is located on a hilltop overlooking the North Bosque at about +853 (See Figure 3.c.). It includes a broad lithic scatter, in the center of which is an occupied house. The house, not including additions, is a clapboard one reported by the property owner to have been built in 1871 (E. L. Sadler, personal communication). The area is heavily sodded with short grasses and outside of the area which is annually cultivated as a garden, soil visibility is very limited. The property owner showed us three Archaic dart points and four manos which had been found at the site. In the garden, we found a large amount of chert debris between the rows of vegetables. Crockery, bottle glass, and whiteware were also found in the same area.

The site setting is one conducive to settlement, the hill upon which it is located extends to a height greater than +857 feet m.s.l., and has not flooded since the structure was built there. Directly to the southwest, less than 30 meters away, is a intermittent tributary to the North Bosque which keeps the site well-drained. While the site appears to be shallow, it is in an old environment, the terrace upon which it sits is thought to be late pleistocene in age.

Not recommended for further work at the present time, Site 41BQ198 is potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ199

This site is the foundation of a house, associated with a nearby large depression which could be the remains of the root/storm cellar (See Figure 3.c.). The depression was pointed out to us as being a house which predated the one on the hill, Site 41BQ198. In the center of this depression, we found the almost complete fragment of a stoneware dash churn cover, with an off-white salt glaze. The site of the house is heavily overgrown with tall grasses, several small and moderate trees and pear cactus which serve not only to obscure the ground, but the foundation as well. We were not able to find any additional artifacts here. If our informant is correct, these features would seem to be earlier than the standing house.

This could be an important site if it is as early as indicated by our local informant. We feel fairly certain that it that is pre-20th century in age and have no evidence to indicate that Site 41BQ199 is other than a house. At the present time, Site 41BQ199 is not recommended for further work. It is considered to be a site potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ200

This multiple component site is a prehistoric lithic scatter which was the site of construction for a farm camplex in the first third of the 20th century. On a knoll of the floodplain, at an elevation of +860 feet m.s.l. (See Figure 3.c.), the above-ground features include several outbuildings still in use, associated with a rock and plaster cistern, poured concrete foundation beams and a possible hand-dug well. Artifacts associated with the historic occupation, thought to include a house, were fragments of an ironstone plate or saucer, fragments of aquamarine and purple glass, one with an "Owens Scar," an early ABM mark. Prehistoric materials recovered here include a biface fragment, thought to be the mid-section of a dart point, and flakes, chips, and a chunk of chert.

Site 41BQ200 is outside the area to be affected by Lake Bosque. The only archeological feature of interest at this site was the one thought to be a hand-dug well. It could contain artifactual material that would reveal data concerning the historic inhabitant of this site. There could also be prehistoric or historic features buried under recent colluvium and obscured by the short grasses. Not recommended for investigation at the present time, this site is one which could merit inclusion within the National Register of Historic Places.

Site 41BQ201

At an elevation averaging +860 feet m.s.l., this prehistoric lithic scatter is eroded to reddish clay. On a small rise at the edge of the floodplain of the North Bosque (See Figure 3.c.), we found several flakes and chips and fragments of mussel shell. We collected a couple of flakes and searched for pieces of shell, but recovered only 2.8 grams, too small a sample for radiocarbon dating purposes. Erosion has been accelerated here as a result of machinery having been used to clear the site for pasture.

This site is not recommended for further work. Given our present level of knowledge concerning this site, it is not thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ202

The westernmost site discovered during our investigation was this open prehistoric campsite at an elevation above +860 feet m.s.l. (See Figure 3.c.). This slowly sloping upland terrace is covered with a light lithic scatter of chert debris and small fragments of mussel shell on red clay, surrounded by loose, red sand. The site has been disturbed by the construction of two nearby stone-lined ponds of unknown age and is cut through by a primitive road which descends here to the floodplain and the North Bosque River, some 60 meters to the south.

Outside the area affected by inundation or flooding, and not recommended for further work, Site 41BQ202 is not thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ203

This prehistoric site is located on a gently sloping terrace which overlooks the broad valley of the North Bosque (See Figure 3.b.). Wind and water have served to erode the site to red clay, with red sand along the lower slope, stabilized somewhat by short grasses among the prickly pear and mesquite. Initially discovered while crossing from a roadway through a pasture gate, a very light scatter of chert flakes and chips and fragments of clamshell was traced to just above the floodplain, where the material is buried by the sand. A lack of time-diagnostic tool forms prevents estimating the age of the site or the period of its use. With no observable in-place features, and apparently derived downslope, little remains of this open campsite.

With moderate to heavy erosion, and material culture out-of-place, Site 41BQ203 is not recommended for further work. The site is not one considered to be a potential candidate for a determination of eligiblility for inclusion within the National Register at this time.

Site 41BQ204

An intermittent tributary to the North Bosque marks the location of this multiple component site (See Figure 3.b.). Situated on the edge of the terrace above the floodplain of the Bosque, a spring may have once originated here. Today, a stock tank is located directly upstream from the site; its construction altered the site along the southwest margin. The evidence that this site was once a prehistoric campsite was a small fragment of clam shell and a couple of flakes. There may be more of the prehistoric site here than was observable.

The subsequent occupation of the area as a housesite during the late 19th century has obscured the marks of the earlier inhabitants. The remains of the apparently undisturbed foundation of the house is found on a slight rise beside an old primitive road. Scattered around and amid the limestone rocks, the historic artifacts are from the mid-1800's to the 20th century. Stoneware fragments included whiteware, such as pearlware, and ironstone and two with under-glaze transfers in plate, saucer, bowl or chamber-pot forms. Other stoneware sherds found were of wheel-thrown crockery, one with a dark brown slip on the exterior, the other was white on the interior and blue-and-red sponged pattern underglaze on the outside. Glass fragments appear to all come from light green, brown and colorless bottles. Also recovered was a broken piece of a cast iron, part of the remains of a stove.

The location of this housesite plus the age of the artifacts found there imply that Site 41BQ204 is one of the earlier historic sites in the project area. While the margin of the site is somewhat disturbed by earth moving, the road that cuts through the site may be one of its original features and not a later intrusion. Archival research into titles should yield data useful in dating the origin of the occupants and the length of use. This site contains in-place historic features which should be mapped subsequent to clearing and removal of vegetation. Archeological sampling to determine the potential for discovering buried in-place prehistoric or historic deposits is recommended. This site is considered to be one potentially eligible for inclusion within the National Register of Historic Places. It is a candidate for designation as a State Archeological Landmark.

Site 41BQ205

This small historic site is thought to be the location of a single-pen log cabin, situated on the second terrace above the North Bosque (See Figure 3.b.). In a thicket of elm and oak surrounded by juniper and thickly covered with short and moderate height grasses, almost none of the foundation can be seen. Although the area in which the site is located is relatively accessible, the site is difficult to discern in the general landscape and, therefore, the boundaries of the only feature recognized were heavily marked with flagging tape. Our search of the ground yielded a tantalizing artifact, a colorless bottle base with the scar of a pontil, an old method of holding molten glass, on the bottom. Pontils are normally associated with antebellum glass, but our subsequent analysis of the artifact reveals it may be the bottom of a font, or fluid reservoir, for an oil lamp. Lamp parts, especially globes, were made of blown colorless glass from the late 18th well into the 20th century. Fonts such as this one, which sat below the burner, date after the use of the thick organic or vegetable lamp oils which were gravity fed, certainly after 1840 and generally after the middle of the 19th century.

The paucity of artifacts serves to limit our ability to date the site, but not to reduce its importance. Small sites such as this tend to be earlier than complex, larger settlements or homesteads, and of shorter duration, yielding an interpretable slice of time with definite time constraints resulting from analysis of recovered data and archival material. Admittedly speculative, this site is thought to represent an initial settlement, but because of its limited size, of extremely limited duration. If it proves though analysis to be antebellum, it may found to be a cabin once occupied by slaves. The lack of ancillary features, including outbuildings, fences, or a nearby terrace suitable for horticulture or cultivation, plus its relationship with Site 41BQ204 and 41BQ207 reminds us of a pattern seen before, one suggestive of a southern plantation operating with the use of slaves (Briggs 1985).

Regardless of our speculation, the site is considered to be worthy of further investigation. Accordingly, Site 41BQ205 is one thought to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ206

A nineteenth century road that connects Site 41BQ205 and 41BQ207 passes down the slope from an upper to a lower terrace (See Figure 3.b.). The tracks of the wheels have become ruts which have accelerated erosion through a thin blanket of tan sand to the red clay bedrock, exposing this prehistoric campsite. Along the eroded margins of the road, the site can be seen in profile, but generally, ground exposure elsewhere was restricted to less than 15 percent visibility. Nevertheless, fragments of five dart points (See Figure 5.f., m. & o.), tools and tool fragments (See Figure 11.a.), flakes, a mano and fragments of mussel shell were collected.

The exposure along the roadway implies that this site is not a deep one, but is one which contains a large amount of cultural material over a moderately broad area. Sub-surface sampling of this site may yield information usable in achieving a better understanding of Site 41BQ206, occupied during the Middle Archaic period. At an elevation of +838 to 842 feet m.s.l., portions of this site will be periodically flooded. This site is considered to be one potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ207

Thought to be linked with Site 41BQ205, and possibly 41BQ204, this small historic site consists of the foundation of a structure surrounded by a light scatter of historic material culture. The setting is similar to 41BQ205, on the second terrace above the river, and also appears to be restricted in size and complexity. Only the partial remains of the dry-stacked limestone foundation mark the site above ground. On the surface, fragments of a cast iron stove and kettle, stoneware, including pearlware, ironstone, underglaze blue transfer and spongeware, and aged dark brown, dark green and aquamarine bottle glass were observed and collected.

Site 41BQ207 should be subjected to additional sampling, including clearing, mapping, surface collecting and a search for sub-surface features. Archival research into this property should yield data useful in interpreting this site. Whether this structure served to house a new pioneer into the area, was used as slave quarters or had other functions, the site is considered to be important to an understanding of the early local history. Site 41BQ207 is considered to be one potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ208

There was no way for us to tell the six-foot tall johnsongrass that obscured this site had days before been sprayed with herbicide, and so we entered it early one morning, when it was still covered with dew. The experience proved uneventful, but it pointed out the need to remain in close contact with property owners. This field of high grass was once in cultivation and will be again. The site is located just northeast of an old ford of the North Bosque, known as Pilot Crossing (See Figure 3.c.). Thought to be the location of a prehistoric open campsite, the site has been dispersed over the floodplain by tillage. A scatter of lithic material was observed, associated with mussel shell and two Middle to Late Archaic dart points (See Figures 5.i. & 6.i.).

The property owner, Ervin J. Moore, developed this and many of the other fields on his property, by clearing away most of the large trees and underbrush. When the fields were plowed, he noticed a large quantity of chert and mussel shell being exposed and on inspection, found a number of projectile points and tools. He gathered these, not because he is a collector, but because not removing them would cause the artifacts to be broken by repeated passes of machinery, which would further scatter them, and likely result in their being lost (personal communication). In the process, Mr. Moore has accumulated a large number of artifacts which span from the earliest use of the project area by PaleoIndians to late prehistoric Neo-American populations. The collection is an admixture of more than half a dozen sites located on his property and is one thought to be extremely useful in establishing a local typological and chronological framework for the project area and perhaps elsewhere. Before we completed our survey work on the Moore place, our investigations had confirmed the presence of artifactual material and sites which corroborated the time frame implied by his collection.

This site is recommended for further investigation. Sub-surface sampling would reveal the depth of agricultural disturbance and reveal if any of this site retains sufficient integrity for future investigations. Mussel shell collected simultaneous to other work would be useful for radiocarbon dating, resulting in a better understanding of the overall chronology of the human use of the project area and specifically, the time frame of the Middle to Late Archaic at this site. Site 41BQ208 is considered to be which might prove eligible for inclusion within the National Register of Historic Places.

Site 41BQ209

With the North Bosque River only twenty meters to the north, this prehistoric campsite of unknown age is located on the floodplain (See Figure 3.c.). Tilled and planted, this field of sorghum has a light lithic scatter of chert debris with small fragments of mussel shell mixed throughout the surface of the light tan alluvial loam. On a very slight rise, the site may mark what was once the opposite side of the channel of the North Bosque River, a possibility strongly suggested by similar settings at Sites 41BQ210, 41BQ211 and 41BQ212.

Sub-surface sampling is recommended at Site 41BQ209 to determine the possibility of encountering undisturbed cultural deposits, in-place features, or geomorphological data concerning the growth and movement of the North Bosque River. Samples of mussel shell adequate for radiocarbon testing can be collected from the surface, but better samples may be found below the plowzone. Site 41BQ209 is one considered to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ210

On a floodplain rise in a field on the southern bank of the North Bosque (See Figure 3.c.), this prehistoric site is heavily vegetated in low forbs, mostly longspine sandbur (USDA 1970: 52). A light scatter of chert and mussel shell fragments can be found over much of the site, with more along the southern side.

Sampling of this site similar to and in conjunction with those sites nearby is recommended. Site 41BQ210 is one thought to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ211

This is thought to be another prehistoric site, located in the same general microenvironment as the previous two, a slight rise in the floodplain on the south side of the North Bosque (See Figure 3.c.). The main difference is that only mussel shell was found here, and the site may be slightly buried, just at the plowzone. We took a 129 gram sample of mussel shell for later radiocarbon dating.

Sampling of Site 41BQ211 at the same time as those sites nearby is recommended. Site 41BQ211 is one thought to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ212

Perhaps more disturbed by agriculture than the three sites recorded previously, Site 41BQ212 is a scatter of mussel shell and chert flakes located on the eastern edge of a floodplain rise on the south bank of the North Bosque (See Figure 3.c.) Mussel shell are common, but highly fragmented, hence, only 21.3 grams were recovered. None of the site appears undisturbed.

This site is not thought to be one worthy of further investigation. At the present time, Site 41BQ212 is not one thought to merit a determination of eligibility for inclusion within the National Register of Historic Places.

Site 41BQ213

A prehistoric site, this one on the opposite side of the drain that separates it from those nearer the North Bosque (See Figure 3.c.), Site 41BQ213 is buried under about 30 cm of alluvial fill on a moderate rise on the edge of the first terrace above the floodplain. Short and medium grasses cover the ground surface, which is dominated by bull nettle, *Cnidoscolus texanus*, and horse nettle, *Solanum carolinense*. A small amount of chert debris from lithic reduction was observed, but not collected. A sample of mussel shell was recovered, however, with a total weight of 123.2 grams, for radiocarbon testing (See Table 1.1). The date from this sample, TX-5787, is 1350 ± 50 years before the present.

The majority of this site is thought to be buried under alluvial deposits of a thickness adequate to protect it from disturbance by agricultural practices. Accordingly, Site 41BQ213 is recommended for further sampling. This site is one which may prove eligible for inclusion within the National Register of Historic Places.

Site 41BQ214

On the second terrace above the floodplain of the North Bosque, fairly close to Pilot Ford, Site 41BQ214 was discovered between the planted rows of a field (See Figure 3.c.). A widely distributed, extremely light lithic scatter and small fragments of clamshell are all that remain of this eroded prehistoric open campsite. Because ground visibility was excellent, it was apparent that this site was an ephemeral one before it was destroyed by tillage.

This site does not merit further investigation. Site 41BQ214 is not considered to be a site potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ215

On a relatively high rise thought to be late Pleistocene in age on the first terrace above the floodplain of the North Bosque, Site 41BQ215 is an open prehistoric camp which is presently planted in peanuts (See Figure 3.c.). The color of the soil changes throughout the site, but it is generally a light brown to reddish sandy loam overlaying a red clay loam. Visibility was excellent, and a broad, thin scatter of chert was found to extend for about 200 meters up the gentle slope.

A wide variety of artifacts and lithic material was observed. Projectile points found at the site indicate intermittent occupation of the site beginning in the PaleoIndian period and extending to the Middle Archaic (See Figures 5.a. & j.). A core with a striking platform prepared by the removal of a series of flakes, was used for the production of lamellar flakes, then, perhaps broken or rejected, was subsequently used as a tool (See Figure 12. a.b.c.). Biface fragments were fairly common, one apparently altered after breakage (See Figure 4.e.). Other artifacts included a mano ground flat on several sides and strongly exhibiting machine scratches or plowmarks. A piece of polished tooth enamel of unknown age, thought to be from an American bison, was also found at the site.

This site has been affected by plowing and erosion, but because of its age and the wide array of stone artifacts found there, it is one which merits further investigation. Site 41BQ215 is considered to be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ216

This late prehistoric site was found on the first terrace south of the North Bosque, 120 meters from the natural ford of the river known as Pilot Crossing (See Figure 3.c.). The site was in sorghum at the time of our survey and amid the rows were considerable amounts of mussel shell, chert debris and burned rock. This extensive deposit of cultural material extended to the edge of the terrace to the west and to a natural levee along the south. Included in the lithic material recovered were three fragmentary arrow points, two were *Perdiz*-like, and the other has a slightly expanding stem, with convex base (See Figure 6.m.- o.). A sample of mussel shell was

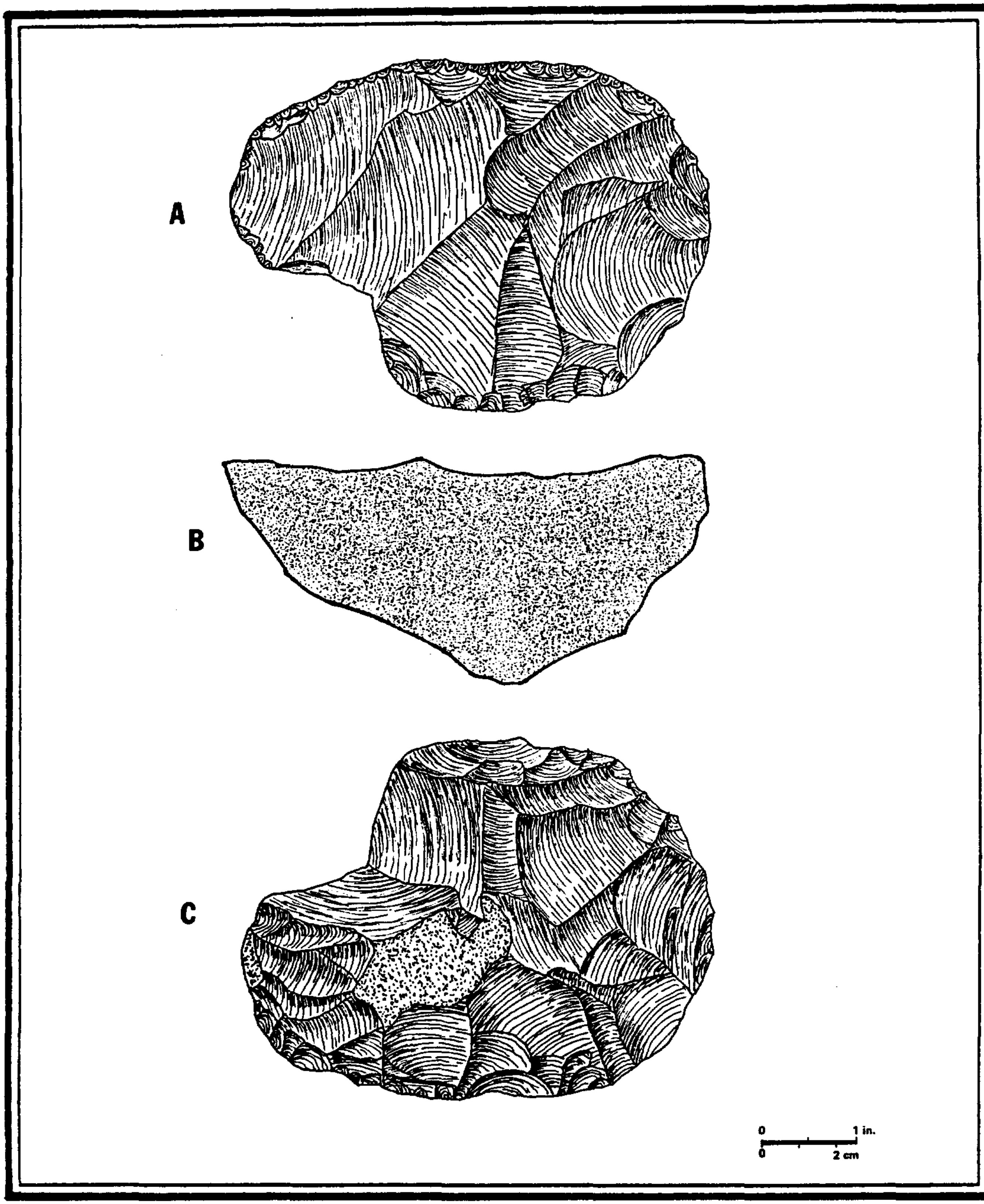

Figure 12. Bifacial core recovered from Site 41BQ215 during the survey of proposed Lake Bosque

recovered for radiocarbon dating, with the resulting age of 1530 ± 70 years before the present (See Table 1.1).

This site appears to have discrete, but adjacent accumulations of burned rock and mussel shell, admittedly somewhat plow strewn about the surface. Nevertheless, site 41BQ216 is thought to be an important one in understanding the late prehistoric utilization of the North Bosque River and the surrounding area. This Neo-American site is thought to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ217

This site was recorded in an erosional gouge that ran along the western side of Site 41BQ216 (See Figure 3.c.). At about 3.4 meters, or 11 feet, below the surface, much mussel shell was found in profile, along with other cultural material in the bottom of the gouge at a depth of about 3.7 meters or about 12 feet. No easy method of determining whether this material was in-place or redeposited from nearby Site 41BQ216 forthcoming, a fairly large sample of mussel shell was recovered from the profile along with a nearby sandstone metate (See Figure 13.).

The sample of mussel shell was submitted for radiocarbon testing, with the hope that it would prove to be a much older deposit than 41BQ216. When the sample was run, we were initially disappointed to learn that the date of the sample was essentially identical with that recovered at 41BQ216, in fact, the dates overlap (See Table 1.1). Any disappointment concerning the age of the sample faded when we calculated the amount of earth which would have to be removed before it could have been proven that no cultural material at this depth was *in-situ.* In addition, the date of 1410 ± 60 years before the present linked the metate recovered with Site 41BQ216.

Only a sub-surface redeposition of an already recorded cultural deposit, Site 41BQ217 is not recommended for further investigation. Site 41BQ217 is not considered to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ218

In a sorghum field on a moderate rise in the floodplain on the south side of the North Bosque, this open prehistoric campsite was found eroding from between cultivated rows (See Figure 3.c.). A moderate lithic scatter including a core, chert flakes and other debris, tools (See Figure11.b.) and tool fragments, including a Middle Archaic dart point (See Figure 5.k.). Mussel

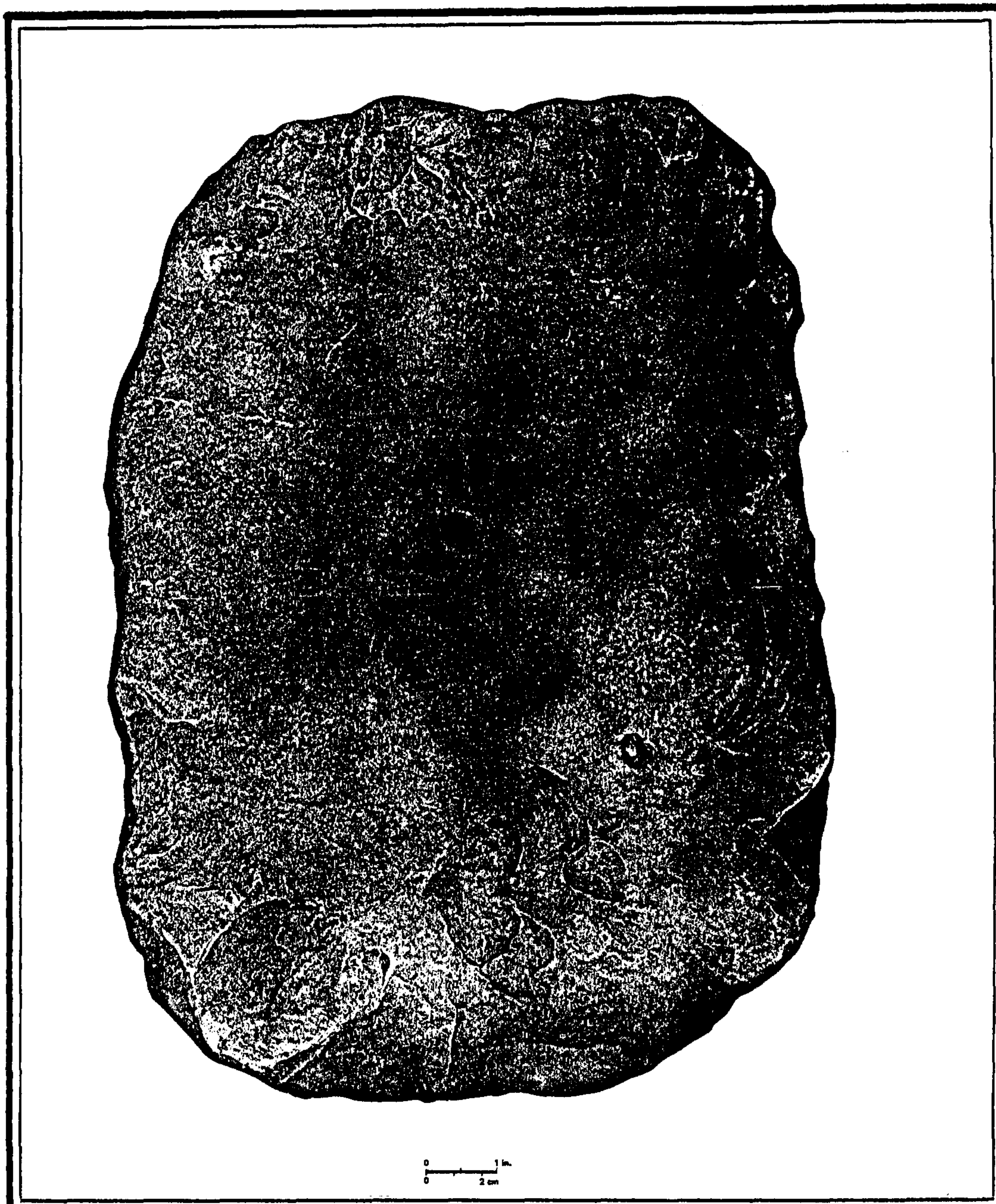

Figure 13. Metate, or milling stone recovered from Site 41BQ216 during the survey of Lake Bosque

shell fragments intermixed with thermally altered and cracked hearth rock were observed throughout the site.

While this site is somewhat eroded and derived as a result of plowing, it may contain buried deposits of archeological value. Recommended for additional sampling, Site 41BQ218 is a site that may prove eligible for inclusion within the National Register of Historic Places.

Site 41BQ219

This open prehistoric campsite on a slight rise in the floodplain is another in a cultivated field of grain sorghum (See Figure 3.c.). Visibility was excellent, and scattered burned rock was the first indicator of this locality. Mixed in with the hearth rock is a light scatter of chert and fragmented mussel shell. No time-diagnostic artifacts were recovered, but the geological position of the site could be used to speculate that it is a relatively late occupation.

Site 41BQ219 is not recommended for further investigation, and the site is not presently considered to be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ220

This prehistoric site is on the second terrace above the North Bosque, well-drained by two tributary gouges on the east and west (See Figure 3.c). Once plowed and now fallow, this field is covered with the vegetation which grows in old fields, horse nettle, bull nettle, and johnson grass intermixed with short grasses and forbs. This site had been churned by the feet of cattle and although visibility was fair, only a small amount of cultural material was visible here. In areas free of vegetation where stock had been fed, a small amount of chert, some fragmented mussel shell and a few scattered burned rocks were observed, indicators of the open campsite once located here. At its elevation above +840, this site will rarely be affected by the floodwaters of Lake Bosque.

Site 41BQ220 is not recommended for further investigation. It is not presently considered to be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ221

Located on the centerline of the dam on the west side of Bosque (See Figure 3.a), this historic scatter in a heavily grassed, upland savanna consists of bottle glass and stoneware, including ironstone and polychrome underglaze on white ground. The distribution and type of late 19th century material observed are consistent with those found at a housesite, although no foundation material or above-ground features were noted. The search continued, working from the area of discovery to ever-expanding circles and transects, without results.

Without features or structural landmarks to provide a locus of origin, Site 41BQ221 is not recommended for further investigation. It is not considered to be a site for nomination to the National Register of Historic Places.

Site 41BQ222

A modern house is built where a historic house once stood on an upland terrace overlooking Willow Springs Creek to the southwest (See Figure 3.b.). Behind the current house, on a slightly lower terrace descending slowly towards the creek, was found the stone construction of the root/storm cellar, apparently contemporary with the late 19th century housesite. Bottle glass, stoneware, including ironstone and crockery, and cut nails are the residue of this historic occupation. The current house is just above the floodpool of Lake Bosque and will remain.

The remnants of the 19th century occupation at this site have been scattered by later construction as well as disturbance resulting from continuous occupation. Not recommend for further investigation, Site 41BQ222 is not considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ223

Erosion has contributed to the destruction of this prehistoric site on an upland slope with a grade greater than five percent. Located just southwest and on the terrace below Site 41BQ222 (See Figure 3.b.), the evidence of this open campsite includes a small biface, an end scraper, amid a very light lithic scatter. The ground surface has been disturbed through the use of heavy machinery, probably a bulldozer, to clear away mesquite, juniper and other brush to improve this pasture. This process of gaining additional range for livestock has contributed to the mixing of cultural material and erosion already under way.

Little remains of Site 41BQ223 for further investigation. This site is not recommended for designation as a State Archeological Landmark or for inclusion within the National Register of Historic Places.

Site 41BQ224

A small cemetery resting on an upland terrace slope of about eight percent, this historic site will not be affected by the floodpool of Lake Bosque (See Figure 3.c.). At least eight interments are here, most not marked. The major feature inside the cemetery fence is a limestone obelisk, with a height under six feet which reads in an arch, KING P. HARVICK, over the Masonic symbol, below which is BORN/ MAR 14TH 1822//DIED/ JAN 29 1873, underneath which is JOHN M. HIS SON LIES BURIED ON THE RIGHT, HIS TWO INFANTS LIES BURIED NEXT. To the west are two more headstones, these more typical in form, which read, J. A. ALLEN / BORN DEC 3, 1845 / DIED SPT 11, 1873 and, T.J. ALLEN / BORN FEB 22, 1853 / DIED APR 21, 1874. Two areas to the south of the Harvick obelisk bear no headstones, but the recent summer rains had differentially soaked into the disturbed and undisturbed soils. The outline of more interments were revealed as two rectangular patches of greenery in the grasses growing here.

Cemeteries are not usually considered to be eligible for inclusion within the National Register of Historic Places, and Site 41BQ224 is no exception. At an elevation above +860 feet m.s.l., the cemetery is almost twenty feet higher in elevation than the maximum pool proposed for Lake Bosque.

Site 41BQ225

This prehistoric site is located at the toe of the slope, on the first terrace above the floodplain of the East Bosque River (See Figure 3.b.) Well-drained, the site is adjacent to a seep to the south. Erosion along the terrace slope is extreme, and considerable amounts of redistributed material are in evidence. The site was initially noticed because of the presence of thermally altered and fractured limestone, the residue of hearths. Nearby, chert flakes were observed and a biface fragment and a small dart point collected. This site hugs the toe of the slope below the hill and is one of the few areas level enough to be suitable for use as a road, and so one passes through this site, causing further disturbance and accelerating erosion resulting from wheel ruts.

This site is not recommended for further investigation. It is not thought to be one potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ226

The first indicator that a historic site might be located nearby was a wrought iron fireplace shovel. We continued our search along the edge of the first terrace above the floodplain of the East Bosque (See Figure 3.b.). Historic artifacts which were observed or collected included fragments of bottle glass, and stoneware, such as ironstone and crockery. Our search finally led us to an area disturbed by the construction of a corral or cattle pen, the likely location of an earlier historic structure. During our search, we spied a ringneck snake, *Diadophus punctatus*, this one the prairie variety, with a yellow heavily spotted underside which changes to bright red near the tail (Ramsey 1985: 436).

Site 41BQ226 is thought to be the site of a late 19th century structure, the remains of which have been destroyed by subsequent construction in the same place. Sites such as 41BQ226 are generally not considered to be eligible for inclusion within the National Register of Historic Places.

Site 41BQ227

Situated between two drains on a heavily eroded sloping terrace, this thin and widely scattered prehistoric site covers a broad area (See Figure 3.b.). A search of the ground surface resulted in the recovery of fragmented projectile points, one with ground, lower lateral edges, perhaps from the PaleoIndian period (See Figure 5.b. & d.). Also collected were fragments of mussel shell, flakes of chert, mano fragments and a unifacial tool. In combination, wind, water and slope have exposed and derived Site 41BQ227, rendering it of questionable value for archeological purposes.

Site 41BQ227 is not recommended for further work. It is not considered to be a candidate for designation as a State Archeological Landmark nor one thought to be potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ228

This small historic site was really difficult to find, completely overgrown with juniper and smilax and covered with leaf mould. A displaced foundation, thought to be that of a log cabin once built here, was located below and adjacent to an old rock drift fence which parallels the East Bosque River (See Figure 3.b.). Historic artifacts from the mid-late 19th century were recovered, including mold-blown bottle glass fragments, sherds of ironstone dishes (See figure 8.c. & l.) and a fragments of a cast iron stove. A palm-sized fossil ammonite, perhaps collected in the project area and brought home by the original residents, was found amid the scatter of historic artifacts.

At an elevation exceeding +960 feet m.s.l., this historic site will not be affected by proposed Lake Bosque. It is a site which can be revisited in the future, which we recommend, after the site has been the subject of archival research. This site might be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ229

Located on a mesa-like hill, of a type locally known as a flat top, and on the Flat Top Ranch, this historic site marks the location of a late 19th and early 20th century housesite (See Figure 3.b). We followed the road that was excavated into the side of the hill up to the old house site and found remnants of a windmill, stone foundation remains and historic artifacts broadly distributed over much of the southern edge of the flat top. Artifacts were found to be in small concentrations as well, perhaps marking the site of sub-surface features. Eleven different specimens of crockery were counted from the fragments we recovered, including one fairly complete lid from a dash churn, and one fragment of earthenware. Ceramics included the remains of about a dozen plates, saucers, bowls, a teacup and a casserole cover which was decorated with black transfer underglaze in a floral pattern. Several of the ceramic sherds were marked (See Figure 8.i. & k.). Glass fragments included canning jars, bottles and pressed glass of unidentified form. Metallic artifacts included a cut nail, a cast iron stove fragment and a reed plate from a mouth-harmonica (See Figure 7.d.).

At an elevation of greater than +900 feet m.s.l, this site is well outside the effects of proposed Lake Bosque. The abundant artifacts and remaining features mark this as a site which could reveal information concerning the historic occupation of this portion of the East Bosque River, and accordingly, Site 41BQ229 is considered to be one potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ230

The heavily eroded prehistoric site has been destroyed by floodwaters which flow over it from an upstream dam during periods of extreme rainfall. A few flakes of chert and a mid-section of a large thin biface, elevated in the clay on pedestals by subsequent direct erosion by rain, were the only objects to mark past human activity here. Only twenty meters west of the East Bosque

River, this now heavily eroded drain would have been an interesting setting for further study (See Figure 3.b.).

At an elevation of +845 feet m.s.l., this destroyed site will not be affected by the creation of Lake Bosque. Site 41BQ230 is not recommended for further work. It is not a candidate for inclusion within the National Register of Historic Places.

Site 41BQ231

In the shadow of seven majestic oaks, this historic housesite is located on the edge of the terrace overlooking a drain to the East Bosque River (See Figure 3.b.). On the basis of artifacts, this site was occupied in the late 19th and early 20th century, as evidenced by glass, stoneware and metal. Fragments of glass thought to represent as many as nine bottles were found in colorless, weathered colorless glass turned purple, green, light green and brown along with a piece of milk glass lid from a Mason jar. Stoneware included white ironstone, embossed ironstone, transferwares in blue and green floral patterns in plate and saucer forms, and a couple of fragments of wheel-thrown crockery. Metallic artifacts included a wrought-iron bracket and the rusted seam of a "tin" food can.

Among the oaks is found the original foundation of the house, covered with leaf mould, or humus, and vegetation. About 15 meters to the north of these stone foundation remains is a depression, of the size and general shape associated with a root/cellar, this one collapsed. Nearby, in what was probably the yard of the original house, there is a small, temporary structure, associated with an outdoor dining table and a recent, circular limestone hearth, all surrounded with artifacts of the present.

Outside of the reservoir area, at an elevation of +860 feet m.s.l., Site 41BQ231 is not presently recommended for further investigation. It is a site which might, with documentary research and archeological investigation, prove eligible for inclusion within the National Register of Historic Places.

Site 41BQ232

This prehistoric lithic scatter is situated on a sloping terrace edge located on the east side of the East Bosque River (See Figure 3.b.). Surrounded by juniper and oak woods, the scatter is in a fossiliferous red sand eroded to red clay. The proximity of the site to the terrace edge and the East Bosque has resulted in its disturbance by a old roadway. The road is no longer passable by conventional means and may no longer be in use. This road adjacent and through the site has greatly contributed to erosion in the ruts and surrounding area, causing downslope derivation of the already sloping cultural deposit. Artifacts found in the wash included three fragmented bifaces, all probably projectile points, several fragmentary tools and chert debris.

Outside the project area, Site 41BQ232 is not recommended for further investigation. It is not thought to be one eligible for inclusion within the National Register of Historic Places.

Site 41BQ233

Located on an upland terrace slope of six percent above the East Bosque River and surrounded by ashe juniper, this prehistoric site is found in a clearing where artifactual material has washed from the light brown sandy loam over red clay (See Figure 3.b). The surface bears a very light lithic scatter, i.e. three chert flakes, a triangular biface and a small metate. The metate is made from a hard, flat river cobble, with one face ground slightly concave, and evidence of grinding of the opposite side. No in-place features or burned rock were observed at this open campsite. The setting of the site, with a relatively high slope for comfortable occupation, is probably significantly altered since occupation, but we noticed no artificial contributors, such as machine pushing for brush clearing which would have hastened its alteration.

Site 41BQ233 is at an elevation above 850 feet m.s.l. and above the effects of Lake Bosque. This site is not recommend for further investigation or for inclusion within the National Register of Historic Places.

Site 41BQ234

This was the site of a historic house occupied in the late 19th century which was located on a high terrace edge overlooking the East Bosque River (See Figure 3.b.). It was served by the same old road which passed by the housesites, Site 41BQ234 and Site 41BQ103. When it came time to relocate the road, it was moved away from 41BQ234 and 41BQ103, but it was moved toward 41BQ234, the principal structure of which was either demolished or cleared for the right-of-way of Ranch to Market Road 927. A large pile of foundation rock from the house remains on the northwest side of the road, and here we found weathered purple pressed and embossed glass fragments and a piece of British ironstone(See Figure 8,j.).

Nothing remains of archeological value at this bulldozed housesite. It is not recommended for inclusion within the National Register of Historic Places.

Site 41BQ235

One of the larger prehistoric sites in the project area is this one located along the north side of Gibson Branch for more than 300 meters (See Figure 3.a.). This site extends into the flat terrace where it shows up in eroded areas, animal trails, roadways, ant beds, etc. Along the creek channel, erosion is extreme, with the soil cut into small hummocks stabilized by bedrock and tree roots, and here the lithic scatter is fairly heavy and mixed with moderate quantities of mussel shell fragments. Periodically, an historic artifact, a piece of ceramic, aged glass, or a fragment of metal would be noticed among the prehistoric material, the signature of a historic site in the area. The prehistoric artifacts included three projectile point fragments (See Figure 6.c.), several biface fragments, small thick bifacial scrapers, three edge-battered bifaces, assorted uniface and other fragments and many flakes which were retrieved as chert samples. Not enough mussel shell was found to be used as a radiocarbon sample, but additional sampling could probably find a usable sample, perhaps with charcoal from a hearth. Some burned rock was observed along the eroded margins of the site, thought to be late Middle Archaic to early Late Archaic in age.

This site is recommended for extensive sampling. Site 41BQ235 is thought to be a candidate for designation as a State Archeological Landmark and one that is potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ236

On an upland terrace edge on the north side of Gibson Branch, this historic house site is located in the northern portion of the prehistoric site 41BQ235. The historic artifacts found in Site 41BQ235 were traced to this area, heavily vegetated with juniper, oak, mesquite woods mixed with medium grasses and low forbs. The housesite was difficult to find, so we marked the area to aid in its relocation. Our search among the dense grass revealed the apparently intact limestone foundation remains of a cabin, presumed on the absence of cut nails, to be a log one. The artifacts include fragments of stoneware, white British marked ironstone (See Figure 8.f.), and crockery, and several fragments of glass in light green, purple, brown and colorless, in panel, sauce, beverage and other forms. In general, the artifacts depict an occupation here in the middle late 19th century, perhaps earlier.

Site 41BQ236 is recommended for further work, including clearing, mapping and a search for sub-surface features, associated with archival research. This site is thought to be a candidate for State Archeological Landmark status and eligible for inclusion within the National Register of Historic Places.

Site 41BQ237

In danger of sloughing into Gibson Creek and already cascading down the sidewall of the channel, this prehistoric site is buried in a deposit which generally is dark brown loam (See Figure 3.a.). At a few places along the profile, color differentiation associated with charcoal and other organic staining is mixed with mussel shell, obvious indicators of cooking and cultural activity. Chert is apparent in the profile and was seen at several widely dispersed eroded areas on the margin of the site. This buried campsite has been plowed repeatedly, but never so deep as to reach the deposit of cultural material below. In one area of the site, on the edge cut by Gibson Creek with a profile created by sloughing, the depth of deposits appears to extend to 2.5 meters below ground surface, but one must be cautious about assuming it is not redeposited material from above, as was learned at Site 41BQ217. A sample of mussel shell was removed from the cleaned profile at the uppermost portion of the site which was submitted to the Radiocarbon Laboratory at the University of Texas at Austin. This sample, TX-5790, provided a date of 2040 ± 60 years before the present (See Table 1.1). This site is extensive and appears to measure more than 90 meters at its widest point.

Site 41BQ237 is recommended for further investigation. Considered to be a candidate for designation as a State Archeological Landmark, Site 41BQ237 is also one that is potentially eligible for inclusion within the National Register of Historic Places.

Site 41BQ238

This prehistoric site is located on a slight rise and down the gently sloping floodplain overlooking an old channel scar to the southwest, with the current channel of the North Bosque to the northeast (See Figure 3.a.). In a cleared field which currently is not in clutivation, traces of the site were found on the sloping surface descending to the channel; these included some flakes of chert and small fragments of mussel shell. Initially, the site gave the appearance of being very limited in size, just an expression along the channel edge, but below the plow zone. We searched from the field to the fencerow. There, the soil around the fence posts was inspected. Fragments of mussel shell and chert revealed that at a depth below the plow but within the reach of a post hole digger was this buried site. Given the depth and proximity of Site 41BQ237, Site 41BQ238 may be of similar or younger age. Like 41BQ237, this site appears to be horizontally extensive.

Site 41BQ238 is recommended for further investigation. It is considered to be a site for potential designation as a State Archeological Landmark, and one thought to be eligible for inclusion within the National Register of Historic Places.

SETTLEMENT

Sometimes, when a cultural group interacts with the environment, the interaction is reflected in alterations of the landform. These alterations can be as subtle as the introduction of soils from elsewhere on the bottom of feet into an occupation area, or the flaking of chert and not carrying away the debotage, to the extinction of many species as a result of changes in climate, habitat, and hunting pressure. Such alterations may be expressed in areas of activity or occupation, associated with recognizable evidence, such as sites. This section reviews settlement, the relationships of sites with the landform. The discussion includes soils, habitat preference and chronology.

SITES AND SOILS

There are nine principal soil types in the general area of the project, which can be divided into two major groups, those which occupy the uplands and are underlain by limestone and those which are found on the floodplains and stream terraces. The uplands soils important to settlement include the undulating Purves-Maloterre association, the Cranfill gravelly clay loam, the hilly Brackett-Eckrant association, and the undulating Tarrant association. Soils in the bottomland include the Minwells fine sandy loam, Bastrop fine sandy loam, Sunev clay loam, Frio silty clay loam and the Bosque loam (See Figure 14.).

In the uplands as well as the entire project area, the soil type most popular for settlement is the undulating Purves-Maloterre association. More than a fourth of the sites found in this survey are situated on this soil association. Of these 38 sites, 27 are prehistoric--four of which were later occupied during the 19th century by historic populations, and 11 additional historic ones. Second in popularity in the uplands is the gravelly Cranfill clay loam. Seventeen sites, nine of them prehistoric (two of these were later occupied by historic settlers), along with eight historic sites, were recorded here. There were nine sites recorded in the hilly Brackett-Eckrant association, with a considerable preference during historic settlement, or five historic sites as compared with four prehistoric sites. Nine sites were also recorded in the undulating Tarrant association. Here the strong preference for this soil type by historic settlers was profound; only one of these nine is a prehistoric site. When all the sites in the uplands are counted and compared to the lowlands, almost two-thirds of the sites are located in the uplands and of these, historic sites amount to slightly more than 45 percent.

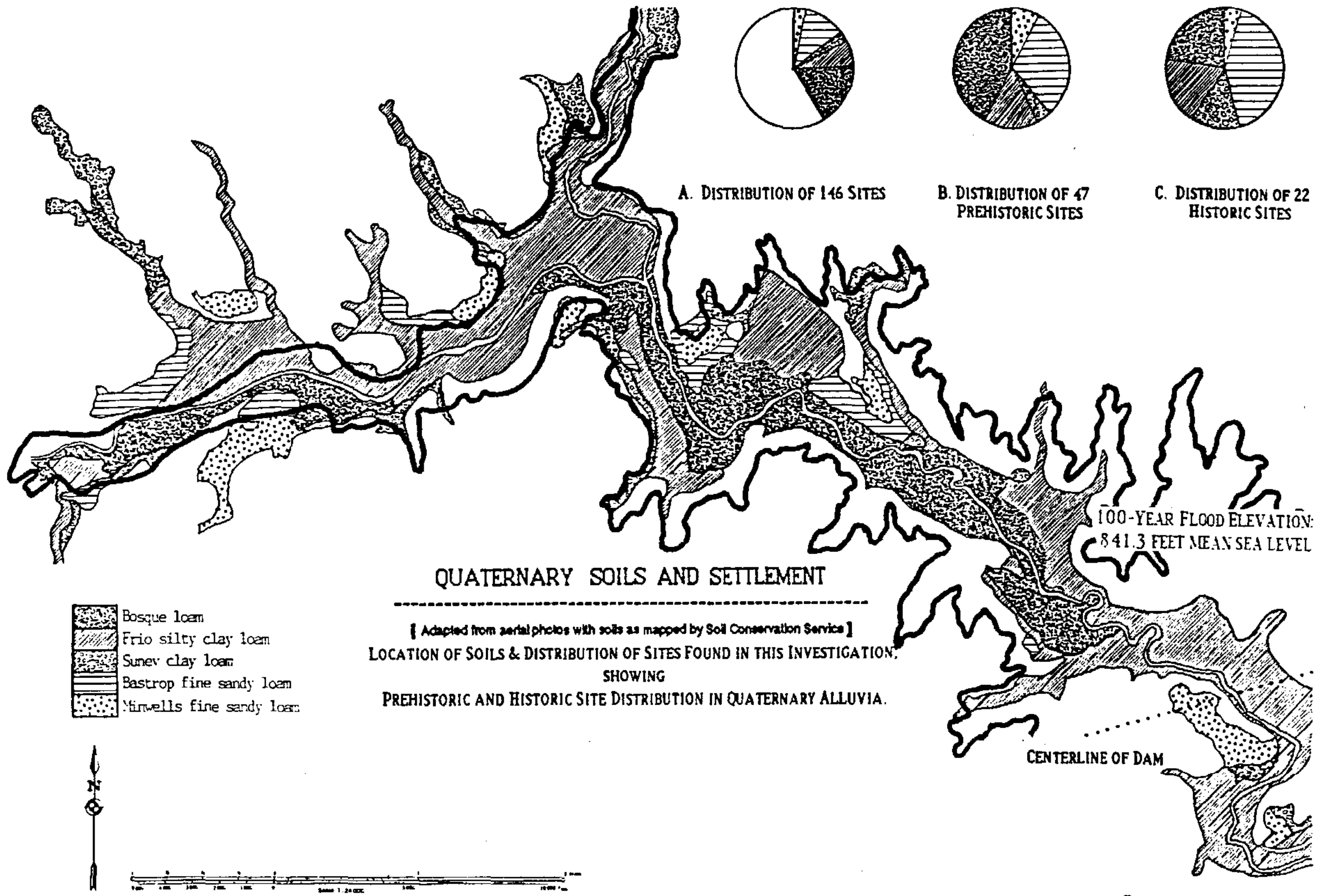

Figure 14. Quaternary Soils and Settlement

Of the soils in the lowlands, that most popular for settlement is the Bosque loam, with a total of 24 sites, one-sixth of the project total. Eighty percent of these site are prehistoric ones. Seventeen sites are found in the Bosque loam, and sixty percent of these are prehistoric. The Frio silty clay loam has a population of ten sites, seven of which are prehistoric, with one of the prehistoric sites later used by historic settlers, and three historic sites. Four sites are found in the Minwells soils, all of them are prehistoric ones with one later reused during the historic. The same number of sites are found in the Sunev clay loam, and of these four, two are prehistoric (one of these later reoccupied during the historic period) and two are historic in age.

A comparison between the prehistoric and historic selection and utilization of soils and associated environments was made by counting the number of sites which were within each alluvial soil from the standpoint of all sites found throughout the survey (See Figure 14.A.). The frequency of occurrence of prehistoric and historic sites within each alluvial soil type was determined and compared (See Figure 14. B. & C.). Prehistoric populations located more sites in the Bosque loam than anywhere else (43%), followed by the Bastrop fine sandy loam (29%), and the Frio silty clay loam (15%). Historic populations preferred those of the Bastrop (41%), then the Bosque (23%) and the Frio (18%).

To learn more about the age of these soils and the prehistoric sites within them, we sorted through our sites in the lowlands where mussel shell had been retrieved, emphasizing the selection of samples drawn from good context, from cleaned, naturally cut banks of streams or the river, profiles, sampling, etc. From these alluvial sites, we selected samples from six sites in the most popular soil type in the lowlands, the Bosque clay loam (Sites 41BQ147, 41BQ148, 41BQ169, 41BQ213, 41BQ216, & 41BQ217), and two from the Frio silty clay loam (Sites 41BQ122 & 41BQ237). And, two samples were selected from prehistoric sites in the most preferred of uplands soils, the Purves-Maloterre association (Sites 41BQ167 & 41BQ189). Along with other samples gathered to be used in determining the affect of inorganic carbon uptake on dates from mussel shell, the above samples were submitted for ^{14}C dating. Although the ^{14}C samples were drawn from just three soil types, a wide variety of microenvironments are represented. They include the confluence of a minor stream with the river channel (BQ122), a natural bedrock dam in the floodplain of the river (BQ147), the river channel (BQ148), the upland terrace edge (BQ167 & BQ189), the floodplain of the river (BQ169), a floodplain rise next to an abandoned channel of the river and Hester Branch (BQ213), a stream terrace (BQ216), a tributary gouge with the sample recovered from 11 feet below surface (BQ217), and from a profile on a stream channel (BQ237).

CHRONOLOGY

As the survey progressed, it was hoped that before the investigation was completed, a site would be found which appeared to be a single component one associated with shell. This site might be used to correlate estimated ages of projectile points with radiocarbon from mussel shell and charcoal from a hearth. It was considered the manner in which to begin to address the inorganic carbonate problems associated with the dating of mussel shell.

The site was found and given the number 41BQ216. It was associated with fragmentary arrowpoints, a *Scallorn, eddy* variety (Jelks 1962: 28-29), and two *Perdiz*(Figure 6, n, m & o), thought to have been in vogue about 800 to 950 years before the present (B. P.). No other artifacts from other time periods were discovered on the site. The site had discrete accumulations of shell and burned rock. It had an ancillary feature of interest; directly adjacent to the site was a ditch which we entered. We cleaned a profile at eleven feet below the surface, and removed a sample of shell. Unable to determine if these were stratified or redeposited materials, we gave this manifestation the site number 41BQ217, and sent the sample to the malacologist for identification as to species and thence for radiocarbon testing.

Because the sample was removed from eleven feet below the surface of 41BQ216, we estimated the date of the sample from 41BQ217 could be as much as 2,000 years older than that from 41BQ216. As the results came forth, the physicist identified the shells as essentially the same sample. On the basis of radiocarbon, our dilemma as to whether the site was a stratified multiple component one or redeposited material was answered in the laboratory (See Table 1.1). The dates, however, were about 600 years older than the time frame we had estimated using projectile points. Could this date be the reflection of the intake of inorganic carbon during the life-span of the mussel, carbon that would make the shell date older? Submitting a series of mussel shell samples for dating, we started using the 600-year-older adjustment in the laboratory, while a search of the landform continued for a mussel that could serve as a control. We submitted what we called Sample Number 10 for radiocarbon testing (Neck's Sample No. 8--See Appendix A), expecting an ultramodern date. It dated ultramodern, to the turn of the 21st century, an effect of the intake by the mussel of particles resulting from atomic events since the 1940's. Where would a modern shell that predated atomic testing be found? Several historic sites had

Table 1.1: Radiocarbon Dates from the Bosque Area

Site Number	Lab Number	Estimated Date	Based on	Radiocarbon
41BQ122	TX-5794	2000-3000 B. P.	geology	2300 ± 70 B. P.
41BQ147	TX-5795	3700-4200 B. P.	artifacts	3010 ± 50 B. P.
41BQ148	TX-5793	4000-4500 B. P.	artifacts	3830 ± 70 B. P.
41BQ167	TX-5789	1500-3000 B. P.	geology	2600 ± 80 B. P.
41BQ169	TX-5792	1200-1500 B. P.	geology	3020 ± 50 B. P.
41BQ189	TX-5788	1500-2500 B. P.	geology	1140 ± 60 B. P.
41BQ213	TX-5787	1700-2300 B. P.	geology	1350 ± 50 B. P.
41BQ216	TX-5768	800- 950 B. P.	artifacts	1530 ± 70 B. P.
41BQ217	TX-5769	2000-3000 B. P.	geology	1410 ± 60 B. P.
41BQ237	TX-5790	2500-3500 B. P.	geology	2040 ± 60 B. P.
Sample No. 10	TX-5791	ultramodern	post-atomic	+143 ± 5 B. P.
Sample No. 11	TX-5810	28 B. P.	cemetery	710 ± 50 B. P.

mussel shell associated with them, but we could not be certain that the shell was not prehistoric; perhaps shell could be found in a privy or some other historic feature to indicate it was modern. As the results from the samples we submitted came in, a chronology of ^{14}C dates was emerging, two or so at a time (See Table 1.2).

Weeks later, while visiting a historic cemetery near the project area, we found a potential sample. On a grave from 1922 were several large mussel shells. We recovered one for radiocarbon testing, estimating its age to be twenty-eight years before the present [for radiocarbon purposes, before the present begins in 1950]. Sample No. 11 returned with a date of 710 ± 50 years before the present. The sample dated 680 ± 50 years older than it was thought to be. Considering the standard deviation, our lab estimate of -600 years was not only acceptable, it is supported by this sample. The chronology of dates has been adjusted to reflect the one suggested by the radiocarbon date of Sample 11 (See Table 1.3). Not so presumptious as to be offered as true dates, the adjusted chronology is put forward as being closer to true dates than those offered above without benefit of adjustment. To those who will follow us, these sites with associated dates should prove beneficial in the search for older sites. A selective return to sites with mussel shell is recommended to find shell within intact features, associated with other kinds of datable samples.

As regards the dating of sites within the three soils types, and the span of use reflected by the ^{14}C samples (See Table 1.3), we found the dates in the Bosque clay loam were chronologically clustered into two groups, an early one from 3,150 to 2,330 B.P. (TX-5793, 5792 & 5795), and a late one, from 850 to 670 B.P. (TX-5768, 5769 & 5787). We think these late ones are not dating the Bosque loams, but are actually the dates of the sites themselves. The dates from the soil identified as the Frio silty clay loam were also clustered, from 1,620 to 1,360 B.P. (TX5794 & 5790). Sites on the upland terrace edge of the Purves-Maloterre complex revealed widely separated occupations, as expected, from 1,920 B.P. (TX-5789) and 460 B.P. (TX-5788).

As a result of the ^{14}C testing in the Bosque Reservoir area, we believe that the use of mussel shell for the relative dating of sites is an important one. Not only easy to spot in dark alluvial soils and profiles, mussel shell is durable when undisturbed, yet its brittleness allows for little disturbance. Fragments of friable shell mark areas of disturbance, even if struck only once by a plow, a posthole digger, or dug into by animals or relic hunters.

Table 1.2: Chronology of Radiocarbon Dates from the Bosque Area

Site Number	Lab Number	Estimated Date	Based on	Radiocarbon
Sample No. 10	TX-5791	ultramodern	post-atomic	+143 ± 5 B. P.
Sample No. 11	TX-5810	28 B. P.	cemetery	710 ± 50 B. P.
41BQ189	TX-5788	1500-2500 B. P.	geology	1140 ± 60 B. P.
41BQ213	TX-5787	1700-2300 B. P.	geology	1350 ± 50 B. P.
41BQ217	TX-5769	2000-3000 B. P.	geology	1410 ± 60 B. P.
41BQ216	TX-5768	800- 950 B. P.	artifacts	1530 ± 70 B. P.
41BQ237	TX-5790	2500-3500 B. P.	geology	2040 ± 60 B. P.
41BQ122	TX-5794	2000-3000 B. P.	geology	2300 ± 70 B. P.
41BQ167	TX-5789	1500-3000 B. P.	geology	2600 ± 80 B. P.
41BQ147	TX-5795	3700-4200 B. P.	artifacts	3010 ± 50 B. P.
41BQ169	TX-5792	1200-1500 B. P.	geology	3020 ± 50 B. P.
41BQ148	TX-5793	4000-4500 B. P.	artifacts	3830 ± 70 B. P.

Carefully selected from excavations, sorted as to species, and then graded for consistency, these samples should be paired with charcoal from hearths, and other ^{14}C samples, to learn their respective variation, stability and utility. If shell samples from a relatively stable, albeit high, geochemical background of carbonates such as the North Bosque River are found to be consistent in their dating, their use in investigations in the Upper Brazos River basin, where mussel shell is common in sites, could prove invaluable. The further investigaton of proposed Lake Bosque, because of the wide cross-section of sites which contain mussel shell and the variety of species, has the potential to conclusively determine their appropriate use in dating sites

Another sort of chronology was discovered associated with historic sites in the project area of Lake Bosque, one based on reed plates of diatonic mouth-harmonicas or eolinas (See Figure 7), shown in the figure with the oldest thought to be on top, and the youngest at the bottom, John Lomax would have confirmed for us something we already knew--the most common musical instruments of the west were not the guitar or violin, but the more portable ones, like harmonicas, jews harps and ocarinas, and apparently, an occasional concertina. Harmonica reed plates are ubiquitous artifacts at historic housesites. Whether additional work will serve to verify our observations--that harmonica reed plates seem to slowly change through time, changes which might be quantified into a meaningful framework--remains to be learned from further research.

Table 1.3: Chronology of Radiocarbon Dates from the Bosque Area, with suggested adjustment for inorganic carbon

Site Number	Lab Number	Estimated Date	Radiocarbon	Adjusted
Sample No. 10	TX-5791	ultramodern	+143 ± 5 B. P.	-
Sample No. 11	TX-5810	28 B. P.	710 ± 50 B. P.	680 ± 50 B. P.
41BQ189	TX-5788	1500-2500 B. P.	1140 ± 60 B. P.	460 ± 60 B. P.
41BQ213	TX-5787	1700-2300 B. P.	1350 ± 50 B. P.	670 ± 50 B. P.
41BQ217	TX-5769	-	1410 ± 60 B. P.	730 ± 60 B. P.
41BQ216	TX-5768	800- 950 B. P.	1530 ± 70 B. P.	850 ± 70 B. P.
41BQ237	TX-5790	2500-3500 B. P.	2040 ± 60 B. P.	1360 ± 60 B. P.
41BQ122	TX-5794	2000-3000 B. P.	2300 ± 70 B. P.	1620 ± 70 B. P.
41BQ167	TX-5789	1500-3000 B. P.	2600 ± 80 B. P.	1920 ± 80 B. P.
41BQ147	TX-5795	3700-4200 B. P.	3010 ± 50 B. P.	2330 ± 50 B. P.
41BQ169	TX-5792	1200-1500 B. P.	3020 ± 50 B. P.	2340 ± 50 B. P.
41BQ148	TX-5793	4000-4500 B. P.	3830 ± 70 B. P.	3150 ± 70 B. P.

SUMMARY AND RECOMMENDATIONS

When the archeological survey of Lake Bosque began on the ground, the survey team soon discovered that a considerable portion of the sites were just outside the area to be affected by the construction of this undertaking, at a slightly higher elevation. These sites outside the project were part of the overall pattern of human settlement and important in understanding the interaction of people throughout the forks of the Bosque. So, we wandered outside the area to be directly affected. Consequently, the survey recorded more sites than were initially predicted, those predictions based exclusively on the estimated acreage of the floodpool. The data gathered as a result of this added coverage were important in that they provided a look outside the hard edge imposed by the floodpool elevation on the sampling universe, to determine if there were any differences. Because the floodpool of the lake is a function, among other things, of topography and geology, perhaps it is not remarkable that many sites were discovered on the erosion-resistant, hence, rather flat edge of the uplands, just above the proposed floodpool. These and other sites above +842 feet m.s.l. total forty, or 27.6 percent of the sites located during this investigation. These sites will remain after the lake is operating.

As to the fate of these sites, their eventual obliteration can be predicted. Archeological sites are generally subject to some form of degradation or alteration, little of which enhances the interpretation of the data. The natural effects of gravity, water and wind, plants and animals take their toll, but more slowly than the blade of a harrow, turning plow, middle buster behind a tractor, or the tooth-edged bucket of a tracked loader or bulldozer. Many of the sites discovered in this investigation have been scraped by machinery to bedrock to clear away brush, a form of range management carried out through much of the project area. The cultural material is still there, out of place and mixed, altered beyond archeological utility.

Another form of damage to sites comes from those digging for specimens without regard for recording the nature of the surroundings and the circumstances of removal. So-called "relic hunters" are frequently local history enthusiasts who destroy the very heritage for which they are searching. This form of site predation is low in the project area, mostly confined to better known historic sites--only one prehistoric site is known to have been looted, and this one not recently.

Perhaps the relic hunters learned that here, save those eroded ones, prehistoric sites are hard to find. If so, they would have confirmed our observation. Upland-edge prehistoric sites are eroded, some to bedrock, so there is nothing for a relic hunter to dig there except in selected locations. The survey team used these exposed upland sites to get a better idea of the general size of sites and of the type and distribution of material culture in them. Chert samples were taken to reflect the array of materials selected by the autochthones.

Even upland sites were not heavily scattered with chert, a reflection that lithic resource material has always been a precious or traded commodity in the North Bosque valley. As we walked along and down the slopes to the midlands and lowlands, however, the chert scatters were more likely to be covered with colluviums, and on the floodplain, alluvium. Our shovel probing, which worked well in the midlands, proved of limited value in the floodplain, and rarely produced the flakes of chert or other signs of cultural activity we were seeking. Probing proved of more utility *after* a site was discovered, to determine the nature of the constituents and especially the potential depth of deposits.

Organic or carbon-staining of alluvia was uncommon, and chert was almost impossible to see in the chocolate to almost black soils in the floodplain. Occasionally, broken or burned limestone out of place in the floodplain would prove a clue to aboriginal habitations. Our most reliable indicator of prehistoric activity proved to be the fragmented remains of mussel shell, which most of the time led us to a few flakes of chert or other confirmatory evidence, although periodically, it was the only indicator we found. Another bonus associated with the shell was that its albedo provided a stark contrast to the alluvial soils, allowing for the discovery of sites at depth in a profile or along an eroding terrace edge.

The immediate concern of this investigation is the fate of the sites in the space required for Lake Bosque. As mentioned initially in this section, more than one-quarter of the archeological sites located in this survey appear to be outside the direct effects of proposed Lake Bosque. For archeological purposes, some of these sites are essentially destroyed, while others are considered significant and potentially eligible for inclusion within the National Register of Historic Places. Of these forty sites above the elevation of +841.3 feet m.s.l., sixteen are considered to be significant and perhaps eligible for National Register status (See Table 2-1 through 2-8, Effects-on-sites Characterization for Lake Bosque, for information regarding specific sites).

Table 2-1: Effects-on-Sites Characterization for Lake Bosque Project.

Site	Elevation	Period of	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
Number	Feet m.s.l.	Occupation	SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ93	840-842	prehistoric	-	-	erosion	cattle	seasonal	damage	none	-	-	erosion	waves	once	damage
41BQ94	832-835	multiple	-	-	scouring	creek	seasonal	damage	none	-	-	erosion	waves	-	-
41BQ95	850-860	prehistoric	-	☒	erosion	cattle	seasonal	damage	none	-	-	looting			
41BQ96	833-835	historic	-	-	mixing	vehicles	on-going	damage	mixing	dam	loss	none	-	-	-
41BQ97	820-842	prehistoric	-	-	erosion	cattle	seasonal	damage	mixing	clearing	loss	none	-	-	
41BQ98	812-820	historic	-	-	scouring	creek	seasonal	damage	none	-	-	siltation	lake	seasonal	-
41BQ99	802-806	historic	-	-	mixing	human	on-going	damage	none	-	-	siltation	lake	seasonal	damage
41BQ100	809-812	prehistoric	-	-	erosion	cattle	seasonal	neutral	none	-	-	none	-	-	-
41BQ101	820-830	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ102	828-840	historic	☒	☒	filling	wash	seasonal	positive	none	-	-	erosion	lake	seasonal	damage
41BQ103	832-836	historic	-	-	none	-	-	-	mixing	clearing	loss	none	-	-	-
41BQ104	820-870	historic	-	-	erosion	wash	seasonal	damage	-	-	-	none	-	-	-
41BQ105	834-839	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ106	805-806	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ107	820-824	multiple	☒	☒	erosion	wash	seasonal	damage	none	-	-	erosion	lake	on-going	loss
41BQ108	805	historic	-	-	none	-	-	-	removal	clearing	loss	none	-	-	-
41BQ109	837-840	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	erosion	flood	seasonal	loss
41BQ110	820-825	multiple	☒	☒	erosion	cattle	on-going	damage	none	-	-	erosion	lake	on-going	loss

Table 2-2: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS		EFFECTS OF NO ACTION				EFFECTS OF CONSTRUCTION			EFFECTS OF OPERATION			
			SAL	NRE	Impact	Agent	Occurs	Result	Impact	Agent	Result	Impact	Agent	Occurs	Result
41BQ111	805-808	prehistoric	⊠	⊠	turned	tillage	annual	damage	none	-	-	inundation	lake	pool	loss
41BQ112	828-830	historic	⊠	⊠	altered	building	on-going	damage	removal	clearing	damage	inundation	lake	pool	loss
41BQ113	845-860	prehistoric	-	-	eroded	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ114	820-850	historic	-	-	eroded	slope	on-going	damage	none	-	-	none	-	-	-
41BQ115	842-848	prehistoric	-	-	eroded	wash	on-going	-	none	-	-	none	-	-	-
41BQ116	815-820	prehistoric	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ117	840-855	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ118	840-850	multiple	-	-	erosion	cattle	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ119	860-868	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	none	-	-	-
41BQ120	853-856	multiple	-	-	altered	building	once	loss	none	-	-	none	-	-	-
41BQ121	838-850	prehistoric	-	-	cleared	dozer	once	damage	none	-	-	inundation	lake	flood	loss
41BQ122	820-828	multiple	⊠	⊠	buried	alluvial	flooding	preserved	none	-	-	inundation	lake	normal	loss
41BQ123	842-845	historic	-	⊠	none	-	-	-	F.M. 927	relocation	unknown	none	-	-	-
41BQ124	818-822	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ125	818-819	prehistoric	⊠	⊠	turned	tillage	seasonal	damage	none	-	-	inundation	lake	normal	loss
41BQ126	818-820	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	normal	none
41BQ127	819-824	historic	-	-	razed	owner	unknown	loss	none	-	-	inundation	lake	normal	none
41BQ128	810-816	historic	-	-	none	-	-	-	none	-	-	inundation	lake	normal	loss

Table 2-3: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ129	820-828	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	normal	loss
41BQ130	845-846	historic	-	☒	clearing	owner	unknown	damage	none	-	-	none	-	-	-
41BQ131	826-836	historic	-	-	cleared	owner	unknown	loss	none	-	-	inundation	lake	pool	none
41BQ132	870	historic	-	-	cleared	owner	unknown	loss	none	-	-	none	-	-	-
41BQ133	856-860	historic	-	-	cleared	owner	once	loss	none	-	-	none	-	-	
41BQ134	850-854	historic	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ135	858-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	none	-	-	-
41BQ136	830-850	historic	-	-	cleared	dozer	once	loss	none	-	-	none	-	-	-
41BQ137	810-822	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ138	808-812	multiple	☒	☒	cleared	owner	once	disturbed	none	-	-	inundation	lake	pool	loss
41BQ139	796-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ140	802-804	historic	-	-	razed	owner	once	loss	none	-	-	inundation	lake	pool	-
41BQ141	780-793	historic	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ142	810-820	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	inundation	lake	pool	-
41BQ143	800-810	prehistoric	-	-	erosion	rill	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ144	805	historic	-	-	erosion	drain	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ145	856-862	prehistoric	-	☒	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-
41BQ146	860-870	prehistoric	-	-	erosion	wash	seasonal	damage	none	-	-	indirect	-	-	-

Table 2-4: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ147	820-830	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ148	800-820	prehistoric	☒	☒	erosion	wash	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ149	810-823	multiple	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ150	846-850	prehistoric	-	-	eroded	wash	seasonal	loss	none	-	-	none	-	-	-
41BQ151	840-851	prehistoric	-	☒	clearing	highline	once	damage	dam	spillway	loss	none	-	-	-
41BQ152	815-828	historic	☒	☒	erosion	wash	seasonal	damage	dam	dam	loss	none	-	-	-
41BQ153	785-805	historic	☒	☒	filling	wash	seasonal	positive	spillway	haul road	loss	none	-	-	-
41BQ154	800-838	prehistoric	-	-	erosion	wash	seasonal	damage	spillway	haul road	loss	none	-	-	-
41BQ155	790-830	prehistoric	-	-	clearing	highline	once	damage	none	-	-	none	-	-	-
41BQ156	775-780	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ157	820-825	historic	-	-	altered	building	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ158	774-779	prehistoric	☒	☒	sloughing	river	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ159	833-843	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	damage
41BQ160	810-811	prehistoric			erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ161	812-824	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	none
41BQ162	800-810	historic	☒	☒	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ163	815-817	prehistoric	-	-	eroded	wash	on-going	loss	dam	dam	-	none	-	-	-
41BQ164	869	historic	☒	☒	none	-	-	-	none	-	-	none	-	-	-

Table 2-5: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ165	835-838	historic	-	-	none	-	-	-	dam	dam	loss	none	-	-	-
41BQ166	842-845	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ167	832-835	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ168	774-788	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundaton	lake	pool	loss
41BQ169	763-766	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ170	800-820	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	pool	-
41BQ171	830-840	historic	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ172	830-835	prehistoric	-	-	scraped	dozer	once	loss	none	-	-	inundation	lake	flood	-
41BQ173	788-790	prehistoric	☒	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	pool	loss
41BQ174	835-841	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	damage
41BQ175	812-814	geological	-	-	-	-	-	-	-	-	-	-	-	-	-
41BQ176	859-861	multiple	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ177	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ178	840-843	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ179	845	multiple	-	-	cleared	machine	once	loss	none	-	-	none	-	-	-
41BQ180	813-823	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ181	820-826	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ182	833-836	historic	-	-	displaced	machine	once	loss	none	-	-	none	-	-	-

Table 2-6: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	STATUS NRE	EFFECTS OF NO ACTION Impact	EFFECTS OF NO ACTION Agent	EFFECTS OF NO ACTION Occurs	EFFECTS OF NO ACTION Result	EFFECTS OF CONSTRUCTION Impact	EFFECTS OF CONSTRUCTION Agent	EFFECTS OF CONSTRUCTION Result	EFFECTS OF OPERATION Impact	EFFECTS OF OPERATION Agent	EFFECTS OF OPERATION Occurs	EFFECTS OF OPERATION Result
41BQ183	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ184	850-853	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ185	800-802	historic	☐	☐	none	-	-	-	removal	clearing	loss	none	-	-	
41BQ186	829-834	historic	☒	☒	displaced	machine	unknown	damage	none	-	-	inundation	lake	pool	loss
41BQ187	840-844	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ188	802-806	historic	-	-	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ189	825-828	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ190	828-830	historic	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ191	839-842	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ192	830-832	prehistoric	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	flood	-
41BQ193	826-829	historic	-	-	cleared	machine	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ194	825-828	prehistoric	-	-	eroded	road	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ195	810-818	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ196	822-829	multiple	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ197	900-905	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ198	853-857	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ199	846-850	historic	-	☒	none	-	-	-	none	-	-	unknown	-	-	-
41BQ200	860	multiple	-	☒	none	-	-	-	none	-	-	none	-	-	-

Table 2-7: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ201	856-862	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ202	860-870	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ203	840-845	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	flood	-
41BQ204	821-830	multiple	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	loss
41BQ205	835-845	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ206	838-850	prehistoric	-	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	flood	loss
41BQ207	835-842	historic	-	☒	none	-	-	-	none	-	-	inundation	lake	flood	loss
41BQ208	842-849	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ209	841-846	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ210	843-845	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ211	832-836	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ212	830-835	prehistoric	-	-	turned	tillage	seasonal	loss	none	-	-	inundation	lake	flood	-
41BQ213	842-846	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ214	846-849	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	unknown	-	-	-
41BQ215	848-858	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ216	839-845	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	loss
41BQ217	830-840	prehistoric	-	-	redeposit	wash	on-going	loss	none	-	-	none	-	-	-
41BQ218	846-854	prehistoric	-	☒	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-

Table 2-8: Effects-on-Sites Characterization for Lake Bosque Project.

Site Number	Elevation Feet m.s.l.	Period of Occupation	STATUS SAL	NRE	EFFECTS OF NO ACTION Impact	Agent	Occurs	Result	EFFECTS OF CONSTRUCTION Impact	Agent	Result	EFFECTS OF OPERATION Impact	Agent	Occurs	Result
41BQ219	846-851	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	unknown	-	-	-
41BQ220	840-852	prehistoric	-	-	turned	tillage	seasonal	damage	none	-	-	inundation	lake	flood	-
41BQ221	828-832	historic	-	-	disturbed	road	unknown	damage	dam	dam	loss	none	-	-	-
41BQ222	836-848	historic	-	-	disturbed	house	unknown	damage	none	-	-	inundation	lake	flood	-
41BQ223	820-830	prehistoric	-	-	disturbed	dozer	unknown	loss	none	-	-	inundation	lake	pool	-
41BQ224	860-862	historic	-	-	none	-	-	-	none	-	-	none	-	-	-
41BQ225	828-840	prehistoric	-	-	erosion	road	seasonal	damage	none	-	-	inundation	lake	pool	-
41BQ226	834-842	historic	-	-	construction	pens	once	loss	none	-	-	inundation	lake	flood	-
41BQ227	820-850	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	inundation	lake	pool	-
41BQ228	860+	historic	-	☒	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ229	900-920	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ230	845-848	prehistoric	-	-	eroded	wash	on-going	loss	none	-	-	none	-	-	-
41BQ231	860+	historic	-	☒	none	-	-	-	none	-	-	none	-	-	-
41BQ232	860-870	prehistoric	-	-	erosion	road	on-going	loss	none	-	-	none	-	-	-
41BQ233	850-860	prehistoric	-	-	erosion	wash	on-going	damage	none	-	-	none	-	-	-
41BQ234	834-838	historic	-	-	cleared	highway	once	loss	none	-	-	none	-	-	-
41BQ235	820-842	prehistoric	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ236	822-832	historic	☒	☒	erosion	wash	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ237	778-780	prehistoric	☒	☒	sloughing	creek	on-going	damage	none	-	-	inundation	lake	pool	loss
41BQ238	789-791	prehistoric	☒	☒	none	-	-	-	none	-	-	inundation	lake	pool	unknown

When the field investigation began, the survey team worked from enlarged U.S.G.S. 7.5' quad topographic maps which were associated with aerial photographs at the same scale. We plotted our sites on the aerial photos and estimated our elevations from the topographic maps. Later, we used an electronic altimeter-weather station which we carried with us, periodically recalibrating it at known elevations. It was fairly accurate to within 10 feet. After we returned from the field, better maps became available. The elevations which are used in this report are based on this most recent map with contour intervals of two feet.

One hundred and five sites are below the floodpool elevation of +841.3 feet mean sea level. Of these sites, Forty-three or forty-one percent are considered to be significant. About one-quarter or eleven of these forty-three sites are above the conservation pool of Lake Bosque, at +830 feet mean sea level. Thirty-two archeological sites, or about seventy-five percent, are to be inundated by Lake Bosque operating at a normal pool elevation of +830 feet mean sea level.

Of those thirty-two archeological sites found below the normal pool of Lake Bosque, sixteen are prehistoric, seven are multiple component ones containing prehistoric and historic material culture, with the remaining nine being historic sites. All of these are within the fee simple lands to be purchased by the Brazos River Authority, and hence eligible for designation as State Archeological Landmarks. In addition to these, there is the Pearce Cemetery and the possible grave near Otter Creek (Site 41BQ185). A local informant says another grave will be found near the large liveoak at Site 41BQ112. Subsequent to a search for and notification of living relatives, excavation, exhumation, possible study and relocation of corporal remains to a nearby cemetery, such as the Hanna, Barry, Fulton or elsewhere, is suggested.

Limited sampling to obtain comparable data and to search for earlier sites is warranted at prehistoric components at the following sites below 830 feet m.s.l.: 41BQ111, the three localities of 41BQ124, 41BQ125, 41BQ138, 41BQ168, 41BQ173 and 41BQ195. Limited sampling is defined here as a series of non-contiguous units measuring 1 x 2 meters, through the cultural deposit into culturally sterile matrix. Depending upon accessibility, time of year and depth of deposit, machinery use may be appropriate. Early expenditures for special sampling, including radiocarbon dating of charcoal and other samples, malacological, geological and paleoenvironmental consulting should be considered along with the cost of machinery. This work should commence almost immediately after the decision is made to construct Lake Bosque, for as many as two of these sites may be later considered for extensive sampling, leading to linear or broad excavation of important features or sub-areas of the sites. As time to conduct this work will be limited, investigation and excavation must be conducted throughout the seasons and should include consideration of time which will be lost because of inclement weather.

Extensive sampling of prehistoric sites 41BQ122, 41BQ137, 41BQ149, 41BQ158, 41BQ162, 41BQ169, 41BQ235 and 41BQ238 is recommended. The form of sampling units suggested here are contiguous and/or isolated 1 x 2 meters units. Linear excavation of areas generally two meters wide, with expanded units as deemed appropriate to cope with encountered cultural features is recommended. Depending on the depth, age and constituents, as many as two sites from this category might be considered for extensive, broad excavation, in units as large as five meters along one side, through the cultural deposit. Comments concerning special studies and consultants mentioned above are appropriate, only moreso. One should anticipate the need for the services of a malacologist, a geomorphologist and paleoecologist throughout this investigation.

Extensive archeological investigation is recommended at 41BQ147, a shallow Late Archaic site situated on a natural dam or ridge of Paluxy sandstone. Broad excavation units should be considered here A neighboring site, 41BQ148, is large, considerably deeper, with what appear to be sloping, stratified layers of burned rock with cultural deposits deeper than one meter. It is contemporary with but also has deposits thought to be slightly earlier than 41BQ147. The excavator should contemplate shoring or stepped-back excavations in this site; this is the one which after it was located, sloughed into the North Bosque River. Site 41BQ148 may be dug in levels as thin as 5 centimeters, in relation to the slope as determined by extensive probing, or if required, coring. This site will be slow-going if the data within it are to be effectively extracted, requiring delicate handling of faunal material, but it will be rewarding. Chert is especially abundant, with a high frequency of tool forms.

Site 41BQ189 is the most recent prehistoric site known in the project, based on radiocarbon dates. Its position on the upland terrace edge is in constrast to those sites just mentioned which are located on or near the channel of the river. Site 41BQ189 has an extensive, but thought to be shallow, deposit, generally less than 50 centimeters. Natural mixing by plants and animals may hinder interpretation of cultural materials. Using the adjusted radiocarbon dates, this site dates from about the time of the discovery of the New World. Intact features may be found by opening broad areas of this site, which is rich in chert debris and fragmented shell. Unless preserved by pockets of alkaline soils, faunal remains other than shell are not common here.

Site 41BQ237 is a broad floodplain deposit adjacent to a creek, the fourth microenvironment recommended for excavation. A buried deposit below the plow zone, this Transitional Archaic site is horizontally extensive, with broadly separated profiles revealing remarkably consistent deposition. The soil type, tight black alkaline alluvium, is thought to be especially conducive to the preservation of organic remains. After systematic probing to determine the depth of deposit(s), the entire site is recommended for machine stripping, if feasible and it can be accomplished without significant disturbance to underlying deposits. Selective excavation of broad areas is then recommended. The writer is of the opinion that acceptable methods of stripping sterile overburden through the use of heavy or appropriate machinery must be perfected early in this mitigation phase, if sites are not going to be lost because they cannot be reached in time by conventional archeological means.

Historic sites below 830 feet m.s.l. which are thought to contain information important to an understanding of local history include the site of the house and dugout barn (41BQ101 & 41BQ102), and the site of the Ramsey Cox farm (41BQ110 & 41BQ112) represent the remains of farming complexes which were in operation after the Civil War, in the late 19th century. The house and dugout barn are thought to be relatively undisturbed, the contrary situation found at the Ramsey Cox property. Nevertheless, an above-ground feature still remains at the Cox place. Mapping, selective excavation and controlled collection of artifacts is recommended for these sites, in addition to archival research.

Clearing of vegetation, mapping of features and limited sampling at depth is recommended for 41BQ107, 41BQ152, 41BQ153, 41BQ186 and 41BQ236. One of these may prove worthy of extensive sub-surface sampling such as is anticipated at Site 41BQ138, 41BQ190, 41BQ196 and Site 204. All of these latter four are considered to be candidates for excavation, and substantive archival research.

Consistent and balanced sampling is a threshold to be crossed before final determination of which of the above sites should be scheduled for selective, but comprehensive excavation and analysis. As proposed above, many sampling units will be placed in a large number of sites to obtain as consistent and balanced an array as possible, with subsequent selection of more sites for further investigation. Following along these lines, four prehistoric sites below the conservation pool are recommended for extensive archeological investigation including excavation, with as many as four more being added to this group. Likewise, four historic sites below the normal pool elevation of +830 feet m.s.l. are recommended for extensive investigation, with an additional one to be selected from the others being subjected to less extensive sampling. In addition, work is recommended at the two historic complexes, 41BQ101-41BQ102 and 41BQ110-41BQ112.

In the flood pool at an elevation of 841.3 feet mean sea level, are eleven archeological sites considered to be significant. Eight of these are prehistoric ones, the remaining three are historic sites. Sites in this zone are subject to differential inundation dependent upon elevation. Some are to be flooded relatively frequently, such as once every two years while others are estimated to be subject to a flooding event once during the life of the project.

Prehistoric sites in the floodpool include six thought to be significant. Sites 41BQ191, 41BQ209 and 41BQ211 are recommended for limited and comparable sampling, oriented toward determining more about the extent and nature of cultural deposits than presently known and to recover datable samples. A site may be selected from these for more extensive sampling, such as recommended for Site 41BQ206, with contiguous recovery units.

Site 41BQ216, the Neo-American site with discrete features is recommended for additional sampling to determine if in-place deposits are untouched by the plow. If any of this site remains intact, and this is thought to be the case, then linear excavation units at least 2 meters wide arranged in such a manner as to result in the dissection of these features are recommended. One site, 41BQ167 is recommended for total recovery. This small site is thought to be a hearth associated with an accumulation of food remains and chert refuse. The adjusted radiocarbon date for this site is 1920 ± 80 B. P., or about the time of Christ.

Of the historic sites in the floodpool, two, Site 41BQ205 and 41BQ207 are thought to be early historic settlers or slave cabins associated with Site 41BQ204, a site located below the conservation pool. These three sites are recommended for simultaneous or coordinated investigation including excavation--they are thought to be related and sampling must be consistent if the data are to be comparable.

An additional historic site is recommended for clearing of grass brush and trees, mapping, controlled surface collection as well as a search for subsurface features; it is Site 41BQ159, the extensive historic complex near the west side of the dam of Lake Bosque.

In total, below the elevation of +841.3 feet mean sea level, ten prehistoric sites are recommended to be subjected to limited sampling, ten to extensive sampling, one to linear excavations at least two meters wide, five to broad excavations opening areas as much as five meters wide and one small prehistoric site to total recovery.

In the same fashion, historic sites are recommended for limited sampling at five, extensive sampling at four and limited excavation at seven. A small cemetery and two other areas are recommended for investigation and relocation of corporal remains. There are other measures which can be offered to further mitigate the effects of Lake Bosque on cultural resources, some of which are suggested below:

[1] The survey of the project area included forty additional sites discovered along the margin just outside the project and its effects. These sites will remain after the lake is operational. When the survey began, ninety-two sites were known in Bosque County, with all outside the area of the project. Excluding those sites inside the project area, there is a net gain of forty in the number of sites in Bosque County, increased to one hundred thirty two sites outside the project area.

[2] With the permission of Ervin Moore, study his accumulation of prehistoric lithic material gathered from his property. The collection is to be used as the basis of a projectile point typology for the Upper Bosque Watershed and for use in typing specimens gathered as a result of mitigation efforts.

[3] In the upper reaches of Lake Bosque, at about the elevation of the floodpool are a number of prehistoric sites within close proximity to each other, sites which are considered to be significant They are recommended as being potentially eligible for inclusion within the National Register of Historic Places as a District. These sites will very rarely be affected by Lake Bosque, perhaps during events of extreme flooding coupled with high winds and wave action. The sites are accessible by vehicle, and can be reached on foot. In order to assess the long-term effects of such intermittent and extreme events, these sites are recommended for long-term monitoring. For the first decade of operation of Lake Bosque, quarterly trips to these sites could document the normal background alterations which occur on and in archeological sites through the passage of the seasons, as well as document the periodicity, using flowage records, of harmful or potentially harmful events. Depending on the outcome of the study, it could terminate or continue for another decade, with visit intervals reduced by a factor of two.

The information resulting from this work would prove useful to a host of entities involved in the protection and management of cultural resources.

The measures offered as mitigation for the Lake Bosque project collectively provide a broad spectrum of objectives which must be accomplished if we are to help preserve and understand the past. As engineering or design constraints can reshape and enhance the operation of the project, and change the characteristics of impact on cultural resources, details in the general approach may change. This technical report and suggested plan for ameliorating the impact of Lake Bosque is offered as the beginning point in the long-term management of the cultural resources left by our antecedents at the forks of the North and East Bosque Rivers.

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Appendix A: Report on Various Molluscan Materials with Recommendations for Research Design for the Lake Bosque Project

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Prepared for

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July 1987

Below are the identification and analysis of various molluscan shells provided to the author. Sample numbers refers to numbers placed on sample bags by the author.

Sample 1

Source of this sample is the Lake Bosque Project. It was removed from the North Bosque River on 2 April 1987.

This sample consists of the remnant of the left valve of a large *Potamilus purpuratus*. Length of the original shell is estimated at 160 to 170 mm. The valve is about 12 mm thick at the pallial line.

Sample 2

This sample of shell was removed from the North Bosque River between Meridian and Iredell.

Two right valves of *Lampsilis teres* (neither water tumbled) are included. The male valve (shell length-133.5 mm) is modern with ninety-eight percent of the periostracum remaining. The shell exhibits eight to ten growth periods with fairly constant growing conditions. The female valve (129.1 mm in length) is a modern but weathered valve with about seventy percent of the periostracum remaining. Variable growth conditions are indicated over twelve to fourteen growth periods.

A single modern, but weathered and water tumbled, valve of a female *Tritogonia verrucosa* is present. The left valve measures 129.9 mm in length. The shell exhibits thirteen to fourteen growth periods of fairly constant favorable conditions, although some of the growth periods produced very narrow growth bands.

A single right valve (115.3 mm in length) represents the "robust, squared-off" phenotype of *Potamilus purpuratus*. The valve is modern but seventy percent of the periostracum is missing. "Rough" growth lines (ten growth periods) cause a stair-step effect and represent times of poor growing conditions, probably low water flow. The shell is not water tumbled but is noticeably weathered.

One pair of valves represents *Anodonta grandis* (shell length-157.3 mm, height-102.7 mm, width-69.1 mm). Most of the periostracum has been removed, but part of the hinge is present. Possibly twenty-one growth periods are present.

<u>Sample 3</u>

Lake Bosque Project, Site 41BQ217. This sample was recovered from a depth of eleven feet below ground surface, on 9 July 1987.

Shells of three species of bivalves are present.

Tritogonia verrucosa is represented by a single right valve from a male individual with original shell length of about 105 to 110 mm and height of 64.75 mm. The posterior margin has been removed from this old shell which has not been water tumbled. Eleven growth periods occurred during rather constant conditions.

Amblema plicata is represented by a partial left valve with the posterior margin removed. The remnant is from an old, weathered shell with no periostracum; there is no indication of water tumbling. Seven growth periods occurred during relatively constant conditions. The height measures 54.35 mm while the original length was about 75 to 80 mm.

Quadrula pustulosa mortoni is represented by a partial left valve with the posterior margin removed almost to the pallial line. Interestingly, the posteriad one-third of the outer portion of the prismatic layer is removed. This pattern could be anthropogenic if the shell were utilized as an ornament or other artifact. The shell may be slightly water-worn although *in-situ* incipient dissolution of the outermost portions of the shell is more likely. The shell exhibits twelve to thirteen growth periods under seemingly constant conditions. Original length of the shell was 50 to 55 mm, whereas the height is 48.3 mm.

These three shells from this sample are older shells from an archeological site as indicated by soil staining and absence of the posterior margin of these shells. None of these shells is charred.

<u>Sample 4</u>

These shells come from Site 41BQ235.

Tritogonia verrucosa is represented by a large right valve from a female individual. The poterior margin including about one-third of the pallial line is absent. The shell is not water-worn but exhibits extensive heating from the direction of the outer shell. The shell was probably placed on hot rocks or wood coals lying concave side up. The flesh of the original inhabitant was probably cooked "on the half-shell,' but the degree of heat alteration (with loss of some surface layers of shell) suggests that this shell may have been utilized repeatedly as a cooking utensil. Growth periods are undetectable due to charring and concomitant shell flaking, but growth conditions were probably rather constant judging from examination of the cross-section of the shell on the broken edge. Original length is estimated at 145 to 160 mm with original height estimated at 77 to 82 mm.

Potamilus purpuratus is represented by a remnant whch comprises eighty to ninety percent of the hinge tooth of a right valve. The remnant is charred but not water worn. The original shell was probably about 160 mm in length.

Sample 5

This specimen comes from Site 41BQ211, recovered 9 July 1987.

Amblema plicata is represented by a remnant of a left valve of a very large specimen (original length estimated at +130 mm). The missing portion of the exterior part of the shell does not permit counting of growth periods, but growth periods indicate conditions which appear to have been rather constant. This remnant originated from a shell larger than any modern shells seen by this author and must have exceeded 130 mm. The shell has been removed from its stratigraphic placement, but is not charred, nor does it exhibit signs of water tumbling.

Sample 6

This sample was recovered from the North Bosque River channel, north of Jackson Crossing, and southeast of Iredell, Texas.

Potamilus purpuratus is represented by a single right valve indicating a modern shell which is weathered. About 15 growth periods are detectable and indicate rather constant growth conditions. The shell is very large and represents the more compressed phenotype. Length is 163.4 mm and height is 112.4 mm.

Sample 7

This sample was recovered from the North Bosque River channel, north of Comanche Crossing and south of Jackson Crossing.

This modern pair of *Potamilus purpuratus* has been dead for some time, but the purplish tint of the nacre is still evident. Eighteen growth periods are indicated; some variation in growth conditions is evident especially during the last eight or so growth periods.

<u>Sample 8</u>

This sample was recovered from the North Bosque River channel, between Pilot Crossing and Comanche Crossing.

This modern pair of female *Tritigonia verrucosa* has much of the periostracum missing but the nacre is fresh. At some time, the shell was damaged or suffered some dissolution in the area of the umbo as much periostracum-like flaggy material encircles the pseudocardinal teeth. Flaggy periostracum occurs in projecting layers associated with moderately abrupt periods of growth cessation. This flaggy periostracum appears to result when the animal produces new periostracum at the margin of the shell, but a change in external conditions results in a cessation of shell growth before the prismatic and nacreous layers are produced. Length of this shell is 116.2 mm, height 84.2 mm. and width is 42.8 mm (fourteen growth periods).

<u>Sample 9</u>

This sample was recovered in the channel of the North Bosque River, north of Comanche Crossing and south of the bridge at Jackson Crossing.

This sample consists of a single right valve from a modern specimen of *Potamilus purpuratus*. Most of the periostracum is absent, whereas the nacre is faded but still pink-purple. Moderately constant growth conditions are indicated during thirteen to fifteen growing periods. Shell measures 150.3 mm in length and 92.42 mm in height.

<u>Sample 10</u>

This sample is recovered from the North Bosque River, above Jackson Crossing and below Iredell.

This single left valve from a very fresh modern shell of *Potamilus purpuratus* has the nacre only slightly faded. About fourteen growth periods are exhibited in the shell which measures 173.3 mm in length and 107.65 mm in height.

Sample 11

This sample comes from the channel of the North Bosque River, north of Comanche Crossing, but south of Pilot Crossing.

This sample includes one weathered modern left valve of *Potamilus purpuratus*. The nacre is somewhat chalky, but still purplish. About nine growth periods indicate rather constant conditions during the early portion of this mussel's life, but some growth interruptions occurred during the latter period. The shell measures 133.5 mm in length and 86.85 mm in height.

Also present are five unmatched valves of *Tritogonia verrucosa* of moderate to large size. Some of these valves indicate fairly constant growth conditions, whereas other show inconsistent growth conditions. Obvious growth periods vary from three to fifteen or sixteen among the various valves present. One valve contains periostracum-like deposits above the pseudocardinal teeth. One valve exhibits a very grainy surface as if the shell is acid-etched.

OVERVIEW

The above remarks are detailed, admittedly, considering the limited number of shells examined. However, these remarks are intended to provide a sample of the types of information which can be extracted from a sample of freshwater mussels. Information gleaned from shells of these animals can be arranged into two basic areas: environmental reconstruction and cultural inferences. Environmental reconstruction involves gross analyses of water availability and various general conclusions regarding physico-chemical parameters. Cultural inferences involve determination of relative utilization of freshwater mussels and their shells as food, tools, and ornaments. Analysis may also allow inferences concerning collection sites and methods, general conclusions on food availability and site formation dynamics. No sample will provide all of the above information, but most samples (particularly in comparison to other samples) will be of value.

RESEARCH DESIGN SUGGESTIONS FOR PROPOSED LAKE BOSQUE

The following comments are made subsequent to the above analysis and discussions with personnel from Lone Star Archeological Services. The variety of information which can be extracted from a sample of freshwater mussels has been summarized in the previous section. Such information from a single point of origin is of interest and even somewhat valuable. However, more information can be analyzed if samples from several points of origin which vary in temporal and spatial context are available. With such a set of sample points, questions can be asked (and hopefully answered) about various environmental and cultural topics. Sequential samples provide data which can be synthesized to detect trends through time or different patterns of exploitation in different habitats occupied or exploited at the same time.

Preferred sample size would be forty to fifty valves. In older sites or sites with suboptimal preservation environment, extraction of valves is more difficult and only the umbonal region may be retrieved. Such umbonal areas are generally referable to species (sometimes only to genus). With fine documentation of provenience, additional inferences can be made and hypotheses tested. Following initial analysis of the shells and mapping of provenience, discussions between the malacologist and an archeologist familiar with the sites are a requisite to proper analysis and interpretation of the data.

Appendix B: Forms used during the Archeological and Historical Survey of the Lake Bosque Project

Prepared by

LONE STAR ARCHEOLOGICAL SERVICES
AUSTIN TEXAS

LONE STAR ARCHEOLOGICAL SERVICES
Georgetown & Austin

Landowner Interview Form

NAME ______________________ PROJECT # ______________________

ADDRESS ______________ CITY __________ NUMBER ______________________

TELEPHONE ______________ ZIPCODE __________ ACREAGE ______________________

[1] Is your property a farm ☐ or a ranch ☐? What crops ☐ stock ☐ do you raise? ______________

[2] How long have you owned your property? ______________________

[3] Are they any structures on the property? How old are they? ______________________

____

[4] Do you know of any Indian campsites on your property or places where artifacts like arrowheads or other chert tools are found? ______________________

[5] Are there any old ruins, chimneys, hand-dug wells or cisterns which you know of? ______________

____

[6] Do you know of any famous person or event which is associated with the property? ______________

____

[7] Do you know of any cemeteries on the property? ______________________

[8] Do you know of any springs, deep pools on the river, caves or limestone shelters? ______________

[9] Are you aware of any unusual patches of natural vegetation or other unusual natural features? ______

____

[10] Will you grant us permission to go on your land? ______________________

[11] Are there any special instructions to follow to effect entry? ______________________

____

____

Interview by ______________________ Signature ______________________

Date ______________________ Time ______________________

LONE STAR ARCHEOLOGICAL SERVICES
Georgetown & Austin

Site Worksheet Form

NAME ______________________ PROJECT NAME ______________________

ADDRESS ______________ CITY __________ PROJECT # ______________________

TELEPHONE ______________ ZIPCODE __________ PROPERTY NUMBER ______________

[1] Personnel on site ____

[2] Site Setting ____

____

[3] Nearest Water ______________________ [4] Elevation ______________

[5] Soil origins ([C] ☐ [A] ☐ [E] ☐ [M] ☐) Soil Description ______________

____

[6] Ground Surface visibility ________% Vegetation ______________________

[7] Site Type ____

[8] Distinguishing Features ____

______________________ Depth of Deposit ______________________

[9] Estimated age of occupation ______________ Based on ______________

____

[10] Collections? ☐ no ☐ yes ____

____

[11] Photos? ☐ no ☐ yes ____

[12] Recommendations? ____

____

____

Date ______________________ Recorded by ______________________