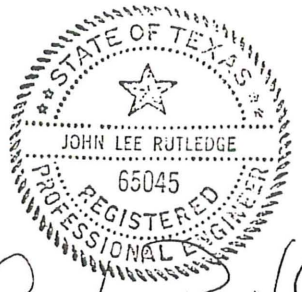
Report Supporting an Application for a Texas Water Right by Somervell County Water District



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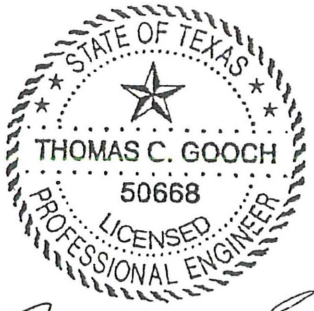

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April 2001

Prepared for Somervell County Water District

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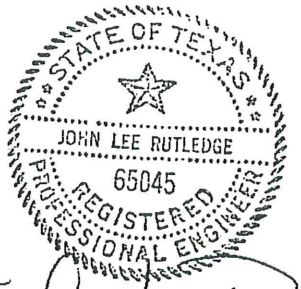
ENGINEER'S CERTIFICATION

I certify that the *Report Supporting an Application for a Texas Water Right by Somervell County Water District*, including associated application drawings and appendices, were prepared by me or under my direct supervision on April 4, 2001.



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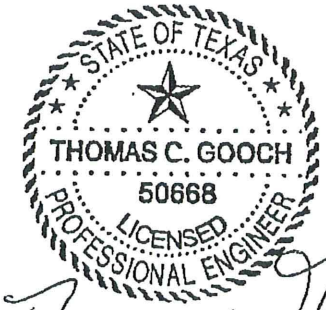

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REPORT SUPPORTING AN APPLICATION FOR A TEXAS WATER RIGHT BY SOMERVELL COUNTY WATER DISTRICT

April 2001

1. BACKGROUND AND NEED FOR THE PROJECT

Introduction

This report was prepared to support an application by the Somervell County Water District to the Texas Natural Resource Conservation Commission (TNRCC) for a Texas water right. The District seeks to impound runoff and water diverted from the Paluxy River into a reservoir on Wheeler Branch with a conservation storage capacity of 4,118 acre-feet, and to divert up to 2,000 acre-feet per year from the reservoir on Wheeler Branch for municipal and industrial use.

Background

In the past, municipal water supplies within the Somervell County Water District have been obtained from wells in the Trinity aquifer. However, declining water levels in the aquifer indicate that the long-term ground water supply is limited. Based on these declining water levels and on recent evaluations of ground water availability conducted as part of the Senate Bill One water planning, it is apparent that the existing municipal wells cannot be counted on to meet the increasing demands that are expected in the future.

In recognition of the need for additional water supplies, the Somervell County Water District had previously worked with the City of Stephenville to pursue the proposed Paluxy Reservoir, which would have provided a substantial water supply for Somervell County, the City of Stephenville and surrounding counties. The Texas Water Commission, a predecessor to the TNRCC, granted a permit for the Paluxy Reservoir, but that permit was overturned in state court. At that point, the City of Stephenville decided to pursue other water supply alternatives.

In 2000, the Somervell County Water District hired Freese and Nichols to examine the need for water supply for the District and investigate alternative sources of supply. The recommended water supply for the Somervell County Water District is to

construct a reservoir on Wheeler Branch for the storage of water diverted from the Paluxy River. This water would then be treated and distributed to the District's customers. The following sections describe the need for the project and the results of the supply alternatives investigation.

Current Water Supplies for Somervell County

The water used for municipal purposes within the Somervell County Water District comes from the formations of the Trinity aquifer. The only major water supplier in Somervell County, the City of Glen Rose, has five wells drawing on Trinity formation groundwater. Municipal use outside of Glen Rose is generally supplied from individual household wells, also drawing from the Trinity aquifer. This aquifer is heavily used and is currently being over-drafted in Somervell County. Storage in the aquifer is being depleted at a rapid rate as illustrated by the declining water levels of Glen Rose municipal well number 2, shown in Figure 1.1. The Texas Water Development Board (TWDB) monitors well number 2, and periodic measurements of the depth to water have been recorded since 1960. Since 1974, water levels in the well have declined by over 130 feet, a rate of about 5 feet per year. If the current rate of decline continues, the existing ground water system will not be able to support current water use in the District, much less provide for expected future growth.

Need for Water Supply

The proposed project is needed to provide municipal supply to the city of Glen Rose and rural residents within the boundaries of the District. As previously discussed, the existing municipal supply in these areas is unreliable and will not support future potable water needs. The projected municipal water requirements developed as part of Senate Bill One planning [1] are shown on Table 1.1 and Figure 1.2. These projections assume a fairly low per capita use for rural municipal users. This low use rate is based on estimates of past use, since reliable data on individual wells are not available. Actual future per capita use in the rural parts of the District may be higher than projected.

TWDB's municipal water use category includes all potable water use for municipal, commercial and domestic requirements throughout the county. According to

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[1] Superscripted numbers in parentheses match references in Appendix A.

the projections, the need for municipal water in Somervell County is slightly more than 1,000 acre-feet per year now and will increase to approximately 2,500 acre-feet per year by 2050.

Figure 1.1
Depth to Water - Glen Rose Municipal Well #2

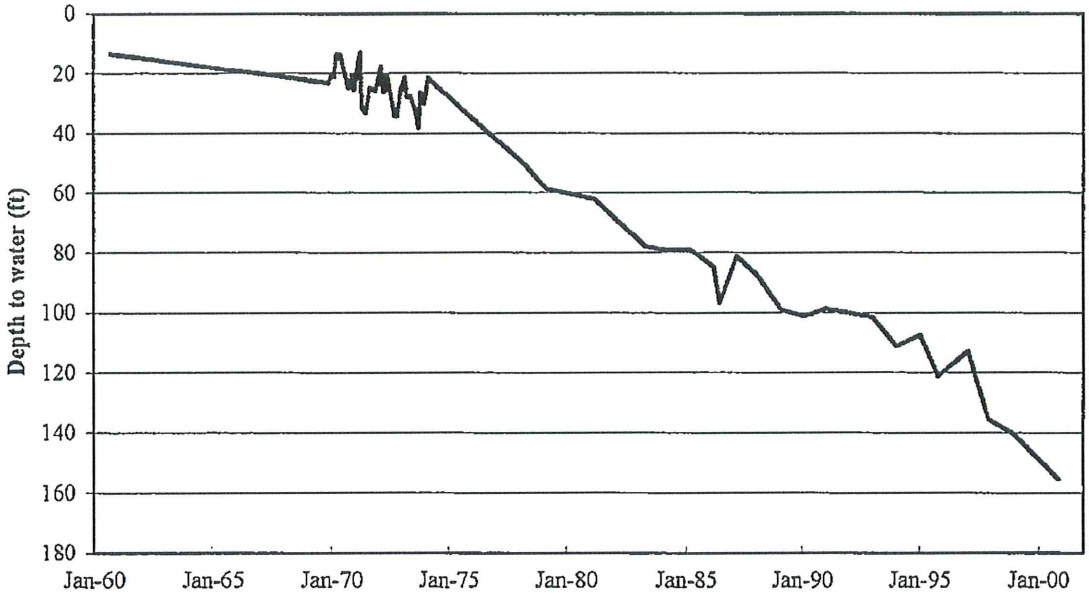
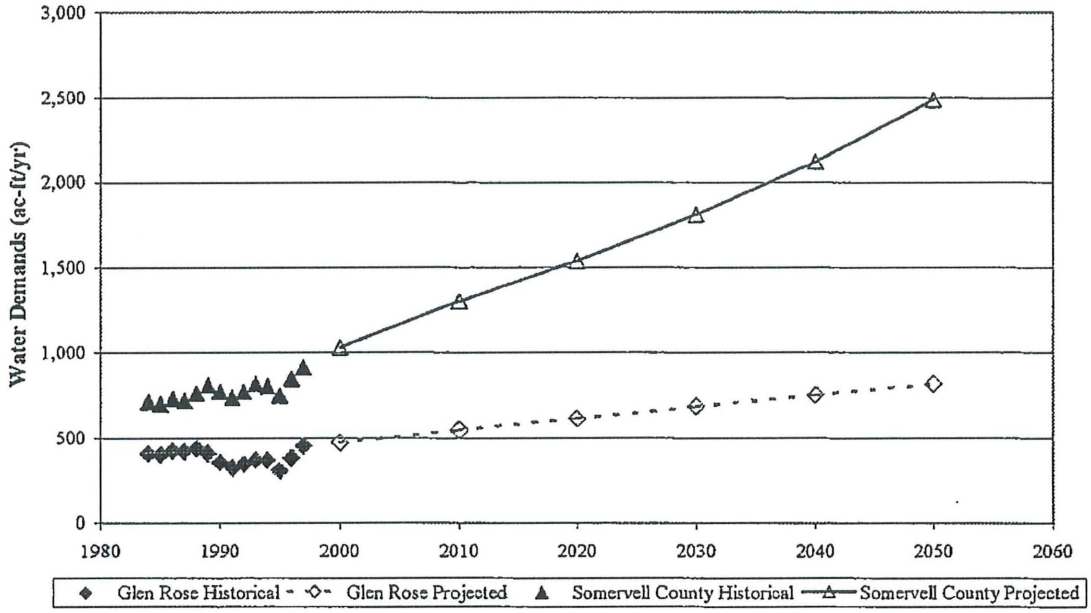


Table 1.1
Population and Municipal Water Use Projections for Somervell County[1]

		Projections				
	2000	2010	2020	2030	2040	2050
Population						
Glen Rose	2,335	2,721	3,107	3,493	3,879	4,265
Rest of County	4,136	5,090	6,322	7,889	9,860	12,319
Total	**6,471**	**7,811**	**9,429**	**11,382**	**13,739**	**16,584**
Water Use(ac-ft/yr)						
Glen Rose	473	546	616	685	752	817
Rest of County	556	753	921	1122	1370	1670
Total	**1,029**	**1,299**	**1,537**	**1,807**	**2,122**	**2,487**
Per Capita Use (gpcd)						
Glen Rose	181	179	177	175	173	171
Rest of County	120	132	130	127	124	121
Total	**142**	**148**	**146**	**142**	**138**	**134**

Figure 1.2
Historical and Projected Municipal Water Use



According to Senate Bill One evaluations, the current available municipal supply in Somervell County is 773 acre-feet per year. This is less than the current dry year demands and considerably less than the projected demands. To meet future demands, the county will need to develop approximately 2,000 acre-feet per year of additional supply by 2050. This amount would enable the District to meet all of the anticipated needs of Glen Rose through 2050 and about 70 percent of the expected requirements for the remainder of the county. Existing ground water wells would remain viable to meet part of the demands in the rural areas. In Glen Rose, ground water would be used as a backup supply, rather than the primary supply.

Conservation to Assure Beneficial Use

The Somervell County Water District and the City of Glen Rose have a strong commitment to water conservation to avoid waste and extend the useful life of current water supplies. The per capita demands in Somervell County have historically been below the average per capita demands in the state. The demand projections shown in Table 1.1 assume reductions in per capita demand due to expected additional conservation efforts.

As required by TNRCC, the Somervell County Water District has developed a Water Conservation and Drought Contingency Plan that addresses water conservation and drought contingency measures for this project. As part of the plan, wholesale customers receiving water from the project will also have to prepare conservation and drought contingency plans meeting TNRCC requirements. A copy of the plan is provided in Appendix K of this report.

2. DESCRIPTION OF THE PROJECT

After a careful review of viable water supply alternatives (described in Section 3 below), Somervell County Water District decided to develop a reliable surface water supply by diversions from the Paluxy River with storage on Wheeler Branch north of Glen Rose. Water would be diverted from the Paluxy River as it flows through Glen Rose and stored in an off-channel reservoir on Wheeler Branch for use when needed in dry times. This project has several advantages over other alternatives:

- It will not affect the rate of flow in the Paluxy River through Dinosaur Valley State Park.
- It will require a relatively small amount of land and has limited environmental impacts.
- It is economically feasible and provides an adequate water supply.
- The quality of water from the Paluxy River is suitable for municipal purposes.

Rights Requested in the Application

Somervell County Water District's application seeks authorization to:

- Impound flow from Wheeler Branch and water diverted from the Paluxy River in a reservoir on Wheeler Branch with a maximum conservation storage capacity of 4,118 acre-feet at a normal operating elevation of 785 feet above mean sea level,
- Impound up to 35.2 acre-feet behind a diversion dam on the Paluxy River,
- Impound up to 5,000 acre-feet per year of runoff from the Wheeler Branch watershed and water diverted from the diversion dam pool on the Paluxy River at a maximum diversion rate of 50 cfs (22,440 gallons per minute) in the reservoir on Wheeler Branch for diversion and subsequent use,
- Divert up to 2,000 acre-feet per year from the reservoir on Wheeler Branch at a maximum rate of 11 cfs (4,937 gallons per minute) for use for municipal, industrial, and irrigation purposes in the Brazos Basin,
- Allow recreational use of the reservoir on Wheeler Branch and the pool of the diversion dam, and
- Allow the use of all return flows generated from the use of project water for municipal, industrial and irrigation purposes in the Brazos Basin and the right to use the bed and banks of the Brazos River and other streams to deliver such water for use downstream.

Overall Project Description

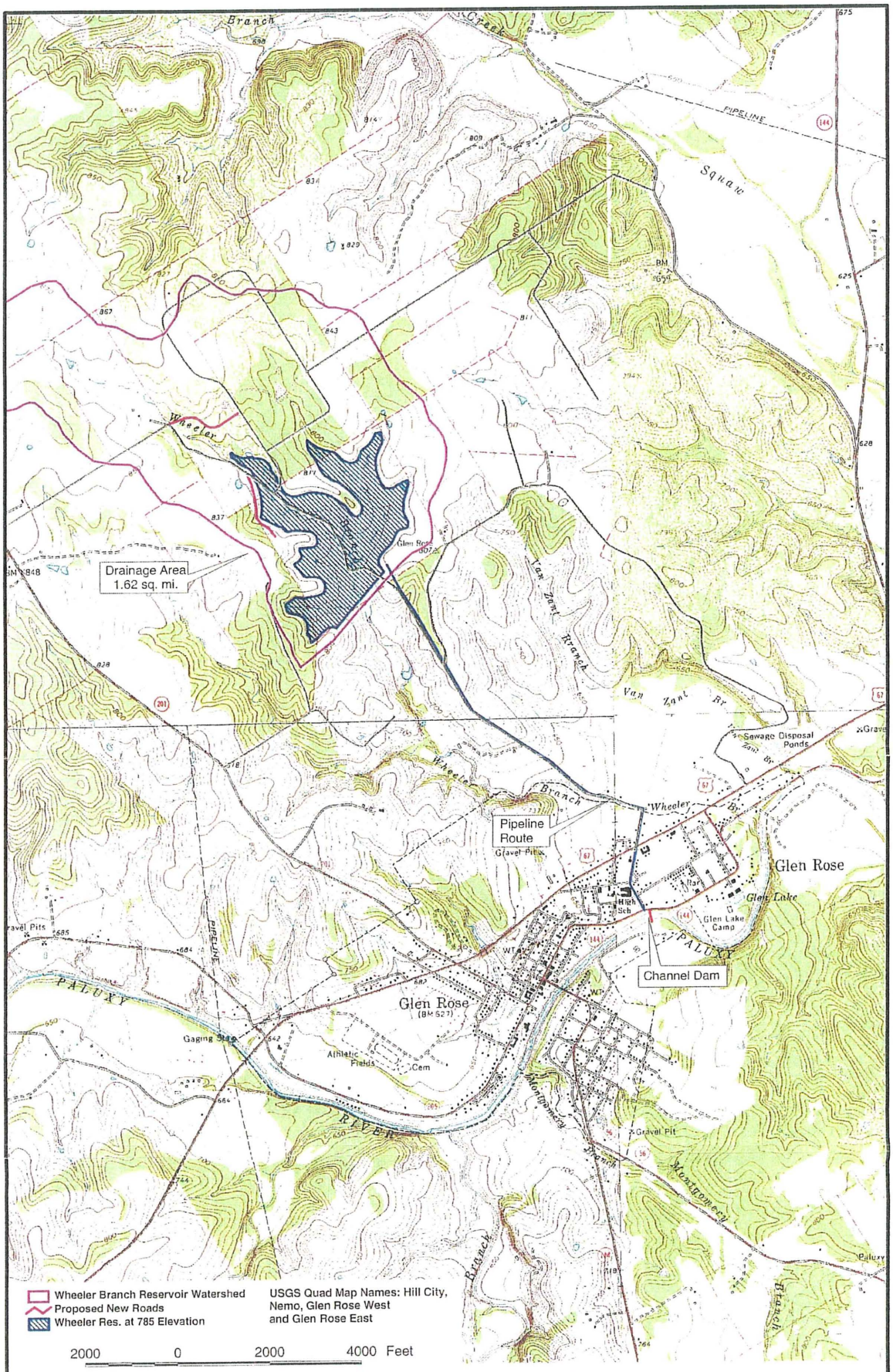
The proposed project consists of a diversion dam on the Paluxy River in Glen Rose, an off-channel reservoir on Wheeler Branch, and a pump station and pipeline to deliver water from the Paluxy River to Wheeler Branch Reservoir. Figure 2.1 is a map showing the layout of the project, and Figure 2.2 is an aerial photograph. Appendix B includes a copy of the water right application drawings for the project.

Wheeler Branch Reservoir

There are several small streams that flow into the Paluxy River near Glen Rose that might serve as suitable sites for off-channel storage. Based on preliminary study of potential reservoir locations, a site on Wheeler Branch approximately two miles north of the Paluxy River was selected. This site is located near Glen Rose, has a small contributing drainage area and therefore can economically be designed to pass a probable maximum flood without overtopping, and has minimal conflicts. There are no existing houses or other buildings within the reservoir area, and the principal man-made conflict is a road that would have to be re-routed. Figures 2.1 and 2.2 show the location of the proposed project facilities.

The application drawings in Appendix B show the layout, plan and profile, and embankment cross-section for Wheeler Branch Dam. Appendix C includes the geotechnical report for the project. The dam will be located approximately two miles north-northwest of Glen Rose. It will be constructed as an earthen embankment, about 1,750 feet in length with a maximum height of about 90 feet. A service road will be provided on top of the embankment. The top of conservation storage will be 785.0 feet above mean sea level (msl). Wheeler Branch Reservoir will be formed by the dam and will have a surface area of 169 acres and capacity of 4,118 acre-feet at the top of conservation storage.

The top of the embankment will be at 796.0 feet above mean sea level, providing 11 feet of freeboard above the top of conservation storage. The upstream and downstream slopes will be three horizontal to one vertical. All of the random fill for the embankment is expected to come from the reservoir area, but there is only limited impervious fill in the area, and some impervious fill may be imported to the site.



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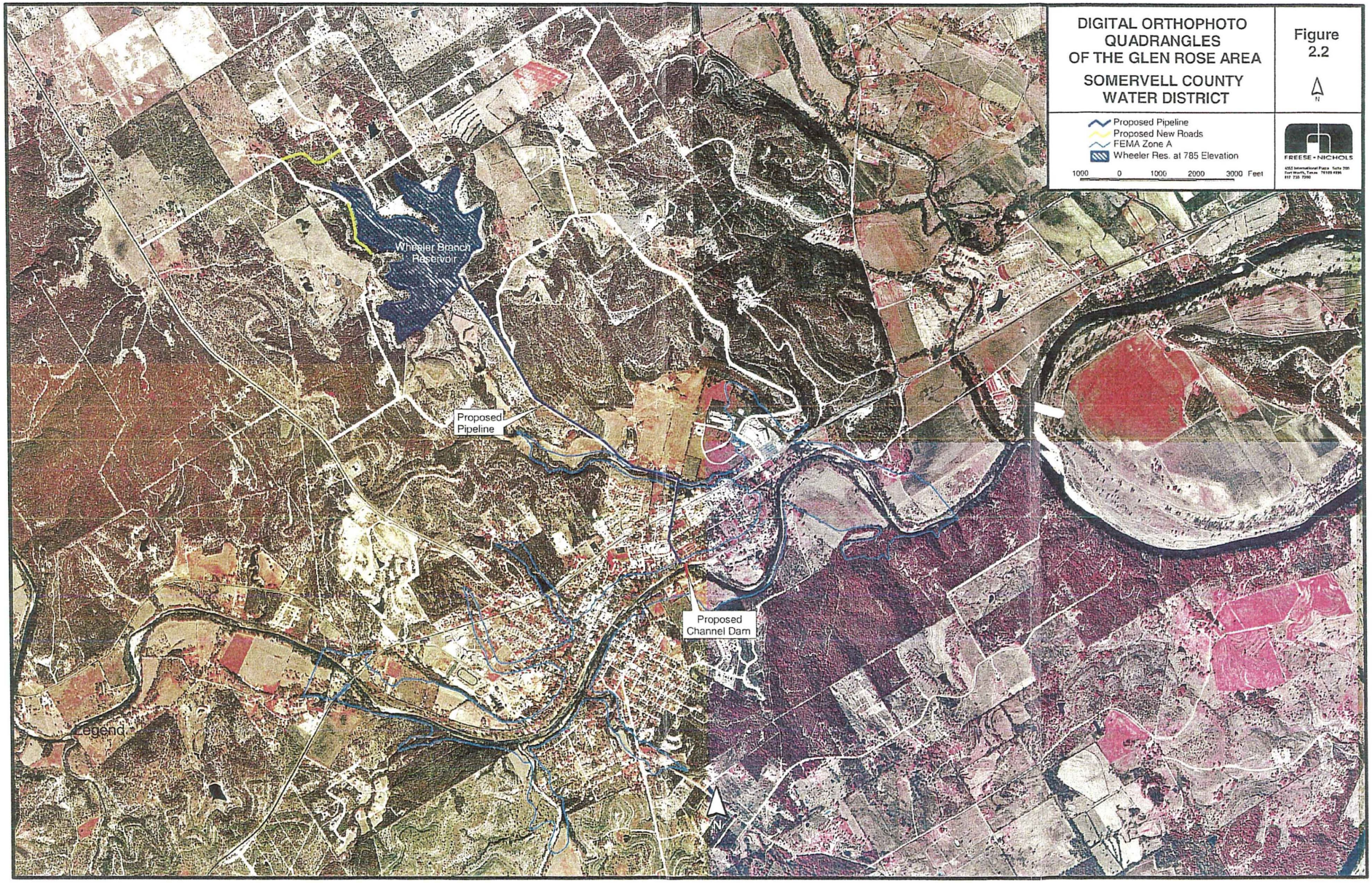
USGS Topography of Wheeler Branch Reservoir Project
Glen Rose, Texas

Somervell County Water District

Figure 2.1


DIGITAL ORTHOPHOTO QUADRANGLES OF THE GLEN ROSE AREA
SOMERVELL COUNTY WATER DISTRICT
Figure 2.2
Proposed Pipeline
Proposed New Roads
FEMA Zone A
Wheeler Res. at 785 Elevation
1000 0 1000 2000 3000 Feet
FREESE • NICHOLS
Wheeler Branch Reservoir
Proposed Pipeline
Proposed Channel Dam
Legend

Twenty-four inches of soil cement will be placed on the upstream slope for erosion protection. The downstream slope will have a grass cover.

The service spillway will be located southwest of the center of the dam. It will consist of a morning glory intake structure and 48-inch conduit with a stilling basin at the downstream end. The crest of the morning glory will be at elevation 785.0 feet above mean sea level, and the service spillway will have a discharge capacity of about 250 cfs. An emergency spillway will be located southwest of the dam. It will consist of a 200-foot wide open channel with a crest elevation at 790 feet msl. The emergency spillway will have a discharge capacity of about 6,000 cfs and will only operate in storms larger than the 100-year event. Runoff from the probable maximum flood was estimated and routed through the dam and spillway to determine the maximum water level of 795.37 feet msl, 0.63 foot below the top of the dam. This meets TNRCC's requirements for a dam classified as "high hazard". The application drawings in Appendix B include additional information about the flood routing for the probable maximum flood. Appendix D includes a more detailed discussion of the design storm analysis and a copy of the HEC-1 output.

Required low flow releases and releases for water supply will be made through a 24-inch diameter pipeline with a multiple-level intake tower in the reservoir. This outlet will have a discharge capacity of about 110 cfs when the reservoir is at the top of conservation storage.

Diversion Dam and Pump Station on the Paluxy River

The diversion dam and pump station will be located upstream from Big Rocks Park on the Paluxy River. The drainage area at the diversion dam is 427.1 square miles. The diversion dam will be about eight feet high and 100 feet in length. This will create an impoundment with a surface area of approximately 9 acres and volume of 35.2 acre-feet at a normal pool elevation of 598 ft msl. The channel dam will be constructed with reinforced concrete to allow overtopping. There will be some regrading of the area adjacent to the dam on the south bank of the Paluxy to prevent flood levels in Glen Rose from increasing because of the dam. The HEC-2 flood elevations for the 10-year and 100-year storm events with the channel dam are included in Appendix D.

The intake from the diversion dam to the pump station will be located on the north bank of the Paluxy River upstream from the dam. The pump station itself will be located north of the road north of the Paluxy River and out of the flood plain. The pump station will be designed to allow variable diversion rates for flexibility of operation. It will have a maximum diversion rate of 50 cfs.

Water Treatment and Delivery

All water diverted from the Paluxy River will be pumped to the Wheeler Branch Reservoir. Water diverted from the reservoir for municipal use will be pumped or flow by gravity to a nearby surface water treatment plant that will be owned and operated by Somervell County Water District. The District will provide treated water to the City of Glen Rose and rural households within its service area through a treated water distribution system.

Estimated Project Costs

Table 2.1 shows the estimated costs for the proposed project, not including potential costs for mitigation of terrestrial habitat. The costs in Table 2.1 include technical services at 15 percent of estimated construction costs (technical services for roadways were estimated at 20 percent). The costs also include an allowance for contingencies of 20 percent for the pump station and diversion dam, 50 percent for land acquisition, and 15 percent for other project components.

Proposed Operation

Most of the yield of the proposed project will be based on diversions from the Paluxy River into Wheeler Branch Reservoir, using the proposed 50 cfs pump station. These diversions will be limited by requirements that flows in the Paluxy River downstream from the diversion dam not be reduced below certain specified limits. When flow in the Paluxy River is in excess of the specified flow limits and the Wheeler Branch Reservoir is less than full, Paluxy River water will be pumped into the Wheeler Branch Reservoir. During periods of low flow on the Paluxy River, water will not be pumped from the river, and water supply needs will be met from reservoir storage.

Table 2.1

Estimate of Probable Costs for the Proposed Project

Item	Estimated Cost
Permitting and Archeology	$500,000
Land Acquisition	$888,800
Wheeler Branch Dam and Spillway	$9,496,000
Conflict Resolution	$379,500
Paluxy Diversion Dam	$1,351,000
Pump Station and Intake- Paluxy River	$2,557,500
Pipeline to Wheeler Branch Reservoir	$1,583,000
Total for Raw Water	**$16,755,800**
Water Treatment Plant (1 MGD Initially)	$4,150,000
Total for Treated Water at Plant	**$20,905,800**

3. ALTERNATIVES TO THE PROPOSED PROJECT

Five primary categories of potential additional water supply were considered in the search for water supply for the Somervell County Water District. The categories of potential supply included:

- Additional groundwater wells
- Existing surface water supplies
- New surface water reservoirs on major streams
- Diversion from a major stream to off-channel storage in a reservoir on a smaller watershed
- Other alternatives.

Table 3.1 is a summary of information on the specific water supply alternatives. Figure 3.1, located at the end of the report, shows the locations of the alternatives that are discussed below. The option of "no action" was not considered feasible because the existing ground water aquifer is presently overdrafted and cannot meet current expected demands during drought. Even with a "no growth" scenario, the current supplies are not adequate.

Additional Groundwater Wells

Developing additional wells will not solve the basic problem of over-use of the Trinity aquifer in Somervell County and is not a realistic alternative. Due to the lack of available groundwater supplies in the area, it was concluded that new supply should be based on surface water, rather than groundwater.

Existing Surface Water Reservoirs

Lake Whitney and Lake Granbury are the two closest surface water reservoirs to Glen Rose with uncommitted yield at this time. Both lakes are owned and operated by the Brazos River Authority. The needed amount of water for Somervell County Water District might possibly be purchased from the BRA, but the waters from these lakes are not of suitable quality for municipal use without demineralization. The added treatment costs for demineralization make this alternative less economically feasible. Other existing surface water sources considered were rejected for the following reasons:

Table 3.1

Water Supply Alternatives for Somervell County Water District

	Source	Description	Yield (Ac-Ft/Yr)	Quality	Cost	Environmental Impact	Permitting Problems	Overall Difficulty	Pipeline Miles	Comments
1	New groundwater	New wells in area	500-	Good	Low	Moderate	Low	Moderate	?	Water table falling rapidly. Limited supply.
Existing Surface Water Reservoirs										
2	Lake Whitney	Pumping from Lake Whitney and desalination	2,000	Poor	High	Low	Low	Moderate	30	Not particularly desirable.
3	SWATS (Lake Granbury)	Buy demineralized water	< 2,000	Good	High	Low	Low	Moderate	14	Water may not be available.
4	Lake Benbrook	Raw water from TRWD	2,000	Good	High	Low	Low	Moderate	33	TRWD policy to avoid sales in Brazos basin.
5	Squaw Creek Reservoir	Purchase from TXU when no longer needed for power plant and desalination	2000?	Good	High	Low	Low	Moderate	4	Water not presently available.
6	Lake Aquilla	Raw water from BRA	Unknown	Good	High	Low	Low	Moderate	40	No yield available.
7	Lake Proctor	Raw water from BRA	Unknown	Good	High	Low	Low	Moderate	45	Depends on water becoming available.
New Surface Water Reservoir										
8	Paluxy Reservoir	On-channel lake	16,700	Good	High	Significant	Severe	Very High	9	Expected to encounter intense opposition.
Diversion and Off-channel Storage										
9	Paluxy River and off-channel storage	Diversion from Paluxy River into off-channel lake	2,000+	Good	Moderate	Moderate	Moderate	Moderate	2	Probably can be done.
10	Brazos River at the mouth of the Paluxy	Diversion and desalination	2,000+	Poor	Moderate-High	Moderate	Moderate	Moderate	2	Probably feasible if found to be preferred.

Table 3.1 (continued)

Water Supply Alternatives for Somervell County Water District

	Source	Description	Yield (Ac-Ft/Yr)	Quality	Cost	Environmental Impact	Permitting Problems	Overall Difficulty	Pipeline Miles	Comments
	Other Sources:									
11	Paluxy River and aquifer storage and recovery (ASR)	Diversion from Paluxy into aquifer storage	2,000?	Good	Moderate	Moderate	Moderate	Moderate-High	?	Aquifer characteristics uncertain.
12	Wastewater reuse	Use of reclaimed wastewater for part of needs	< 500	Uncertain	High	Moderate	High	High	1	Difficult due to public health concerns. Limited supply.

- Lake Benbrook – high cost due to distance; water rights controlled by the Tarrant Regional Water District, which has a policy of not supplying water to the Brazos Basin.
- Squaw Creek Reservoir – high cost because of need for desalination; water committed to TXU for power plant use and not currently available.
- Lake Aquilla – high cost due to distance; no water currently available.
- Lake Proctor – high cost due to distance; no water currently available.

New Surface Water Reservoir on Major Stream

The Somervell County Water District formerly joined with the City of Stephenville in an application for a permit to build a reservoir on the Paluxy River upstream from Glen Rose. The permit was granted but subsequently was overturned in a court appeal. At present, the Paluxy Reservoir site remains as a possible project, but none of the former applicants has chosen to reopen the case by filing a new request for water rights. Without the participation of Stephenville, the Paluxy Reservoir is a larger project than Glen Rose and Somervell County have need for. Stephenville is now concentrating on other alternatives and apparently does not intend to further pursue the Paluxy Reservoir project.

In view of Stephenville's decision not to participate in an application for the right to construct the Paluxy Reservoir, the logical alternative for Somervell County Water District is to pursue a smaller project to meet its needs.

Diversion from a Major Stream and Off-Channel Storage

Diversion from the Brazos River at the mouth of the Paluxy River and use of off-channel storage would require desalination due to the high level of dissolved solids in the Brazos River. As with other alternatives requiring desalination, the high cost of treatment is a major drawback.

Diversion from the Paluxy River to an off-channel reservoir is the selected alternative for a new water supply for Somervell County Water District. This project has several advantages over other alternatives:

- It will not affect the rate of flow in the Paluxy River through Dinosaur Valley State Park.

- It will require a relatively small amount of land and has limited environmental impacts.
- It is economically feasible and provides an adequate water supply.
- The quality of water from the Paluxy River is suitable for municipal purposes.

Other Alternatives

Aquifer storage and recovery and wastewater reuse were also considered as potential sources of water supply. The suitability of the aquifer formations in Somervell County for aquifer storage and recovery is uncertain, and this alternative was not pursued further. Glen Rose is already reusing a portion of its treated wastewater for golf course irrigation, and reuse for municipal supplies was rejected because of the lack of other water for blending and public health concerns with direct reuse.

Off-Channel Storage Alternatives Considered

Several alternatives for off-channel storage were considered before Wheeler Branch was selected. It is desirable to be as near Glen Rose as possible in order to minimize the cost of pipelines from the river to the off-channel storage reservoir and from the off-channel storage reservoir to the water treatment plant and on to Glen Rose. Development is already occurring on many of the streams near Glen Rose. After an initial reconnaissance, potential off-channel reservoir sites on Wheeler Branch and Barker Branch were selected as the most promising. The site on Wheeler Branch was chosen for the following reasons:

- It has a smaller drainage area, which makes dam and spillway construction easier and less expensive.
- It is very efficient, with limited area required for a given amount of storage.
- Based on an initial reconnaissance, the Wheeler Branch site does not include suitable habitat for the two endangered species of birds that may be found in Somervell County, the black-capped vireo and the golden-cheeked warbler.

4. OPERATION AND YIELD OF THE PROPOSED PROJECT

Subordination Agreement with BRA

The Somervell County Water District has entered into an agreement with the Brazos River Authority to subordinate BRA's water right in Lake Whitney to make water available for the proposed project. A copy of the subordination agreement is attached as Appendix F to this report. As the agreement notes, BRA had previously agreed to subordinate its Lake Whitney water right to the proposed Paluxy Reservoir. The subordination agreement for the current project will have less impact on Lake Whitney than the previous subordination to the proposed Paluxy Reservoir.

The agreement allows the Somervell County Water District to divert water from the Paluxy River at times when the flows would otherwise be required to pass the District's diversion point in order to honor BRA's water right. The provisions of the agreement include:

- A maximum annual diversion from the Paluxy River of 5,000 acre-feet, with an average of up to 3,000 acre-feet per year
- Impoundment in an off-channel reservoir with a maximum operating capacity of up to 8,000 acre-feet,
- Annual diversion and use from the off-channel reservoir of up to 2,000 acre-feet.

The agreement extends for 50 years and may be renewed at that time.

Hydrologic Data

The hydrologic data used in the operation analysis are discussed in more detail in Appendix G. The inflow data are based on the long-term records of the historical stream flows of the Paluxy River at a USGS gaging station located 500 feet upstream from the U.S. Highway 67 Bridge near Glen Rose. The drainage area at the gage is 410 square miles, 96 percent of the 427.1 square mile drainage area at the proposed diversion dam on the Paluxy River. Daily flow data are available for the USGS gage since May of 1947. These flows were adjusted for the diversion point based on drainage area ratios. Estimated historical monthly flows at the diversion point from June 1947 to September 2000 are shown with the operation analysis in Appendix H.

Evaporation data have been derived by the TWDB for one-degree quadrangles of latitude and longitude throughout the entire state. Monthly net evaporation values for the off-channel reservoir on Wheeler Branch were developed from the TWDB data as described in Appendix G.

Bypass Requirements for Diversions

Diversions from the Paluxy River are an integral part of the proposed project. The project will be operated so as to provide in-stream flows in the Paluxy River and to protect downstream water rights. To determine how much flow should be passed downstream, the requirements set forth for a similar project nearby were reviewed.

In 1996, the City of Clifton was granted a permit by the TNRCC to divert water from the North Bosque River to a storage reservoir on a tributary stream. In the Clifton permit there is a requirement that the flow of the North Bosque not be reduced below specified limits by the diversions, with the limits keyed to seasons of the year [(2)]. Since the Paluxy watershed and the North Bosque watershed are adjoining, it is likely that a similar condition would apply to the diversions from the Paluxy River. The required by-pass flow rates for the proposed project were therefore assumed to be proportional to the runoff of the contributing drainage areas on the two streams. A comparison of the historical runoff data for the Paluxy River at Glen Rose and the North Bosque River near Clifton from 1978 to 1997 found the average runoff at Glen Rose was slightly more than one third of the Clifton runoff (ratio = 0.3654). Allowing for higher flows due to additional drainage area, the by-pass flows for the Paluxy diversion were set at 0.3812 times the flows required for Clifton. A summary of the monthly median flow rates at the Paluxy diversion and by-pass flow rates for the Clifton permit and Paluxy diversion is presented in Table 4.1.

Project Yield

Computer operation studies of the Paluxy diversion and the Wheeler Branch Reservoir were conducted to determine the diversion rate and storage capacity needed to provide a yield of 2,000 acre-feet per year. The limiting by-pass flow rates listed in Table 4.1 were applied throughout the analyses, and diversions were made only after these flows were allowed to go by. The flow computations were made on a daily basis, and the monthly totals were used in the reservoir operation analysis.

Table 4.1

Required By-Pass Flow Rates at Paluxy River Diversion (cfs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Clifton Permit Bypass	9	14	20	23	23	23	4	4	4	4	4	4
Proposed Paluxy Diversion Bypass	3.4	5.4	7.6	8.8	8.8	8.8	1.6	1.6	1.6	1.6	1.6	1.6
Median Flows at the Diversion Point	17	19	23	23.5	45	29	10.4	4.6	6.3	10.4	14.6	14.6
25^{th} % Flows at the Diversion Point	9.7	11.5	11.5	11.5	12.5	11.5	2.9	0.7	0.8	2.2	5.6	8.3

Note: The required by-pass flow rates at the Paluxy diversion point were derived from flow rates required by the Clifton permit No. 5551. It was assumed that these rates were proportional to runoff ratio (0.3812).

As described in Appendix G, operation studies were made using historical flows in the Paluxy River. For potentially critical periods of low flows, additional operation studies were made considering the potential reductions in flow in the Paluxy River due to Natural Resource Conservation Service (NRCS) flood control structures in the Paluxy watershed. Outputs from the operation studies are included in Appendices H and I.

The findings of the analyses indicated that a diversion pump station with a capacity of 50 cfs and an off-channel reservoir with a capacity of 4,118 acre-feet would provide an annual yield of 2,000 acre-feet. The reservoir levels in the Wheeler Branch Reservoir throughout the 53-year simulation are shown in Appendix G. The analysis of the diversion–reservoir system considering the potential impacts of the NRCS structures found the system could support an annual yield of 2,000 acre-feet, with a minimum content of 1,540 acre-feet. The maximum annual amount diverted from the Paluxy River was 4,529 acre-feet, which occurred in 1979.

Impact on Existing Water Rights

The subordination agreement with the Brazos River Authority allows the proposed project to impound flows that would otherwise be impounded in Lake Whitney. There are no existing water rights on the Paluxy River downstream from the proposed diversion. Between the mouth of the Paluxy River and Lake Whitney, there are five water rights on the Brazos River with a total permitted diversion of 4,385 acre-feet per year. The drainage area at the proposed diversion dam represents 2.5 percent of the total contributing drainage area of the Brazos River at the mouth of the Paluxy River, and the proposed bypass requirements will provide more than a proportional share of the flow required to meet these existing water rights. The minimum historical annual flow for the Brazos River near Glen Rose, which is upstream from the Paluxy River, is 67,974 acre-feet in 1988. There is more than enough flow in the Brazos River to meet these downstream water rights with the proposed project.

5. EXISTING ENVIRONMENT IN THE PROJECT AREA

Archeological Resources

Perhaps the most famous archeological resources in the project area are the dinosaur tracks that occur within the bed of the Paluxy River. The river has some of the best-preserved tracks in the United States, which led to the creation of Dinosaur Valley State Park. The proposed diversion dam is approximately six river miles downstream of the dinosaur tracks found in Dinosaur Valley State Park. Other historic resources in the area include the Somervell County Courthouse and Barnard's Mill. Built in 1860, the mill is listed on the National Register of Historic Places. Table 5.1 includes a listing of the Historical Resources found in Somervell County. While not included in the listings of Table 5.1, there is the remnant of a low water dam built in 1933 by the WPA just downstream from the proposed dam location.

Table 5.1

List of Historical Resources in Somervell County

Barnard Mill
- National Register listing
- Historical marker

Bernard's Trading Post No. 2
- Historical marker

Campbell Building
- Historical marker

Dinosaur Tracks
- Historical marker

Dinosaur Valley State Park
- Museum

First National Bank
- Historical marker

Lanham Mill Community
- Historical marker

Somervell County Courthouse
- Historical marker

Somervell County Jail
- Historical marker

Squaw Creek Indian Fight
- Historical marker

Veterans of the Confederacy, Spanish American War, WWI and II
- Historical marker

Instream Uses

The Paluxy River is a tributary of the Brazos River and originates in Erath County. It flows southeast for 38 miles through Hood and Somervell counties, and flows into the Brazos River just outside of the city of Glen Rose. The Paluxy is formed by the junction of the north and south forks, neither of which can support normal recreational use. The main stem Paluxy is capable of supporting normal recreational use only during periods of heavy rains. The Paluxy is a perennial stream, but there are times in most years where it is more intermittent in nature, with pools scattered throughout the reach. The median flows in the Paluxy at the diversion point range from 4.6 cfs in August to 45 cfs in May. It is approximately 70 feet wide at the proposed diversion dam location.

Instream uses of the Paluxy River in the vicinity of the proposed diversion dam include recreation, fisheries, aesthetics, and aquatic and riparian habitat. The proposed diversion dam site is located approximately 2.65 river miles upstream of the confluence of the Paluxy River and the Brazos River.

The Paluxy River fishery is not well documented. Species that have been found in the Paluxy River at Glen Rose include white bass (*Morone chrysaps*), spotted bass (*Micropterus punctulatus*), perch (*Percitae, sp.*) and black bass (*Micropterus salmoides*). Due to the nature of the hydrology of the Paluxy, the river is likely only marginal for spawning of fish, such as white bass, due to insufficient flow. The river does not support major recreational fishery, nor is the aquatic habitat well developed within the proposed diversion dam area and downstream to the confluence with the Brazos River, where massive limestone shelves are found along the river bottom.

Dinosaur Valley State Park is a 5,524-acre state park bordering the Paluxy River. As previously discussed, the Paluxy River within the park contains some of the best-preserved dinosaur tracks in the country. The park is located approximately six miles upstream of the proposed Paluxy River diversion dam. Recreational use of the Paluxy River in the Park includes walking along the dinosaur tracks during periods of no to low flows.

Wheeler Branch is an ephemeral stream with a drainage area of approximately 1.62 square miles at the proposed Wheeler Branch dam site. Instream uses of Wheeler Branch (when flowing) include cattle and wildlife. When flowing, Wheeler Branch

supplies water to a stock tank located immediately downstream of the Wheeler Branch dam site.

Wetlands

According to the U.S. Army Corps of Engineers (COE), a site must have under normal conditions hydrophytic vegetation, hydric soils, and adequate hydrology to be classified as a wetland [3].

The U.S. Fish and Wildlife Service (USFWS), categorizes most plants according to hydrologic tolerance. Obligate (OBL) wetland plants have a 99 percent probability of occurring in wetlands. Facultative wetland (FACW) plants have a 67 to 99 percent probability of occurring in wetlands. Facultative (FAC) plants are equally likely to occur in wetlands or non-wetlands. Facultative upland plants have a 1 to 33 percent probability of occurring in wetlands. In order for a site to meet the hydrophytic criteria, the area must contain vegetation of which 50 percent or more of the dominant species are OBL, FACW, or FAC.

None of the areas within the proposed Wheeler Branch Reservoir pool contain vegetation that was considered FAC, FACW, or OBL. The narrow riparian corridor of the Paluxy River does not support FAC, FACW or OBL vegetation either.

Hydric soils are soils that are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil layer [4]. None of the soils in the proposed Wheeler Branch Reservoir pool or Paluxy River pool are listed as hydric soils.

For a site to have adequate hydrology to support a wetland, the site must be periodically inundated or have soils saturated to the surface at some time during the growing season [5]. There were no indicators of wetland hydrology observed within the proposed Wheeler Branch Reservoir pool. While the Paluxy River is prone to frequent flash flooding, the hydrology needed to support a wetland is not present. Another issue is the lack of hydric soils in the Paluxy River at the proposed dam site. According to the NRCS[14], there are no hydric soils within the Paluxy River component that will be impacted by the project.

Terrestrial Vegetation

The proposed dam and reservoir site on Wheeler Branch is dominated by dense, regrowth, ashe juniper. The dense juniper thicket dominates the site covering at least 90 percent of the total area. The few hardwoods on the site consist of flameleaf sumac (*Rhus copallira*) and cedar elm (*Ulmus crassifola*).

The proposed diversion dam on the Paluxy River is in a fairly urbanized part of Glen Rose. Trees in the area include hackberry (*Celtis occidentalis*), pecan (*Carya illinoensis*) and oak (*Quercus, sp*).

Endangered and Threatened Species

There are two federal listed endangered species that occur within Somervell County: the golden cheeked warbler (*Dendroica chrysoparia*) and the black-capped vireo (*Vireo atricapillus*).

Typical nesting habitat for the golden-cheeked warbler consists of tall, dense, mature stands of ashe juniper (*Juniperus ashei*) mixed with trees such as Spanish oak (*Quercus buckleyi*), live oak (*Quercus virginiana*), shin oak (*Queruis sinuata*), post oak (*Quercus stellata*), cedar elm (*Ulmus crassifolia*), sugar berry (*Celtis laevigata*), big tooth maple (*Acer grandidentatum*), sycamore (*Plantanus occidentalis*), escarpment cherry (*Prunus serotina var eximia*) and pecan (*Carya Uillinoensis*). Trees used for nesting are usually at least 20 years old and 15 feet tall.

Black-capped vireos require open, patchy shrubland or woodland with vegetation extending from ground level to approximately six feet in height with open grassland separating clumps of shrubs or trees. Habitat is usually dominated by low-growing broad-leaved hardwoods such as Spanish oak, shin oak, live oak, mountain laurel (*Sophora secundi flora*), skunkbush sumac (*Rhus trilobata*), evergreen sumac (*Rhus*

Interior least tern (*Sterna antillarium athalassos*). State listed threatened species that may occur in Somervell County include the Brazos water snake (*Nerodia harteri*), and Texas horned lizard (*Phrynosoma cornutum*).

The Brazos water snake is the only species of snake unique to Texas. It is extremely restricted in range, being confined to the upper Brazos River drainage basin, where it has adapted to the faster flowing portions of hill country waterways[15].

The Texas horned lizard is a flat-bodied lizard with large crown spires on the head. It occurs in dry areas, mostly open country with loose soil supporting grass, mesquite and cactus. It feeds almost exclusively on live large ants.

Water Quality

There is little information available on the water quality of Wheeler Branch. Water quality in the Paluxy River has been monitored for a number of years. According to the State of Texas Water Quality Inventory, there are no known water quality problems in the Paluxy River segment [6]. Recorded total dissolved solids measurements range from 315 to 451 mg/l. Chlorides and sulfates are relatively low, averaging 29 mg/l for chlorides and 46 mg/l for sulfates. The Paluxy River is designated for recreation, high aquatic life and public water supply. The levels of the water quality parameters are considered to be appropriate for a municipal water supply.

Groundwater Resources

The Trinity aquifer is the major aquifer found in Somervell County. Currently, municipal water supplies for the county are obtained from wells in the Trinity aquifer. However, the water table elevations in the aquifer have been declining, indicating overdrafting of the aquifer. As shown on Figure 1.1, the water levels in the Glen Rose municipal well number 2 have declined by over 130 feet since 1974, a rate of five feet per year. If the current rate of decline continues, the existing groundwater system will not be able to support current use in the county.

Bays and Estuaries

The Brazos River estuary is very small. The open water area is about two square miles with about 31 square miles of adjacent wetlands. The Brazos River estuary,

combined with the San Bernard River estuary, occupies approximately 13 square miles. In contrast, the water surface of Galveston Bay covers approximately 540 square miles with 374 square miles of adjacent wetlands [7]. Unlike most Texas estuaries, the Brazos River estuary lacks a large bay behind a barrier island system. The estuary extends from the head of tide, approximately three miles upstream of the Missouri Pacific Railroad at Brazoria, Texas, to the Gulf of Mexico. Water levels average less than one meter at midtide. Additionally, the Brazos has been diverted from its original mouth by a distance of over six miles.

The estuary has a high freshwater discharge to estuary volume ratio. The ratio of freshwater inflow to estuary volume is over 20 times higher than that of any of the major estuaries in the state. The primary source of freshwater into the estuary is the Brazos River [8].

6. IMPACTS OF THE PROPOSED ACTION

The natural environment at the proposed diversion dam location and the reservoir site will be affected by construction and operation of the diversion dam on the Paluxy River and Wheeler Branch Reservoir. The diversion dam on the Paluxy River will be approximately eight feet high and inundate less than two acres of habitat. The Wheeler Branch dam will be approximately 90 feet high and inundate approximately 169 acres of terrestrial habitat.

Archeological Resources

A thorough archeological survey of the proposed project area will be completed prior to the start of construction. The remains of the WPA low water dam on the Paluxy River will be avoided during the construction of the diversion dam. Any cultural resources found in the project area will be assessed to determine their significance, and will be mitigated if they are found to be significant and impacted by the project. The project will not impact the historical resources listed in Table 5.1.

Instream Uses

Instream uses of the Paluxy River currently include recreation, fisheries, aesthetics and aquatic and riparian habitat. Instream uses of Wheeler Branch include cattle and wildlife use when the creek is flowing.

There will be no impact to downstream water rights holders, since the remaining flows in the Brazos River after the diversion will be more than sufficient to meet the existing water rights between the project and Lake Whitney. The project will not affect the rate of flow in the Paluxy River through Dinosaur Valley State Park, since the project is located downstream of the park.

The proposed project will beneficially impact the recreational opportunities on the Paluxy River. The dam will create a pool within the city of Glen Rose. This will create additional aquatic habitat and improve recreational uses, such as swimming, fishing, canoeing, etc. Also, the opportunity for additional economic development along the shoreline exists, with the potential for restaurants, hotels, and other "river walk" businesses.

The proposed diversion dam on the Paluxy River will not impact the existing fishery downstream of the site. Existing recreational fishing is not a major fishery, nor is the river used heavily for spawning due to low flow. Since the project is only 2.65 miles upstream of the confluence with the Brazos River and represents only 2.5 percent of the total contributing drainage area of the Brazos River at the confluence with the Paluxy, it is unlikely that the proposed reduced flow will impact the Brazos River fishery. As discussed in Section 4, the operation of the proposed project will provide for higher flows to be passed allowing the "flushing" effect on the Paluxy and Brazos Rivers.

Wetlands

Based on the lack of hydric soils, hydrophytic vegetation, and adequate hydrology in the project area to support wetlands, there will be no impact on wetlands from the proposed diversion dam on the Paluxy River or the reservoir on Wheeler Branch.

Terrestrial Vegetation

The proposed Wheeler Branch Reservoir will inundate habitat suitable to a number of wildlife species. Terrestrial habitat located within the 169-acre reservoir will be permanently eliminated. In addition to the habitat lost with construction of the reservoir, less than two acres of habitat will be impacted on the Paluxy River. Most of this acreage is along the stream banks and is already subject to varying water elevations from the stream flows. The impact to the Paluxy River habitat will be more varied, due to the existing urban setting, the proposed operation of the system and the small size of the diversion dam.

Endangered and Threatened Species

The endangered and threatened species that could possibly exist or migrate through the project area would not be impacted by the proposed project. A survey of the site to check for suitable habitat for the golden-cheeked warbler and the black-capped vireo found that the vegetation on the proposed Wheeler Branch Reservoir site does not support suitable habitat for either species. Therefore the project will not adversely impact either species.

The four migrant endangered species (American peregrine falcon, Artic peregrine falcon, whooping crane and interior least tern) will not be impacted by the project since they are migratory and could find other suitable habitat within the area.

The two state threatened species (Brazos water snake and Texas horned lizard), will not be impacted by the project, since the Paluxy River is only being raised approximately five feet for several hundred feet in length, and the habitat type at the Wheeler Branch Reservoir site is found throughout the area.

Water Quality

The project is expected to produce good quality water for a municipal water supply. There will be no adverse impact to water quality in the Paluxy River with the proposed dam operation.

Groundwater Resources

The proposed project will have a beneficial impact on the groundwater resources in the project area. Implementing a surface water supply system within Somervell County will decrease the dependence on the Trinity aquifer, which is heavily used and is currently being overdrafted. Data from the TWDB indicate that, since 1974, water levels in their monitor well have declined approximately five feet per year. If the current rate of decline continues, the existing ground water system will not be able to support current water use in the county, much less provide for expected future growth.

Bays and Estuaries

The proposed project is located approximately 520 miles upstream from the mouth of the Brazos River. Due to the small drainage area affected by the proposed project in relation to the total drainage area of the Brazos River, its effect on coastal and marine fisheries will be insignificant.

Flooding

The proposed dam on the Paluxy River will not adversely impact flooding in Glen Rose. Hydrologic analyses indicate that the 100-year flood will not be exacerbated with

the proposed project due to the design of the diversion dam and proposed grading modifications adjacent to the dam structure.

7. SUMMARY

The municipal water supply in Somervell County Water District's service area is currently obtained from groundwater wells in the Trinity aquifer. Declining water table elevations in municipal wells and increasing demands indicate that the existing groundwater supplies will not be able to meet the future needs.

In recognition of the need for additional water supplies, the Somervell County Water District had previously worked with the City of Stephenville to pursue the proposed Paluxy Reservoir, which would have provided a substantial water supply for the area. The Texas Water Commission, a predecessor to the TNRCC, granted a permit for the Paluxy Reservoir, but that permit was overturned in state court. At that point, the City of Stephenville decided to pursue other water supply alternatives.

In lieu of the Paluxy Reservoir, the recommended water supply for Somervell County Water District is to divert water from the Paluxy River to a small off-channel reservoir on Wheeler Branch. To provide adequate supply to the District's service area, the District seeks a water right permit to divert up to 5,000 acre-feet per year from the Paluxy River into a reservoir on Wheeler Branch with a conservation storage capacity of 4,118 acre-feet, and to divert up to 2,000 acre-feet per year from the reservoir on Wheeler Branch for municipal and industrial use.

This alternative includes the construction of an earthen dam on Wheeler Branch, a concrete channel dam on the Paluxy River in Glen Rose, a pump station and pipeline to the Wheeler Branch reservoir, and a 1 MGD water treatment plant located near the reservoir. This project has several advantages over other alternatives:

- It will not affect the rate of flow in the Paluxy River through Dinosaur Valley State Park.
- It will require a relatively small amount of land and has limited environmental impacts.
- It is economically feasible and provides an adequate water supply.
- The quality of water from the project will be suitable for municipal purposes.

APPENDIX A

LIST OF REFERENCES

APPENDIX A

LIST OF REFERENCES

(1) HDR Engineering, Inc: *Brazos G Regional Water Plan,* prepared for the Brazos G Regional Water Planning Group, 2001.

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(14) Natural Resource Conservation Service: Personal Communication with Barbara Nickerson (Freese and Nichols, Inc.), April 3, 2001.

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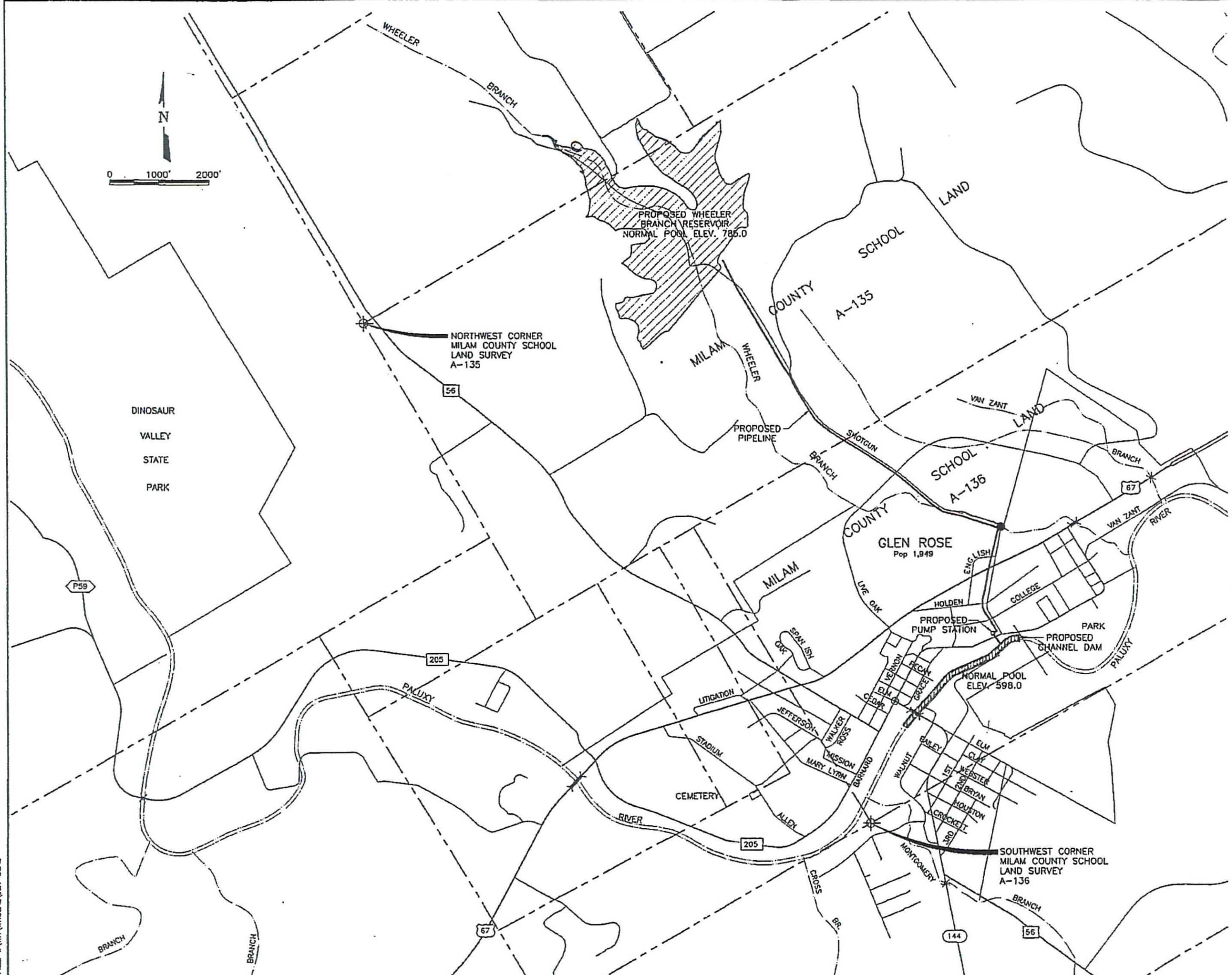
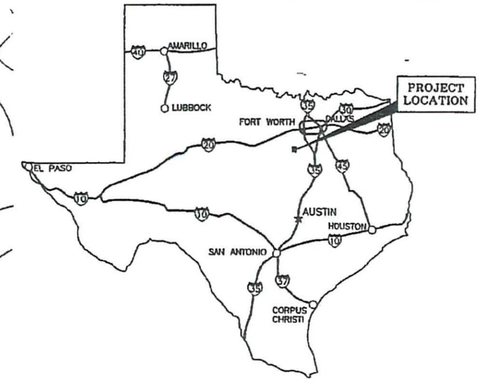
APPENDIX B

APPLICATION DRAWINGS



VICINITY MAP



LOCATION MAP
NTS

INDEX OF DRAWINGS

1. VICINITY AND LOCATION MAP
2. RESERVOIR AND DIVERSION MAP
3. DAM PLAN AND PROFILE
4. TYPICAL EMBANKMENT SECTION AND MISCELLANEOUS SECTIONS
5. CHANNEL DAM PLAN & SECTIONS
6. HYDRAULIC AND HYDROLOGIC DATA

LOCATION TABLE

REFERENCE POINT	LONGITUDE	LATITUDE	BEARING	DISTANCE
*DIVERSION NO. 1	97°44'53" WEST	32°14'18" NORTH	N35°15'E	4,517 FT.
*DAM STA. 10+00	97°44'48" WEST	32°14'20" NORTH	N38°55'E	4,810 FT.
**DIVERSION NO. 3	97°46'05" WEST	32°15'27" NORTH	S83°15'W	6,732 FT.
**DAM STA. 0+00	97°46'11" WEST	32°15'19" NORTH	S86°26'E	6,066 FT.

*BEARING AND DISTANCE ARE REFERENCED FROM SOUTHWEST CORNER OF MILAM COUNTY SCHOOL LAND SURVEY, ABSTRACT NO. 136.

**BEARING AND DISTANCE ARE REFERENCED FROM NORTHWEST CORNER OF MILAM COUNTY SCHOOL LAND SURVEY, ABSTRACT NO. 135.

I CERTIFY THAT THE APPLICATION DRAWINGS FOR PALUXY RIVER DIVERSION PROJECT, SHEETS 1 THROUGH 6 DATED MARCH 2001, OF SOMERVELL COUNTY WATER DISTRICT, WERE PREPARED BY ME OR UNDER MY SUPERVISION.

REGISTERED PROFESSIONAL ENGINEER
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STATE OF TEXAS
JOHN LEE RUTLEDGE
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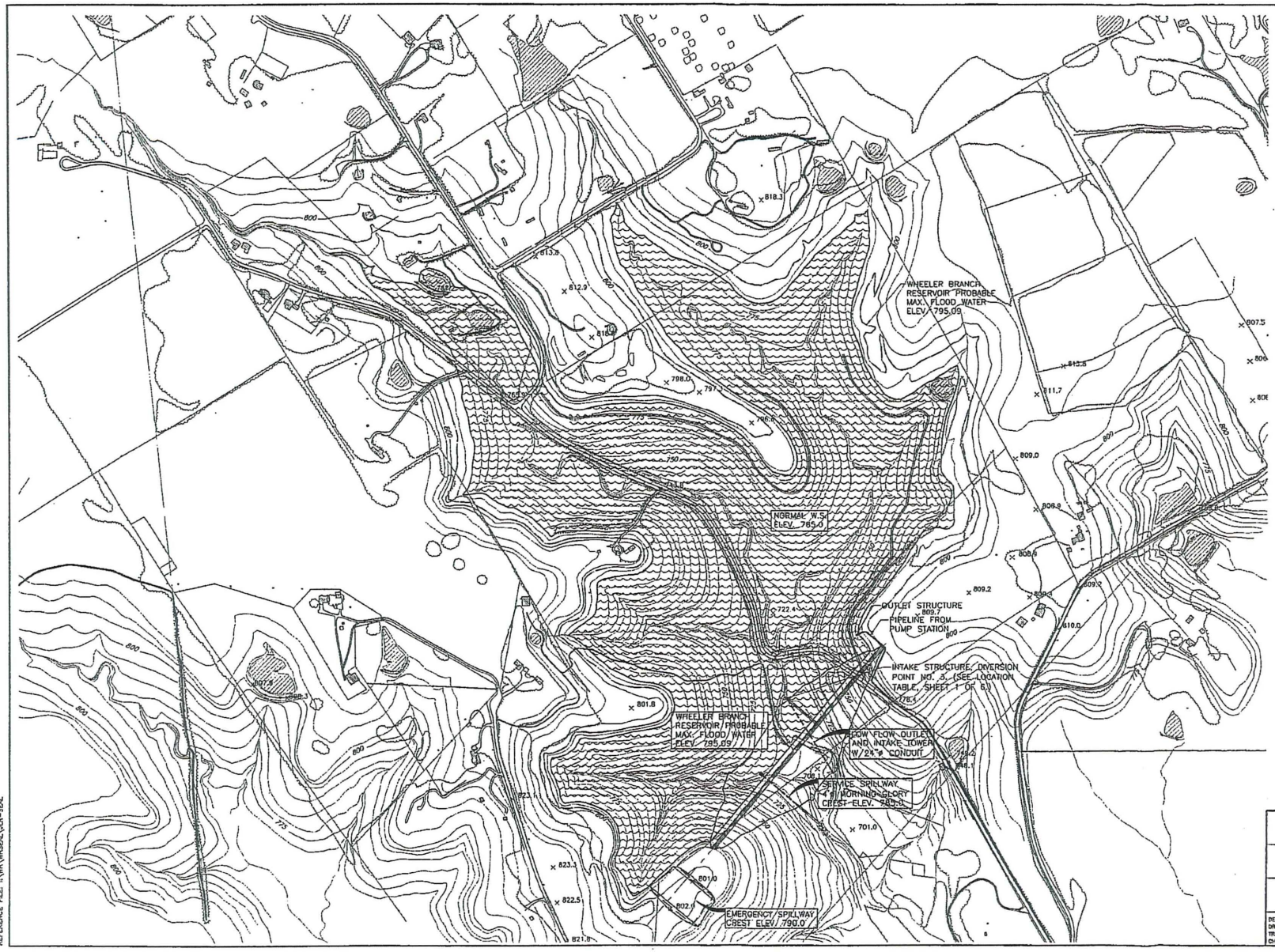
P.O. BOX 1386
GLEN ROSE, TEXAS 76043

PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

VICINITY AND LOCATION MAPS

DESIGNED: JLR DRAWN: JES TRACED: -- CHECKED: TCC		FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 1 OF 6



TOPOGRAPHY TAKEN FROM AERIAL PHOTOGRAPHY BY METROPOLITAN AERIAL SURVEYS, FORT WORTH, TEXAS FLOWN JULY 8, 2000

N

0 300' 600'

I CERTIFY THAT THE APPLICATION DRAWINGS FOR PALUXY RIVER DIVERSION PROJECT, SHEETS 1 THROUGH 6 DATED MARCH 2001, OF SOMERVELL COUNTY WATER DISTRICT, WERE PREPARED BY ME OR UNDER MY SUPERVISION.

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PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

RESERVOIR AND DIVERSION MAP

DESIGNED: JLR DRAWN: JES TRACED: -- CHECKED: TCG	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 2 OF 6

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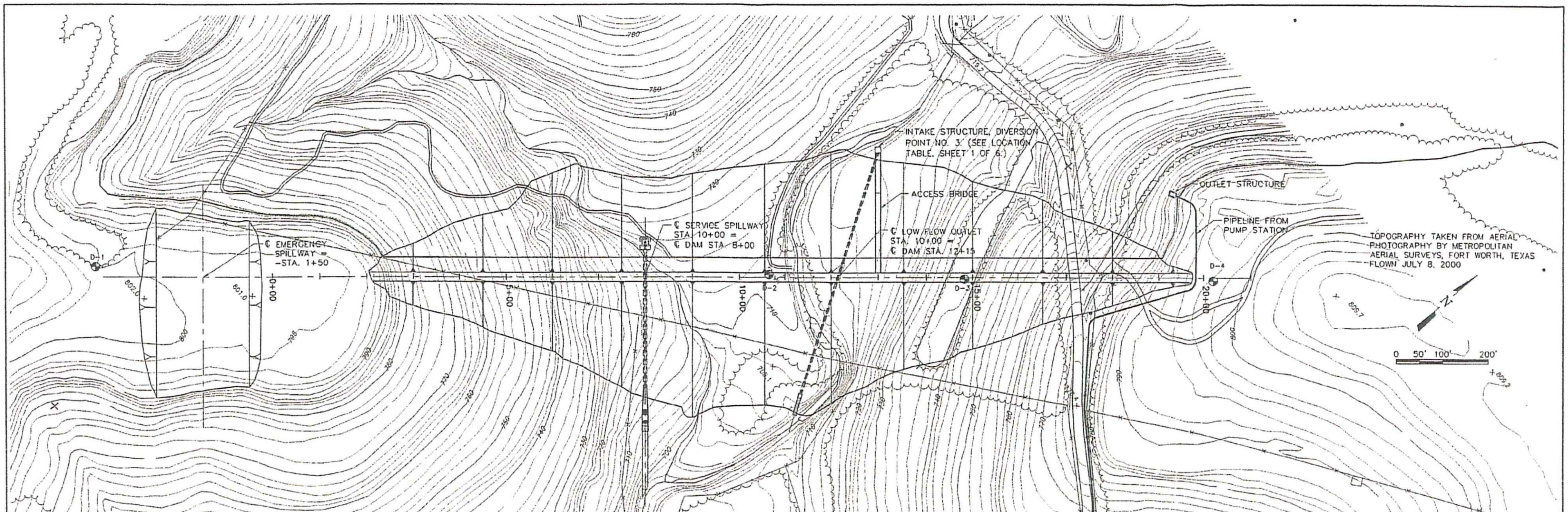
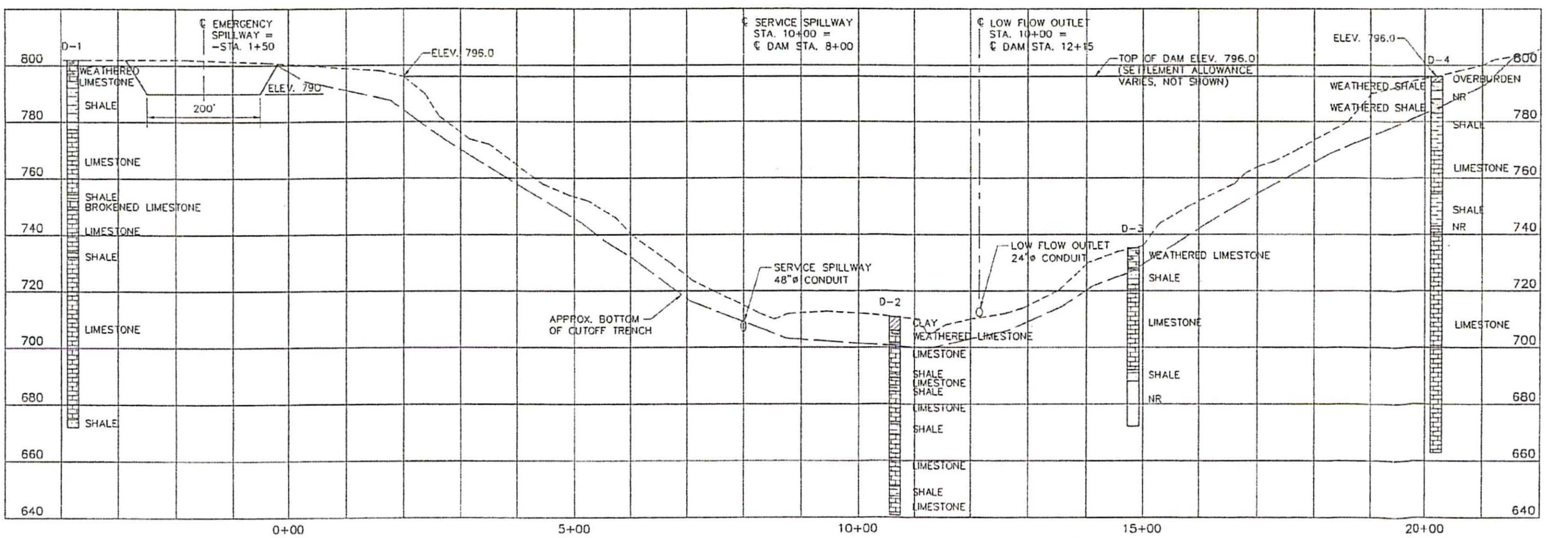


INTAKE STRUCTURE, DIVERSION POINT NO. 3 (SEE LOCATION TABLE, SHEET 1 OF 6.)
ACCESS BRIDGE
OUTLET STRUCTURE
PIPELINE FROM PUMP STATION
℄ SERVICE SPILLWAY STA. 10+00 = ℄ DAM STA. 8+00
℄ LOW FLOW OUTLET STA. 10+00 = ℄ DAM STA. 12+15
℄ EMERGENCY SPILLWAY = -STA. 1+50
TOPOGRAPHY TAKEN FROM AERIAL PHOTOGRAPHY BY METROPOLITAN AERIAL SURVEYS, FORT WORTH, TEXAS FLOWN JULY 8, 2000
D-1
D-2
D-3
D-4
0+00
5+00
10+00
15+00
20+00
N
0 50' 100' 200'



℄ EMERGENCY SPILLWAY = -STA. 1+50
℄ SERVICE SPILLWAY STA. 10+00 = ℄ DAM STA. 8+00
℄ LOW FLOW OUTLET STA. 10+00 = ℄ DAM STA. 12+15
ELEV. 796.0
ELEV. 790
200'
TOP OF DAM ELEV. 796.0 (SETTLEMENT ALLOWANCE VARIES, NOT SHOWN)
SERVICE SPILLWAY 48"ø CONDUIT
LOW FLOW OUTLET 24"ø CONDUIT
APPROX. BOTTOM OF CUTOFF TRENCH
D-1
WEATHERED LIMESTONE
SHALE
LIMESTONE
SHALE
BROKENED LIMESTONE
LIMESTONE
SHALE
LIMESTONE
SHALE
D-2
CLAY
WEATHERED LIMESTONE
LIMESTONE
SHALE
LIMESTONE
SHALE
LIMESTONE
SHALE
LIMESTONE
SHALE
LIMESTONE
D-3
WEATHERED LIMESTONE
SHALE
LIMESTONE
SHALE
NR
D-4
WEATHERED SHALE
WEATHERED SHALE
OVERBURDEN
NR
SHALE
LIMESTONE
SHALE
NR
LIMESTONE
800
780
760
740
720
700
680
660
640
0+00
5+00
10+00
15+00
20+00

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[signature]

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GLEN ROSE, TEXAS 76043

PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

DAM PLAN AND PROFILE

DESIGNED: JLR DRAWN: JES TRACED: CHECKED: TCG	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 3 OF 6

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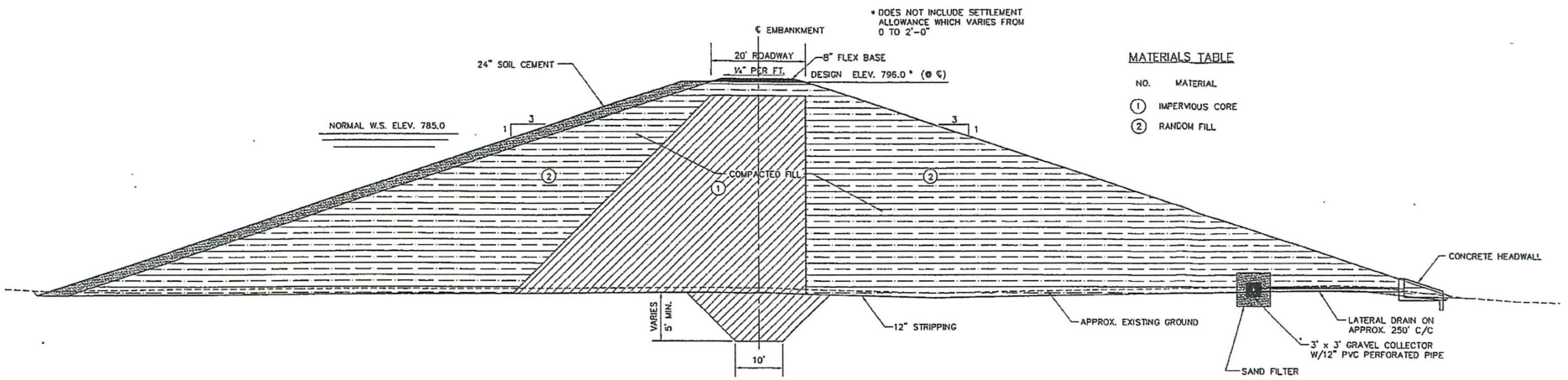
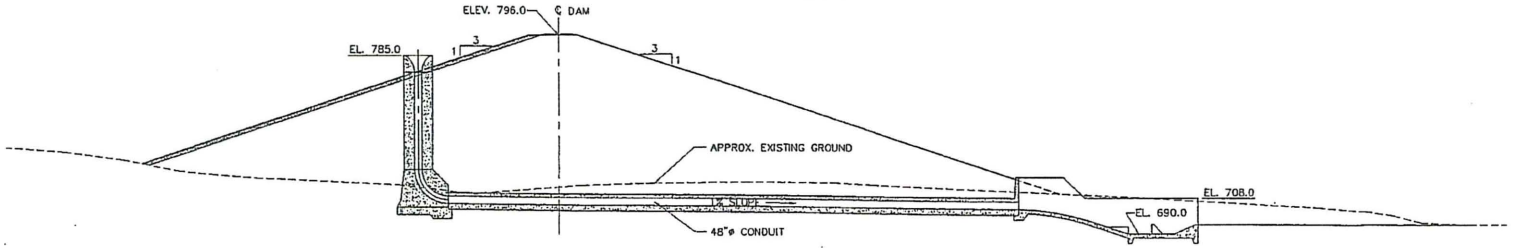


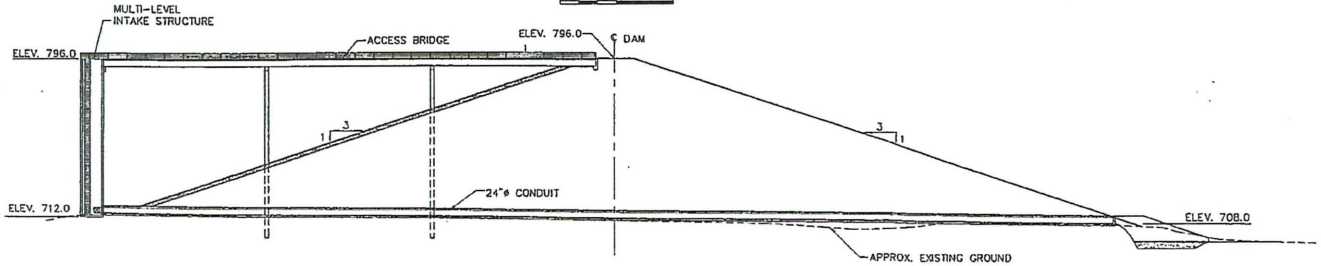
TYPICAL SECTION THROUGH EMBANKMENT

0 10' 20'
SCALE IN FEET



SECTION THROUGH SERVICE SPILLWAY

0 10' 20' 30' 60'



SECTION THROUGH LOW-FLOW OUTLET

0 10' 20' 30' 60'

I CERTIFY THAT THE APPLICATION DRAWINGS FOR PALUXY RIVER DIVERSION PROJECT, SHEETS 1 THROUGH 6 DATED MARCH 2001, OF SOMERVELL COUNTY WATER DISTRICT, WERE PREPARED BY ME OR UNDER MY SUPERVISION.

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STATE OF TEXAS
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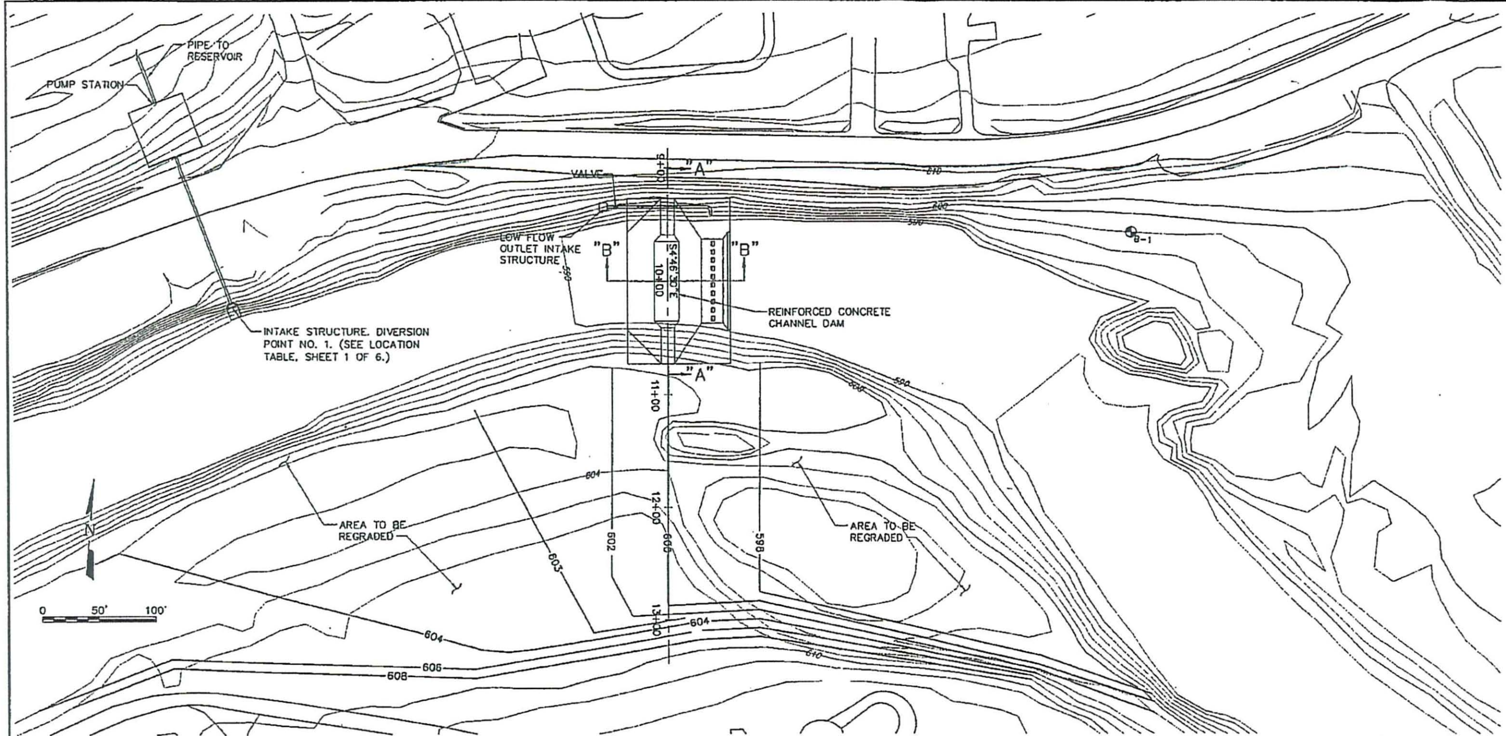
4/3/01

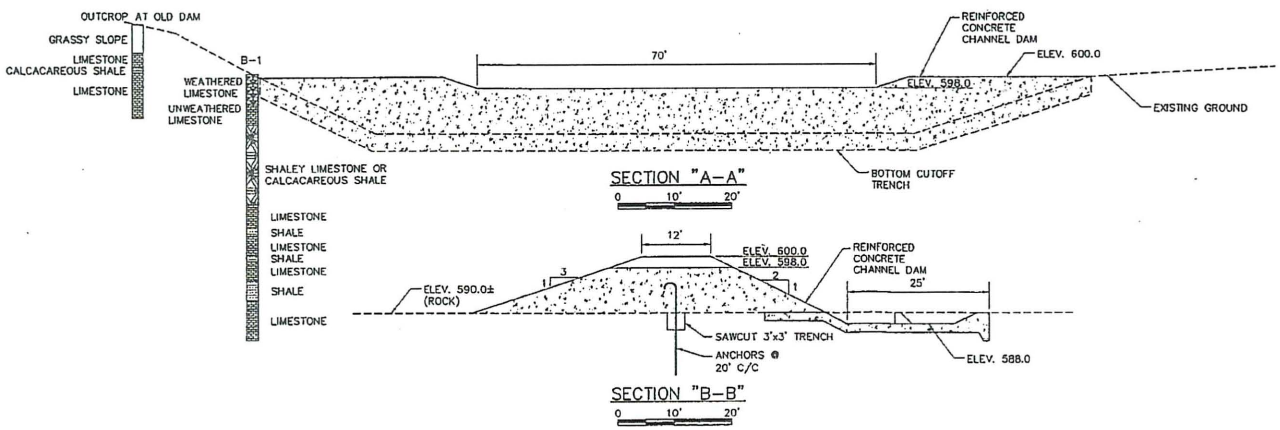
SOMERVELL COUNTY WATER DISTRICT
P.O. BOX 1386
GLENROSE, TEXAS 76043

PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

TYPICAL EMBANKMENT SECTION AND MISCELLANEOUS SECTIONS

DESIGNED: JLR DRAWN: JES TRACED: -- CHECKED: TDD	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 4 OF 6


PIPE TO RESERVOIR
PUMP STATION
VALVE
"A"
LOW FLOW OUTLET INTAKE STRUCTURE
"B"
"B"
S 4°46'30" E
10+00
REINFORCED CONCRETE CHANNEL DAM
INTAKE STRUCTURE. DIVERSION POINT NO. 1. (SEE LOCATION TABLE, SHEET 1 OF 6.)
B-1
11+00
12+00
13+00
AREA TO BE REGRADED
AREA TO BE REGRADED
0 50' 100'
604
606
608
603
602
600
598
610


OUTCROP AT OLD DAM
GRASSY SLOPE
LIMESTONE
CALCACAREOUS SHALE
LIMESTONE
B-1
WEATHERED LIMESTONE
UNWEATHERED LIMESTONE
SHALEY LIMESTONE OR CALCACAREOUS SHALE
LIMESTONE
SHALE
LIMESTONE
SHALE
LIMESTONE
SHALE
LIMESTONE
70'
REINFORCED CONCRETE CHANNEL DAM
ELEV. 600.0
ELEV. 598.0
EXISTING GROUND
BOTTOM CUTOFF TRENCH
SECTION "A-A"
0 10' 20'
12'
ELEV. 600.0
ELEV. 598.0
REINFORCED CONCRETE CHANNEL DAM
25'
ELEV. 590.0± (ROCK)
SAWCUT 3'x3' TRENCH
ANCHORS @ 20' C/C
ELEV. 588.0
SECTION "B-B"
0 10' 20'

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4-3-01

SOMERVELL COUNTY WATER DISTRICT
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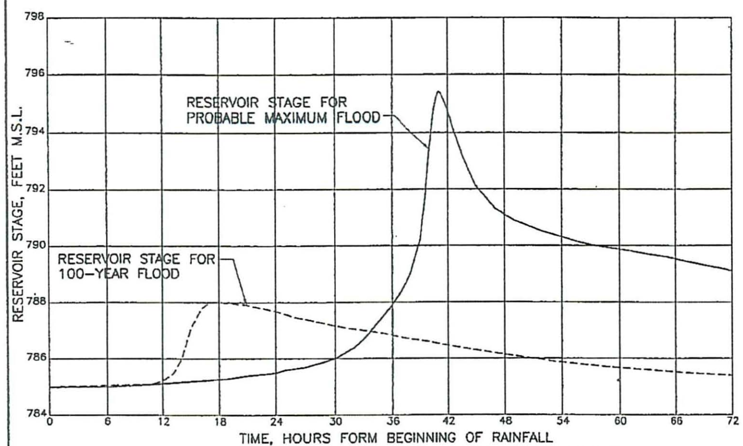
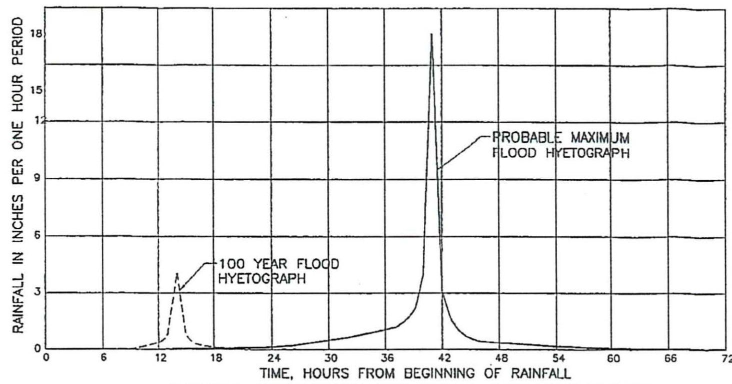
PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

CHANNEL DAM PLAN AND SECTIONS

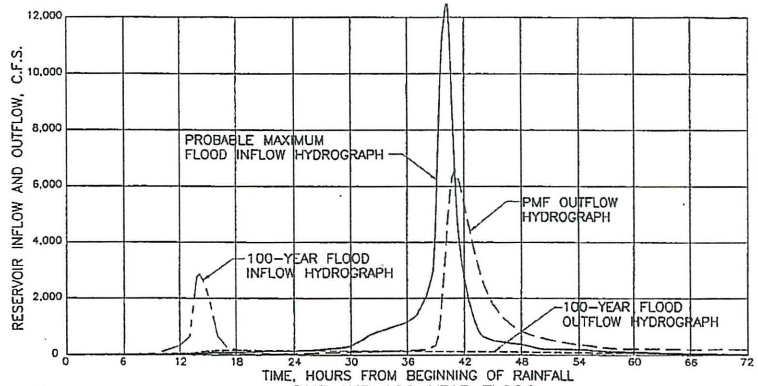
DESIGNED: JLR DRAWN: JES TRACED: – CHECKED: TCG	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 5 OF 6



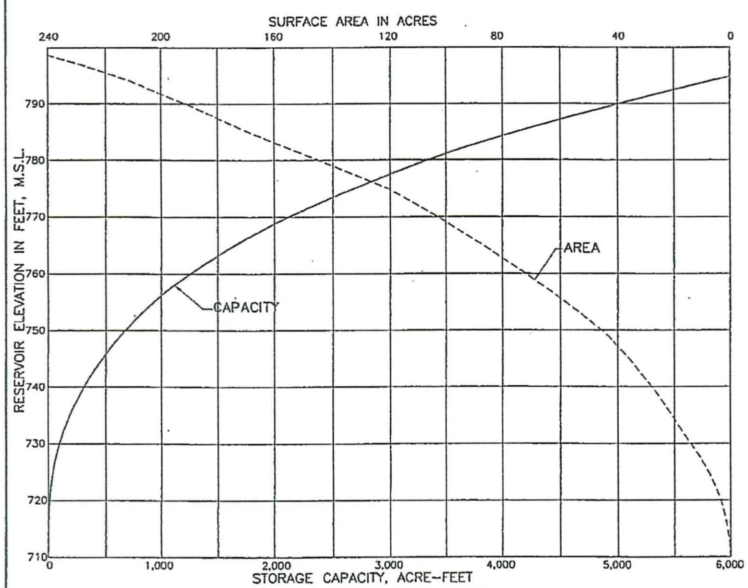
RESERVOIR STAGE FOR PMF AND 100-YEAR FLOOD



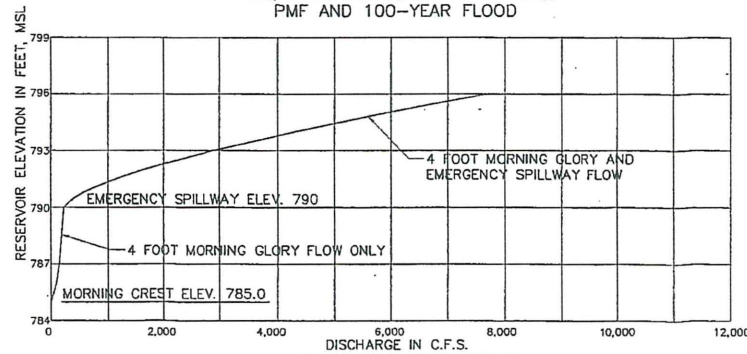
RAINFALL HYETOGRAPH FOR PMF & 100-YEAR FLOODS



PMF AND 100-YEAR FLOOD



AREA – CAPACITY CURVES



SPILLWAY RATING CURVE

PERTINENT DATA
WHEELER BRANCH RESERVOIR

MISCELLANEOUS

DRAINAGE AREA ABOVE DAM, SQUARE MILES	1.62
IMPOUNDED AT NORMAL MAX. W.S. ELEV. 785.0	
SURFACE AREA, ACRES	169
STORAGE CAPACITY, ACRE-FEET	4,118

PROBABLE MAXIMUM FLOOD ON WHEELER BRANCH WATERSHED

PEAK INFLOW, C.F.S.	12,460
VOLUME OF RUNOFF, ACRE-FEET	3,701
VOLUME OF RUNOFF, INCHES	42.83
PEAK OUTFLOW, C.F.S.	6,544

100-YEAR FLOOD ON WHEELER BRANCH WATERSHED

PEAK INFLOW, C.F.S.	2,862
VOLUME OF RUNOFF, ACRE-FEET	630
VOLUME OF RUNOFF, INCHES	7.3
PEAK OUTFLOW, C.F.S.	166

RESERVOIR

FEATURE:

	ELEVATION FEET, M.S.L.	AREA ACRES	CAPACITY ACRE-FEET
TOP OF DAM	796.0	223	6,248
PROBABLE MAX. FLOOD ON WHEELER BRANCH	795.37	219	6,109
100-YEAR FLOOD ON WHEELER BRANCH	788.0	181	4,643
NORMAL W.S.	785.0	169	4,118
STREAMBED	706.0	0	0

SERVICE SPILLWAY

TYPE: UNCONTROLLED 4'ø MORNING GLORY WITH HYDRAULIC JUMP STILLING BASIN

EMERGENCY SPILLWAY

TYPE: UNCONTROLLED EXCAVATED ROCK SURFACE	
CREST LENGTH, FEET	200

DAM

TYPE: EARTHFILL	
TOTAL LENGTH, FEET	1,800
HEIGHT ABOVE STREAMBED, FEET	96
CROWN WIDTH, FEET	20
SIDE SLOPES:	
UPSTEAM	3:1
DOWNSTREAM	3:1

NOTE:
TAILWATER RATING CURVE NOT SHOWN. SPILLWAY DISCHARGE NOT AFFECTED BY TAILWATER.

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PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY TEXAS

HYDRAULIC AND HYDROLOGICAL DATA

DESIGNED: JLR DRAWN: JES TRACED: – CHECKED: TCG	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN SHEET 6 OF 6	

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APPENDIX C

GEOTECHNICAL REPORT

SOMERVELL COUNTY WATER DISTRICT

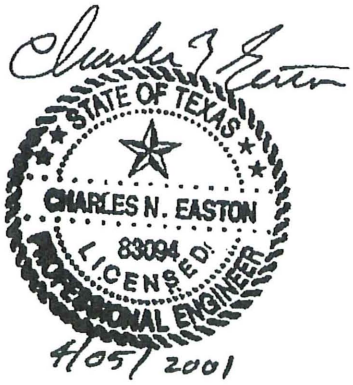
PALUXY RIVER DIVERSION PROJECT

SOM00166

GEOTECHNICAL INVESTIGATION REPORT

APRIL 2001

Prepared for
SOMERVELL COUNTY WATER DISTRICT



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Suite 200
Fort Worth, TX 76109
817/735-7300

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TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 Project Description

The Paluxy River Diversion Project will provide a surface water supply for Somervell County Water District. During periods of sufficient flow, an eight-foot high Diversion Dam across the Paluxy River near Big Rocks Park at Glen Rose will impound water to be diverted at an Intake Pump Station located near the intersection of Gaither Street and State Highway 144. The water will be transmitted through a 36-inch diameter pipeline to a new reservoir created by a dam across Wheeler Branch about two miles north of Glen Rose. Another pipeline will deliver water as needed to a new water treatment plant to be constructed at a later time.

The dam for Wheeler Branch Reservoir will be an earthen structure with a height of about 90 feet. The reservoir will have a conservation storage capacity of 4,118 acre-feet. The normal water surface will be at Elevation 785 feet MSL, and the crest of the dam at Elevation 796. The principal spillway will be a morning glory with a crest at Elevation 785 with a 48-inch conduit. There will also be a 200-foot wide emergency spillway at Elevation 790 in the right (south) abutment. A separate, low-flow gated outlet with a 24-inch conduit is planned at Elevation 712, near the flood plain level. The dam is expected to be a zoned embankment with a clay core and random fill shells. Figures 1 through 4 are adapted from the application drawings submitted for the water rights application for the project and show more details of the project.

1.2 Authorization and Scope

This report presents the findings of a geotechnical investigation made for the Wheeler Branch Reservoir Dam (Main Dam), the Diversion Dam, and the Intake Pump Station. The investigation was authorized by the Engineering Services Agreement dated February 14, 2000, between the Somervell County Water District and Freese and Nichols, Inc. (FNI). This investigation was made to provide supporting information for the water rights application. Additional investigations and analyses will be needed for final design.

This investigation included drilling four core borings at the Main Dam site, installing an observation well in one of those borings, drilling one core boring at the Diversion Dam site, and completing packer infiltration tests in the borings for the Main Dam. Available literature was reviewed, including geologic maps, the Somervell County Soil Survey Report, and the geotechnical investigation reports and plans for the nearby Squaw Creek Dam. A brief reconnaissance for

construction materials was made in part of the reservoir area. Laboratory testing consisted of classification tests on three samples of potential borrow material.

The data obtained in the field and laboratory investigations are presented in this report with a discussion relating the observed geotechnical conditions to preliminary design issues.

1.3 Project Team

Advanced Drilling Technologies drilled the borings. Trinity Engineering Testing Company (TETCO) provided laboratory testing. WF Gunn Surveying and Aerial Mapping Co. surveyed the boring locations and elevations.

Mr. James Christie, C.P.G., supervised the drilling of the borings and logged the cores. Mr. Charles N. Easton, P.E. directed the investigation and prepared this report.

2.0 FIELD AND LABORATORY INVESTIGATIONS

2.1 Field Investigation

Four borings numbered D-1 through D-4 were drilled along the proposed Main Dam centerline during the periods September 19-21 and October 9-12, 2000. The boring locations are shown on Figure 3. The borings were drilled using a truck-mounted CME 75 rotary rig and NQ wireline coring equipment. Before coring began, hollow-stem augers were generally advanced to a depth of about five feet to stabilize the loose materials at the top of the hole and serve as a surface casing. Fresh water was used to cool the coring bits and remove the cuttings.

In Boring D-3, no core was recovered below a depth of 47 feet. After the boring was terminated at a depth of 63 feet and the core barrel was withdrawn, the coring bit was found to be damaged. The driller concluded that a piece of metal had fallen into the boring and damaged the bit.

Infiltration tests were run after drilling was completed in all four borings at the Main Dam. The tests were run by setting a single packer in the boring at a depth of 12 to 15 feet and testing the full depth of the borehole below the packer. The boring was filled with water, a pressure of 15 psi was applied at the top of the riser (one to three feet above the ground surface) using the drill rig pump and a bypass valve, and the volume of water accepted in 10 or 15 minutes was measured using a water meter. Only Boring D-2 accepted a measurable amount of water, one gallon in ten minutes. A second test was run in Boring D-2 with the packer set at a depth of 22 feet, and no water was accepted. The packer test results are summarized in Table 1.

Meaningful water level observations could not be made during drilling because wet rotary methods were used. Little water was lost into the formations during drilling. Borings D-1 and D-4 were grouted upon completion. Boring D-3 was left open for three weeks after drilling. At the end of that period, water could be detected in the boring, but the depth could not be determined because the boring was partially blocked by a rock fragment. An open-riser observation well was installed in Boring D-2 with a screen from 30 to 70 feet and filter pack from 12 feet to 70 feet. The water level in the well was measured 4.9 feet below the ground surface 33 days after completion.

Boring B-1 was drilled on the left abutment about 300 feet downstream from the proposed Diversion Dam location on January 30, 2001. The boring location is shown on Figure 4. Limestone was exposed at the ground surface. A hollow-stem auger was used to a depth of three feet, and NQ wireline coring to the bottom of the boring at 50 feet. The boring was grouted upon completion.

Mr. James Christie logged the bedrock exposure in the slope of the left abutment of the Diversion Dam site. His description is included in Appendix C-1.

All the boring logs and a copy of the State Well Report for the observation well are presented in Appendix C-1. Photographs of the cores are presented in Appendix C-2.

A limited reconnaissance was made on October 24, 2000. Bulk samples were obtained of sandy clay from the stream bank at the dam site and highly plastic clay from a hillside adjacent to the reservoir area. The locations from which the samples were obtained are shown on Figure 2.

2.2 Laboratory Investigation

Laboratory tests were run by TETCO on the two bulk samples obtained from the reservoir area and a sample of proposed off-site borrow material submitted by Mr. Jack Hoggett. The results are presented in Table 2. The core samples have been retained, and additional classification tests on selected samples are planned for the design studies.

3.0 GEOLOGIC AND SUBSURFACE CONDITIONS

3.1 Site Description

Wheeler Branch is an intermittent stream with a channel roughly 20 feet wide and a gradient of about 95 feet per mile. Its valley, like those of similar nearby streams, is steeply incised into a plain that lies at about Elevation 820. The slopes of the dam site and reservoir exhibit a soil cover from a few inches to a few feet thick over limestone and shale and support thin grass and scattered to dense cedars. The slopes are mildly stepped, indicating alternating layers of softer shale or clayey limestone and harder limestone. The creek bed at the dam site is limestone. The alluvium appears to be about three to five feet thick and includes various mixtures of clay, sand, gravel, and cobble-to boulder-sized rock fragments.

At the Diversion Dam site, the Paluxy River also flows on a limestone bed. The right abutment is covered with soil, grass and trees. The left abutment is a steep outcrop of limestone and a one-foot thick receding shale layer. The limestone is nodular, thin-bedded, and variably clayey. Immediately downstream from the Diversion Dam site is Big Rocks Park, where large, irregularly shaped remnants of limestone have been left by the River's erosion.

3.2 Geology

The Dallas Sheet of the Geologic Atlas of Texas indicates that the Glen Rose Formation is the only bedrock formation exposed in the vicinity of the reservoir site and the town of Glen Rose. Some unconsolidated Quaternary Terrace alluvium is mapped along the flood plain of the Paluxy River. The Glen Rose Formation is described as follows: "Limestone, alternating with units composed of variable amounts of clay, marl, and sand. Limestone, distinctly bedded, in part with variable amounts of clay, silt, and sand, soft to hard, various shades of brownish yellow and gray. Gradational to Paluxy Formation above and Twin Mountains Formation below, bench-forming beds included in the Glen Rose Formation. Thickness 40 to 200 feet, thins northward". The Glen Rose, Paluxy, and Twin Mountains Formations are part of the Lower Cretaceous Series.

The ground surface at the Main Dam site ranges from about Elevation 705 to Elevation 800 feet MSL. The riverbed at the Diversion Dam site is about Elevation 590. We believe the rocks cored at both sites are all part of the Glen Rose Formation. Correlation of some distinctive shale beds encountered in the borings at the Main Dam site indicates the strike direction is nearly parallel to the dam axis. Observation of outcrops along Wheeler Branch and in the reservoir area indicates the dip is probably southeastward at about 40 feet per mile.

3.3 Subsurface Conditions

At the Main Dam site, the soil cover was about five feet at Boring D-2 (in the flood plain), two feet at Boring D-4, and negligible at the other two borings. Borings D-1 and D-4, near the ends of the dam, were drilled to depths of about 130 feet, and Boring D-2, in the valley, was drilled to 70 feet. The rock formations throughout the depths drilled can be generally described as alternating layers of limestone and shale. The limestone predominates, and the shale beds seem to thin downward. The thickest shale layer is about 16 to 18 feet thick and is found above about Elevation 785. It contains several thin limestone interbeds. Some shale beds are less than one foot thick. The limestones are generally argillaceous (clayey), and the shales are generally calcareous; many beds could be visually described as either calcareous shale or argillaceous limestone. The bedding ranges from thin to thick. The hardness of the limestone is variable.

A distinctly different layer of green clayey shale or clay was encountered at about Elevation 670. It appeared to be highly plastic and slightly calcareous, and soft enough to be dented by finger pressure. It was about 3.5 feet thick at Boring D-2. Borings D-1 and D-4 ended in this layer.

The observed depth of weathering ranged from 7.5 feet at D-3 to 17.6 feet at D-4. At the Diversion Dam site, Boring B-1 encountered nodular shaley limestone with several thin shale interbeds below a depth of 27 feet. The material from 13 to 23 feet was a borderline argillaceous limestone or calcareous shale. Virtually all the rock was thin bedded; much of it was intact in the core barrel, but parted along sandy seams when handled. Weathering was observed to about five feet.

3.4 Groundwater

As previously discussed, water level information was obtained only in Boring D-2, where the observation well indicated water at the contact between the alluvium and the bedrock. The packer tests generally indicated the permeability of the rock below the weathered zone to be low.

4.0 ANALYSIS AND DISCUSSION

Additional borings, field tests, laboratory tests, and analyses will be required in the preliminary and final design phases to finalize selection of the dam sections and select design criteria. The present investigation provides general information regarding the geologic and geotechnical site conditions that can be used for a feasibility level assessment of the design issues.

4.1 Main Dam

4.1.1 Foundation

The clayey limestone and calcareous shale bedrocks seen at the site can be expected to have sufficient strength and low compressibility to support an embankment of the proposed 90-foot height. The bedrock also appears to have a low permeability below the weathered surface zone. The primary issues will be the depth to which the surface soil and highly weathered rock must be stripped to avoid stability problems associated with a weak zone at the foundation/embankment contact and the depth of a cutoff trench through the permeable weathered bedrock.

It appears that minimal stripping of approximately one foot or less to prepare the foundation for the general embankment will be sufficient in some areas where limestone exists under a thin soil cover. Areas where weathering of the shale has developed a highly plastic soil several feet thick may require several feet of excavation. Fairly detailed delineation of such areas during the final investigation will be needed. Other areas will be intermediate. Differences in the soil tend to correlate with the flat-lying bedrock strata, so areas requiring similar treatment will comprise bands running along the contours of the hillsides. The alluvium along the stream is relatively permeable and compressible; about five feet of excavation will be required to remove it.

The layer of very stiff clay or soft shale encountered at about Elevation 670 represents a weak zone that may affect the stability of the embankment. Strength testing and stability analyses will be necessary to evaluate it. It may prove not to be a limiting factor due to the relatively strong overlying rock layers. Embankment material properties and maintenance issues will probably control the selection of embankment slopes.

If adequate removal of loose and weathered surface materials is done to prepare the foundation, settlement related to compression of the foundation will be small in comparison to compression of the embankment itself. Because any settlement of the conduits will be highly differential relative to the portions supported on competent rock, It will be important to locate the

conduits where their full length can be founded on sound foundation material, not on fill.

4.1.2 Construction Materials

An efficient homogeneous embankment requires a material with both moderately low permeability and moderate to high strength, such as low plastic sandy clay. Where such material is not readily available, zoned embankments are selected to utilize relatively impervious but weak materials for the internal core and more abundant and stronger materials in the outer shells. A low to medium plastic clay for the impervious core and clayey sand, sandy clay, or durable rockfill would be desirable for zoned embankment construction.

The earth materials available in the reservoir and immediate surrounding area consist primarily of limestone and shale bedrock and thin soils weathered from these rocks. Limestone generally weathers to highly plastic sandy clay with stones. In some cases such soil can be suitable embankment material, but the soils above limestone seen at the site so far are very thin. Shale weathers to plastic clay. Bulk sample HS-3 was obtained from a band of clay soil just above the reservoir water line. It exhibited a liquid limit of 75 and plasticity index of 54. Such highly plastic clay can be expected to have relatively low saturated strength, requiring relatively flat embankment slopes. It would also be difficult to process and compact properly. Although such material could be used for an impervious core, clay with lower plasticity would be preferable.

Desirable material within the reservoir area appears limited to a few feet of variable alluvium in the flood plains along the creek. The alluvium includes clay, sand, gravel and stones. This material will probably be suitable for the shells.

The use of shale in embankments generally requires breaking it down and blending in water to produce a clay soil. The process is time consuming and is generally to be avoided in this area when possible.

Limestone could be quarried and broken down to manageable sized particles by blasting and crushing, or in some cases by ripping. Rockfill tends to be permeable and contains sufficient voids to hold considerable additional water that may infiltrate after placement. Limestone with a high clay content may soften with time, becoming compressible and losing strength. Limestone with shale layers that cannot be economically separated can produce rockfill with similar problems. Some of the limestone layers encountered in the cores appear to be sufficiently low in clay and high in strength to produce good rockfill. Such layers do not appear to occur in the ridges; they will more likely be

found in the hillsides, where a quarry would require considerable removal of undesirable overburden. Further study may locate a suitable area for quarrying.

Squaw Creek Dam was built in the mid-1970s about two miles north of the project site and at a similar elevation. The zoned embankment included a narrow clay core, random fill zones, and a rockfill zone. We understand that the clay core and random fill materials came from the alluvial soils in borrow areas in the reservoir. The rock came from necessary excavations for the spillway. Squaw Creek is a larger creek than Wheeler Branch, with wider, deeper alluvial deposits in its flood plains. Similar deposits in the Squaw Creek and Brazos River flood plains may provide adequate quantities of suitable embankment material for the Main Dam.

A mass concrete or roller-compacted concrete dam can be considered. The foundation is probably suitable for a concrete gravity structure. The economic feasibility will depend on the availability of suitable aggregate from a nearby source. We understand that concrete aggregate is not produced locally at the present time.

4.1.3 Seepage Control

A clay core and clay-filled cutoff trench can provide the primary barriers to seepage through the dam and foundation. General practice in similar soils is to extend the cutoff trench through the weathered zone of the bedrock. This depth ranges between about 8 and 18 feet at the borings, and greater extremes probably exist.

The need for a grout curtain in the unweathered bedrock beneath the cutoff trench is uncertain and will require additional evaluation. The packer test results indicate that in many areas the bedrock will be too tight to accept grout. A single line of relatively widely-spaced grout holes could be used to identify the areas where sufficient jointing exists to require grouting. Joints will be exposed in the core trench and will probably require grouting.

A downstream drain is needed to collect and dispose of seepage through the dam and foundation in order to keep the line of saturation low in the downstream shell and prevent excessive uplift pressures at the toe. Squaw Creek Dam included a graded granular filter zone between the clay core and the downstream shell as well as a granular drainage blanket between the foundation and the downstream shell. Sand is produced locally from alluvial deposits in the Brazos River valley. Relief wells or a drainage trench in the foundation can be considered to control uplift, but will probably not be necessary.

4.1.4 Slope Protection

Soil cement or limestone riprap can be considered for wave protection on the upstream slope. The costs of local stone and aggregate are expected to determine the most cost-effective approach. The downstream slopes of earth embankments are commonly protected with grass. Rockfill generally needs no downstream protection.

4.2 Diversion Dam

A concrete gravity structure is proposed for the Diversion Dam. The foundation is expected to consist of clayey limestone suitable to support such a structure. Some stripping of alluvium will be required in the right abutment, and shallow excavation to remove loose and weathered rock will probably be necessary across most of the foundation.

The limestone is thinly bedded and parts easily along bedding planes. It must be considered erodible. A concrete stilling basin is planned to protect the foundation. Some erosion of the abutments can be anticipated and provided for by extending the dam into the abutments or protecting the rock with concrete walls or paving.

A shallow concrete-filled cutoff trench is planned for seepage control. A subdrain may be needed between the dam and the stilling basin to reduce uplift pressures on the basin and the downstream part of the dam.

Rock anchors can probably be used to good advantage to secure the dam and the stilling basin to the foundation. Anchors can be designed to resist hydrostatic uplift, sliding forces, and overturning moments, thereby reducing the mass of concrete needed as well as the extent of seepage cutoffs and drains. Both passive and post-tensioned bar-type anchors can be considered.

4.3 Intake Pumping Station

The Intake Pumping Station structure is expected to be a reinforced concrete box extending to an elevation lower than the riverbed. We expect that the foundation materials will be limestone similar to that cored at the dam site and will be suitable to support the structure on a mat foundation, which will be needed to resist hydrostatic uplift. Because the site is subject to flooding and will be operated during periods of at least moderately high river stage, the structure must be designed to resist uplift and lateral earth pressures associated with fully saturated surrounding soils. Passive rock anchors can be used to increase uplift resistance if necessary. Equivalent fluid pressures of about 90 pounds per cubic foot will likely be appropriate for design of walls that will be backfilled with soil. If investigations indicate that the lower part of the excavation can be cut vertically, casting the walls

directly against the rock or backfilling a narrow zone between the rock and the walls with lean concrete can be considered to increase uplift resistance and reduce lateral pressures.

The soil and rock materials in the upper part of the excavation will probably require sloping or temporary support.

Specific investigation at the pump station location will be needed for design and construction planning.

5.0 LIMITATIONS

This report was prepared specifically for use by Freese and Nichols, Inc., Somervell County Water District, and the Texas Natural Resources Conservation Commission in the preparation and review of the permit application for the project. Information and recommendations presented in this report should not be used for other projects or purposes.

This investigation is preliminary in scope. Additional geologic and geotechnical investigations will be needed for design.

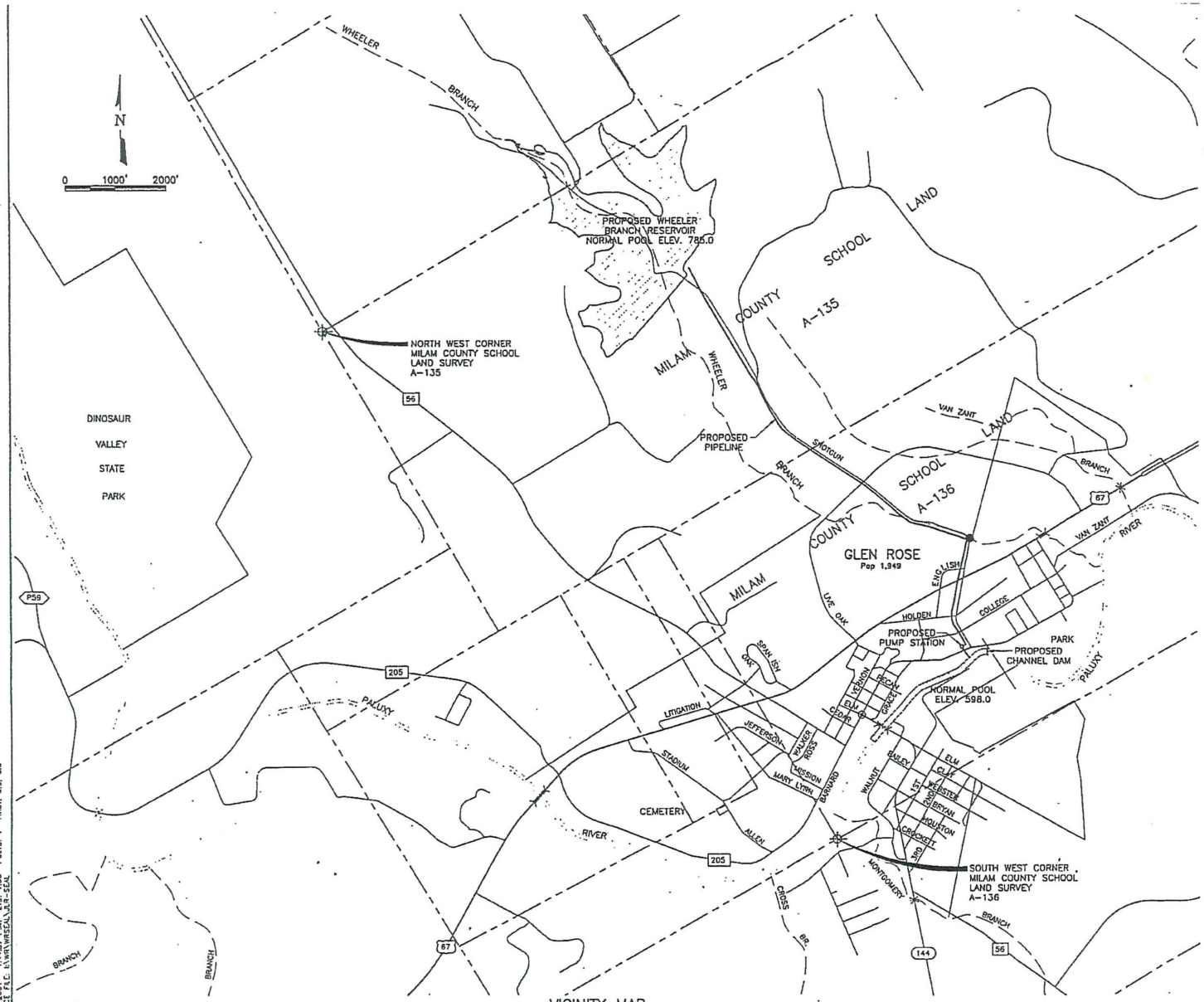
The discussion and conclusions presented in this report are based on our analysis of the data collected for this project. Additive conclusions or recommendations made from these data by others are their responsibility.

PALUXY RIVER DIVERSION PROJECT
TABLE 1
PACKER INFILTRATION TESTS IN BEDROCK

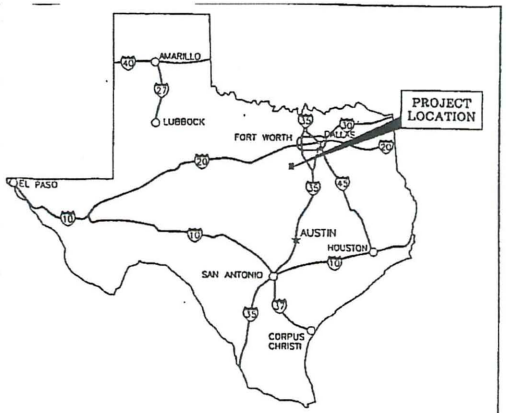
Boring	Depths					Head	Flow	
	Top of Rock	Packer	Bottom of Boring	Tested Interval	Water Table	Gage Pressure	Elapsed Time	Volume Accepted
	ft.	ft.	ft.	ft.	ft.	psi	minutes	gallons
D-1	0.0	13.8	130.0	13.8 - 130.0	Unknown	15	15	0.00
D-2	5.0	12.0	70.0	12.0 - 70.0	5.0	15	10	1.00
		22.0	70.0	22.0 - 70.0	5.0	15	10	0.00
D-3	0.0	12.0	63.0	12.0 - 63.0	Unknown	15	15	0.00
D-4	2.0	14.8	133.0	14.8 - 133.0	Unknown	15	15	0.00

PALUXY RIVER DIVERSION PROJECT
TABLE 2
LABORATORY TESTS ON BULK SAMPLES

Sample Number	Source	USC Classification	Water Content, %	Portion Passing #200 Sieve, %	Liquid Limit	Plastic Limit	Plasticity Index
HD-1	Hoggett Borrow	CL	18	95	47	17	30
HS-3	Hillside	CH	19.0	87.0	75	21	54
WB-1	Streambank	CL	12	52	35	16	19



VICINITY MAP



LOCATION MAP
NTS

INDEX OF DRAWINGS

LOCATION TABLE

REFERENCE POINT	LONGITUDE	LATITUDE	BEARING	DISTANCE
*DIVERSION NO. 1	97°44'53" WEST	32°14'18" NORTH	N35°13'E	4,517 Ft.
+DAM STA. 10+00	97°44'48" WEST	32°14'20" NORTH	N38°55'E	4,810 Ft.
**DIVERSION NO. 3	97°46'05" WEST	32°15'27" NORTH	S83°15'W	6732 Ft.
**DAM STA. 0+00	97°46'11" WEST	32°15'19" NORTH	S86°26'E	6066 Ft.

*BEARING AND DISTANCE ARE REFERENCED FROM SOUTH WEST CORNER OF MILAM COUNTY SCHOOL LAND SURVEY, ABSTRACT NO. 136.

**BEARING AND DISTANCE ARE REFERENCED FROM NORTH WEST CORNER OF MILAM COUNTY SCHOOL LAND SURVEY, ABSTRACT NO. 135.

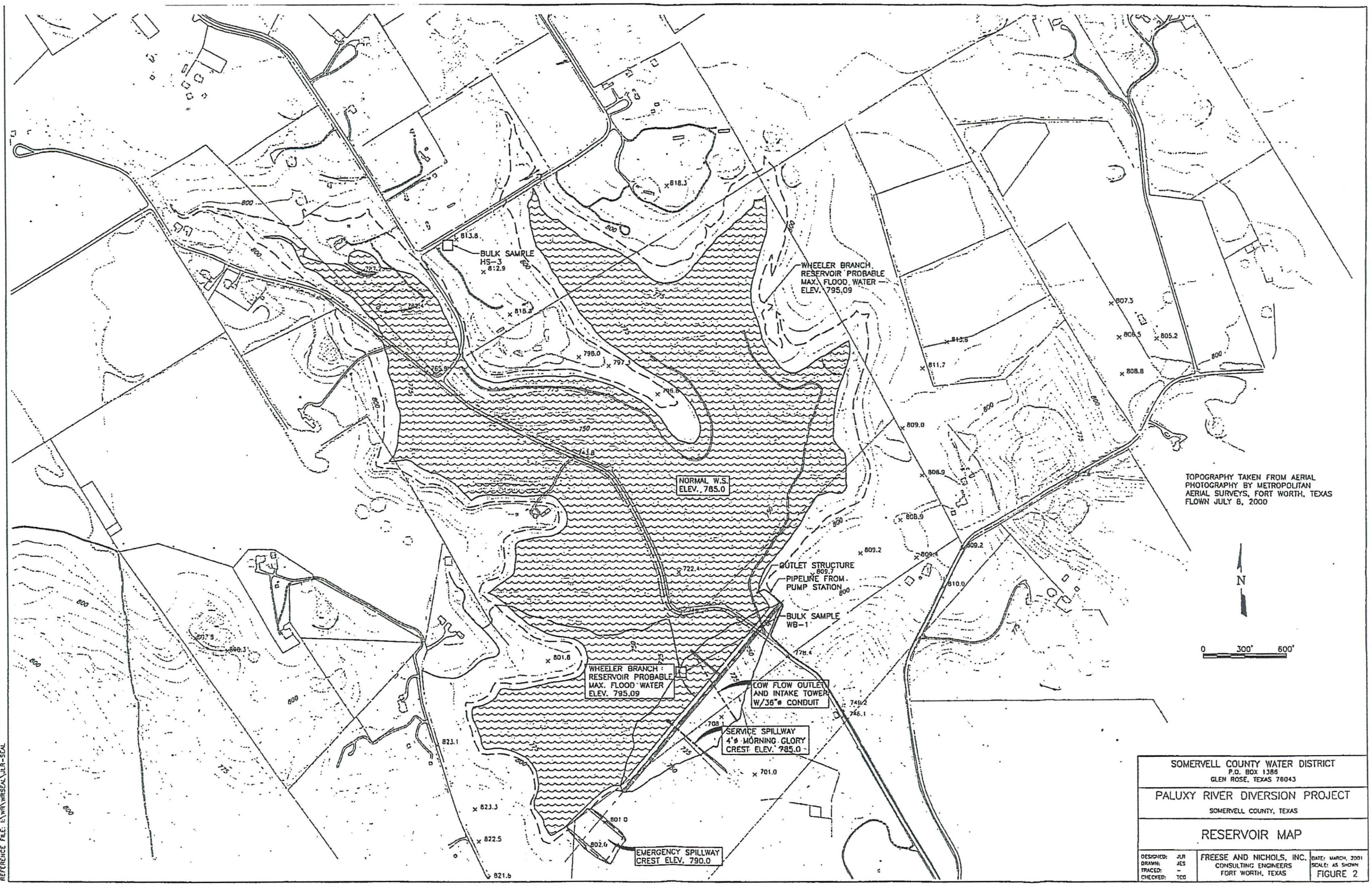
SOMERVELL COUNTY WATER DISTRICT
P.O. BOX 1386
GLEN ROSE, TEXAS 76043

PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

VICINITY AND LOCATION MAPS

DESIGNED: JLR DRAWN: JES TRACED: - CHECKED: TCC	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS	DATE: MARCH, 2001 SCALE: AS SHOWN	FIGURE 1

ACAD Rel 14.0 User: JES
[SDW00166]N:\PDRAWT\GEO-REPORT\VIC_MAP.DWG
MAR 20, 2001 11:43:37 P.M. LTS: 1.00 PSLTS: 1 TWIST: 0.0, 0.0
REFERENCE FILE: L:\MAPWORKS\A_SIZE.DGN


BULK SAMPLE
HS-3
WHEELER BRANCH
RESERVOIR PROBABLE
MAX. FLOOD WATER
ELEV. 795.09
NORMAL W.S.
ELEV. 785.0
OUTLET STRUCTURE
PIPELINE FROM
PUMP STATION
BULK SAMPLE
WB-1
WHEELER BRANCH
RESERVOIR PROBABLE
MAX. FLOOD WATER
ELEV. 795.09
LOW FLOW OUTLET
AND INTAKE TOWER
W/36"ø CONDUIT
SERVICE SPILLWAY
4'ø MORNING GLORY
CREST ELEV. 785.0
EMERGENCY SPILLWAY
CREST ELEV. 790.0
TOPOGRAPHY TAKEN FROM AERIAL
PHOTOGRAPHY BY METROPOLITAN
AERIAL SURVEYS, FORT WORTH, TEXAS
FLOWN JULY 8, 2000
N
0 300' 600'
SOMERVELL COUNTY WATER DISTRICT
P.O. BOX 1386
GLEN ROSE, TEXAS 76043
PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS
RESERVOIR MAP
DESIGNED: JLR
DRAWN: JES
TRACED: –
CHECKED: TCO
FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
FORT WORTH, TEXAS
DATE: MARCH, 2001
SCALE: AS SHOWN
FIGURE 2

ACAD Rel 14.0 User: JES
[SOMO0166]N:\PERMIT\GEO-REPORT\RES-MAP.DWG
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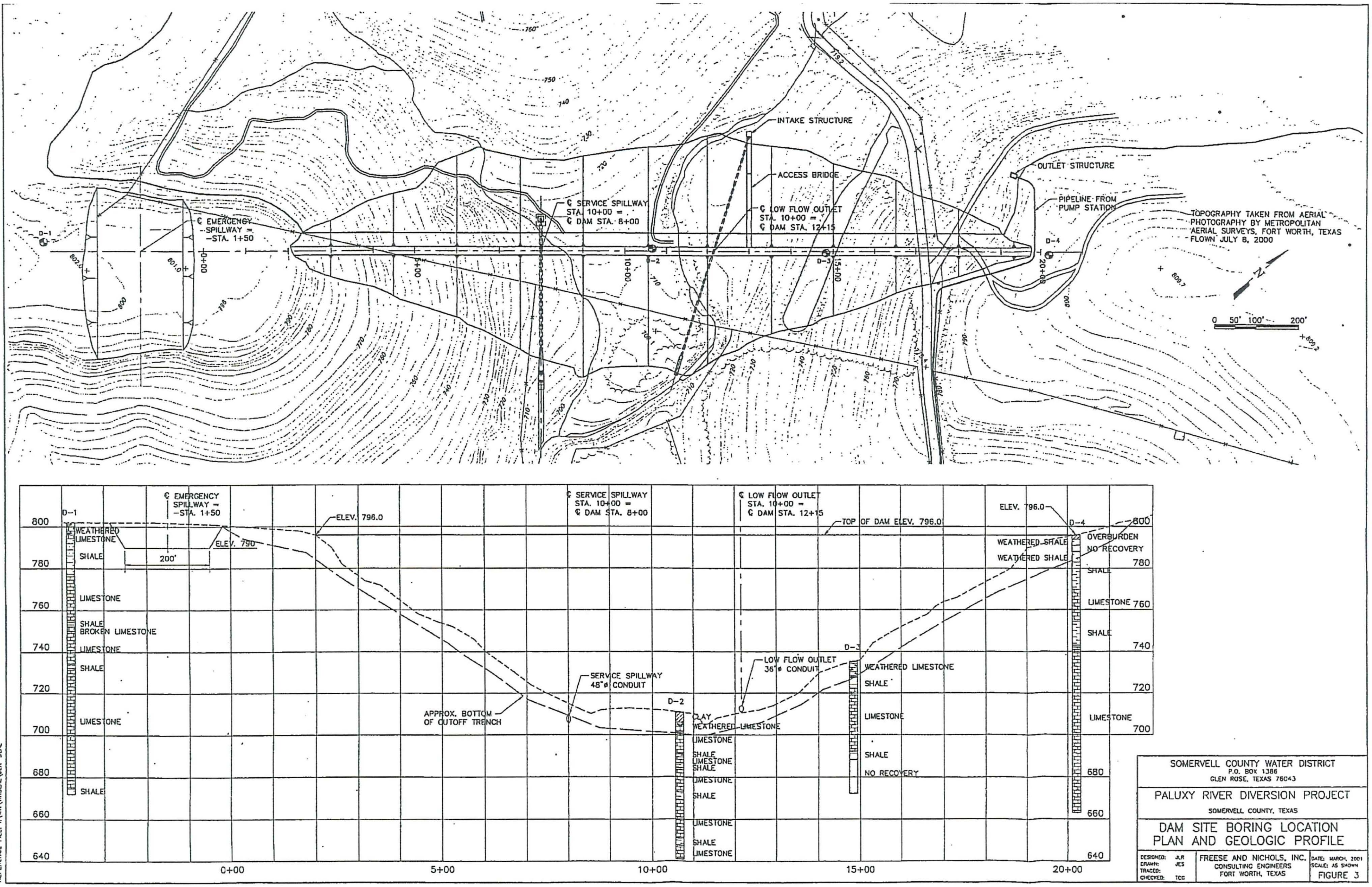
REFERENCE FILE: I:\WR\WRSEAL\JLR-SEAL


INTAKE STRUCTURE
ACCESS BRIDGE
OUTLET STRUCTURE
PIPELINE FROM PUMP STATION
TOPOGRAPHY TAKEN FROM AERIAL PHOTOGRAPHY BY METROPOLITAN AERIAL SURVEYS, FORT WORTH, TEXAS FLOWN JULY 8, 2000
℄ EMERGENCY SPILLWAY = -STA. 1+50
℄ SERVICE SPILLWAY STA. 10+00 = ℄ DAM STA. 8+00
℄ LOW FLOW OUTLET STA. 10+00 = ℄ DAM STA. 12+15
D-1
D-2
D-3
D-4
0 50' 100' 200'
ELEV. 796.0
ELEV. 790
200'
TOP OF DAM ELEV. 796.0
WEATHERED LIMESTONE
SHALE
LIMESTONE
BROKEN LIMESTONE
SERVICE SPILLWAY 48"⌀ CONDUIT
LOW FLOW OUTLET 36"⌀ CONDUIT
APPROX. BOTTOM OF CUTOFF TRENCH
CLAY
WEATHERED LIMESTONE
WEATHERED SHALE
OVERBURDEN
NO RECOVERY
0+00
5+00
10+00
15+00
20+00

SOMERVELL COUNTY WATER DISTRICT
P.O. BOX 1386
GLEN ROSE, TEXAS 76043

PALUXY RIVER DIVERSION PROJECT
SOMERVELL COUNTY, TEXAS

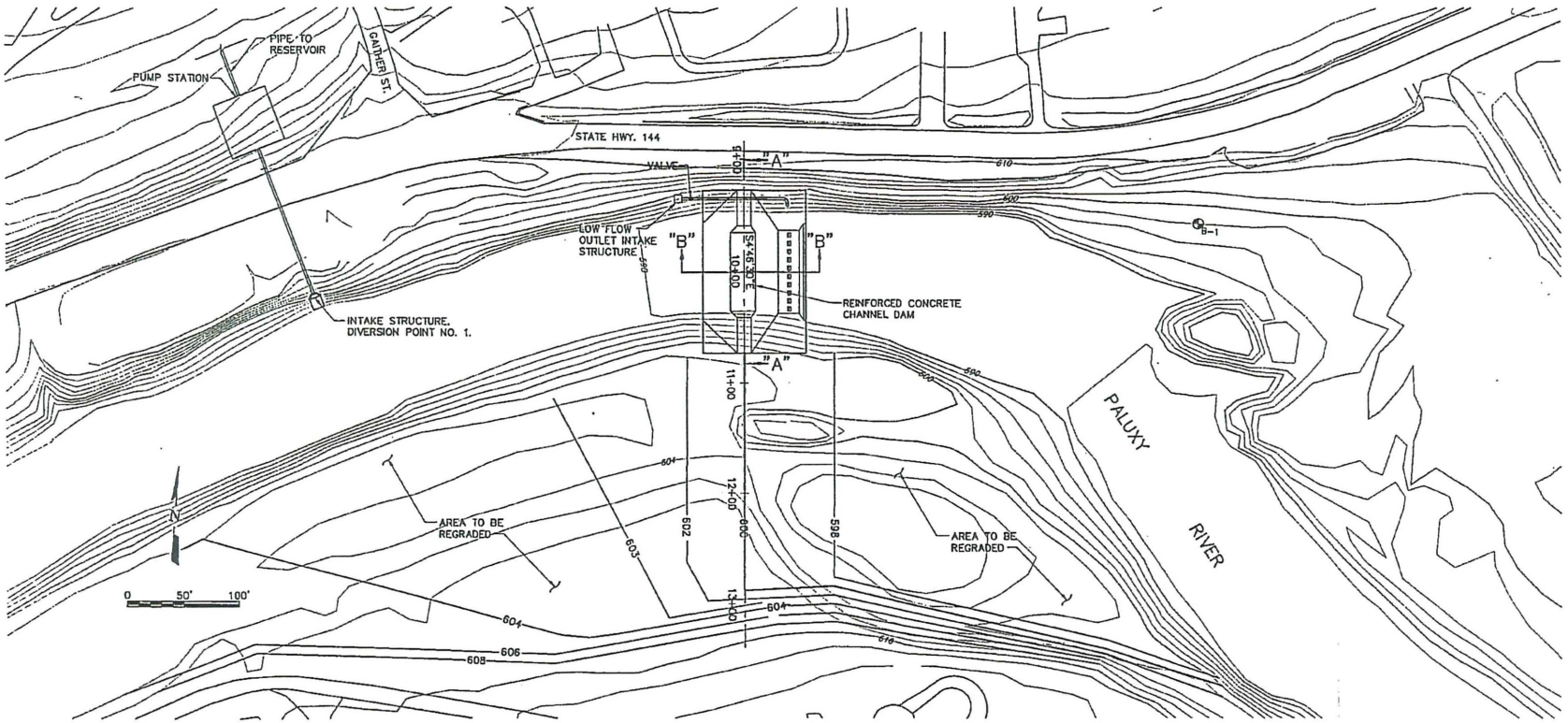
DAM SITE BORING LOCATION PLAN AND GEOLOGIC PROFILE

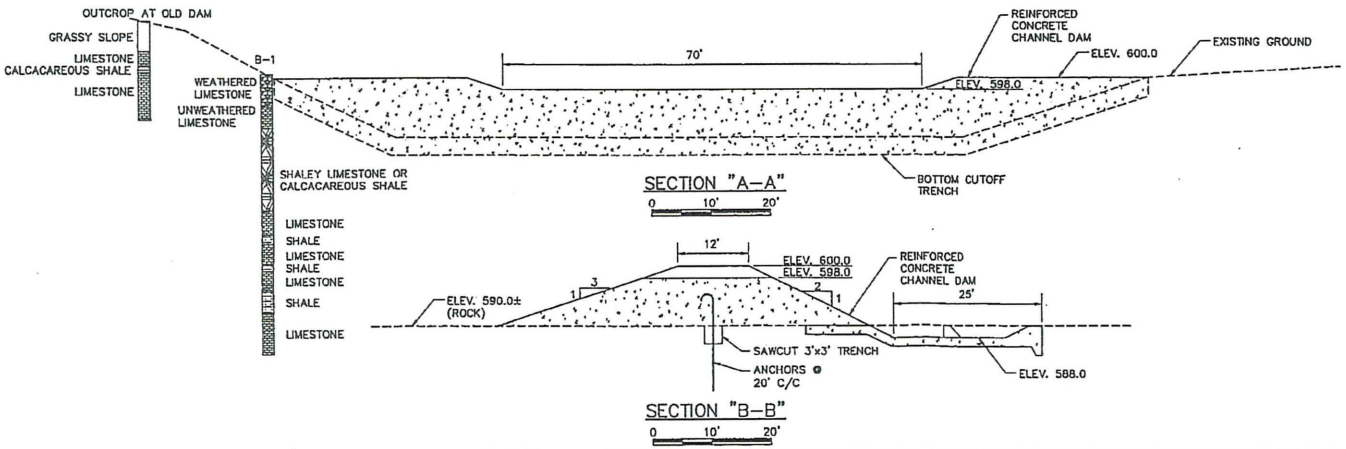
DESIGNED: JLR
DRAWN: JES
TRACED:
CHECKED: TCG

FREESE AND NICHOLS, INC.
CONSULTING ENGINEERS
FORT WORTH, TEXAS

DATE: MARCH, 2001
SCALE: AS SHOWN

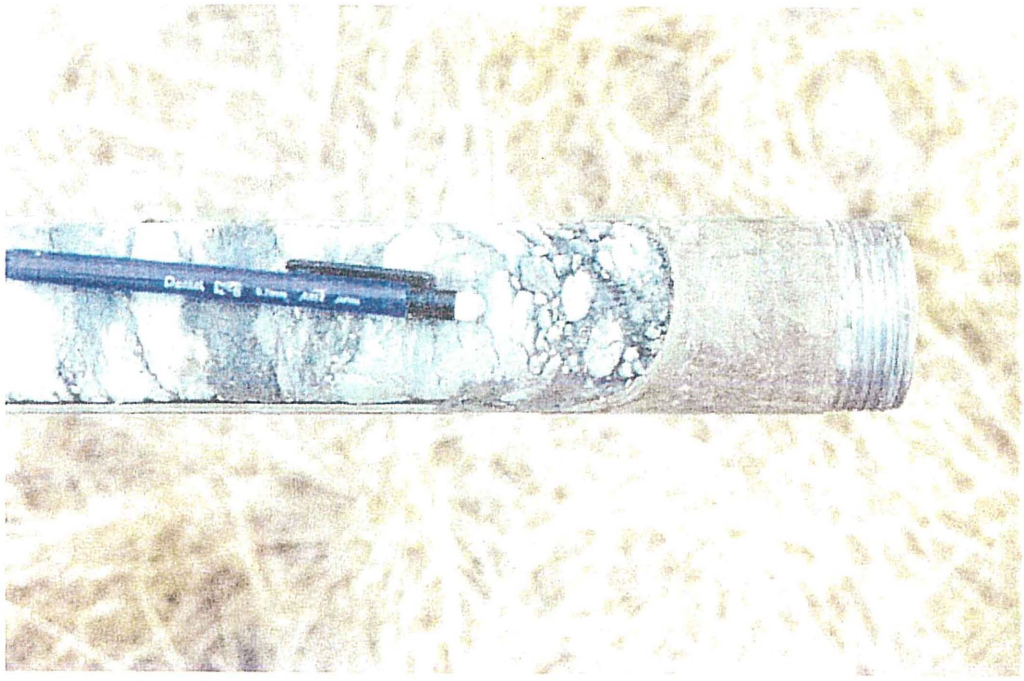
FIGURE 3





SOMERVELL COUNTY WATER DISTRICT P.O. BOX 1388 GLEN ROSE, TEXAS 76043	
PALUXY RIVER DIVERSION PROJECT SOMERVELL COUNTY, TEXAS	
DIVERSION DAM BORING LOCATION PLAN AND GEOLOGIC LOGS	
DESIGNED: JLR DRAWN: JES TRACED: – CHECKED: TCG	FREESE AND NICHOLS, INC. CONSULTING ENGINEERS FORT WORTH, TEXAS
DATE: MARCH, 2001 SCALE: AS SHOWN	FIGURE 4

Observation Well at Boring D-2



Brecciated shale present at depth of 128 ft in Boring D-4

Exposed Bedrock in North Bank of Paluxy River Immediately Downstream from Channel Dam Site

Joint in Exposed Bedrock near Channel Dam Site

Paluxy River Diversion Project

Figure 6

FREESE • NICHOLS

APPENDIX C-1

BORING LOGS AND STATE WELL REPORT

BORING LOG
LEGEND AND NOMENCLATURE

Items shown on boring logs refer to the following:

1. Depth - Depth below ground surface

2. Sample - Types designated by letter:

   A - Disturbed sample, obtained from auger cuttings or wash water.

   S - Split barrel sample, obtained by driving a 2-inch split-barrel sampler unless otherwise noted.

   U - Undisturbed sample, obtained using a thin-walled tube, 3-inch-diameter, or as noted, and open sampling head.

   C - Core sample, using an NQ-sized (2-inch ID) core barrel.

   Recovery - Core recovery is the length recovered divided by the total length cored, expressed as a percentage.

   Resistance - For split-barrel sampling, resistance is designated as follows:

   3 - Numbers indicate blows per 6 inches of penetration of split spoon sampler driven by a 140-pound hammer falling 30 inches. The Standard Penetration Resistance is the number of blows for the last 12 inches of penetration of the split spoon sampler.

   50/4" - Number of blows to drive sampler distance shown.

   pp(TSF) – Pocket penetrometer reading in tons per square foot.

   RQD – Rock Quality Designation, calculated as the total length of unfractured pieces more than 4 inches long divided by the total length cored, expressed as a percentage.

3. Description - Description of material according to the Unified Soil Classification: word description giving soil constituents, consistency or density, and other appropriate classification characteristics. A solid line indicates an approximate location of stratigraphic change. Descriptions may include pertinent observations including type of boring, water seepage, fluid loss, boring termination depth, etc.

4. Legend -

AD -	After drilling	ND	- Not detectable due to drilling method
ATD -	At time of drilling	NR	- Not recorded
HSA -	Hollow stem auger	RWB	- Rotary wash boring
DWL -	Drill water loss	≂1	- Water entry depth at time of drilling
DWR -	Drill water return	⧗2	- Water level in boring at time shown after drilling
NA -	Not Applicable		

5. Laboratory index properties are listed in the right-hand columns. See Appendix C for all test results.

6. Remarks – may include the results of field tests or other special observations.

7. Limitations

The lines between materials shown on the boring logs represent approximate boundaries between material types. The changes may be gradual. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water levels may occur with time. The boring logs in this report are subject to the limitations, explanations and conclusions of this report.

LOG OF BORING NO. B-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project No.: SOM00166
Project Location: GLEN ROSE, TEXAS
Task No.:
Logged By: JLC
Date: 1/30/01
Drilled By: ADT
Rig: CME75
Method: NQ Core

Location: 2201640 East 6770572 North
Surface El.: 600.7' MSL
Total Depth: 50 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION	UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
	A1				Limestone, nodular, shaly, stained to 5.3', thin-bedded, increase in shale content from 9' to 13', medium hard, gray.							600
	C1	89	81									
5												595
	C2	98	62									
10												590
	C3	98	92									
15												585
20												580
					577.7							
	C4	98	72		Limestone, nodular, shaly, with shale seams and layers. 23.0							
25												

Water Level Surface on

Remarks: Boring grouted upon completion.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. B-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT
Rig: CME75

Project No.: SOM00166
Task No.:
Date: 1/30/01
Method: NQ Core

Location: 2201640 East 6770572 North
Surface El.: 600.7' MSL
Total Depth: 50 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION	UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
					@ 27.4' to 28.8' - shale seam							575
30												570
					@32.1 to 33.0' - shale seam							
	C5	100	78									
35					@35.0 to 36.0' - vertical fractures, possibly mechanical breakage.							565
					564.3							
					Shale 36.4							
					560.7							
40					Limestone, nodular, shaly. 40.0							560
	C6	80	46									
45												555
					Total Depth 50.0'							
50												

Water Level Surface on

Remarks: Boring grouted upon completion.

FREESE AND NICHOLS, INC.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. D-1

Sheet 1 of 6

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT
Rig: CME75

Project No.: SOM00166
Task No.
Date: 10/10/00
Method: NQ Core

Location: 2193826 East 6776264 North
Surface El.: 801.2' MSL
Total Depth: 130 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION		UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
0	A1				Weathered limestone with shale interbeds. Auger to 10.0'. Auger penetration rate suggests possible weathered shale commencing at 7.5'.								800
5	A2					793.7							795
					Shale (Glen Rose Formation), calcareous, medium soft, unweathered, light gray, Borderline argillaceous limestone. Nodular limestone seams and interbeds at the following depths: 10.0 to 10.3' 11.6 to 12.3' 15.4 to 15.7' 18.3 to 19.1' Dark gray, soft, laminated shale seams at the following depths: 13.7 to 14.1' 17.3 to 17.4'	7.5							
10	C1	100	91										790
15													785
	C2	89	88										
20													780
						778.2							
25	C3	85	82		No recovery from 23.0 to 24.5'.	23.0							

Water Level Surface on

Remarks: Boring gouted upon completion.

FREESE AND NICHOLS, INC.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. D-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT
Rig: CME75

Project No.: SOM00166
Task No.:
Date: 10/10/00
Method: NQ Core

Location: 2193826 East 6776264 North
Surface El.: 801.2' MSL
Total Depth: 130 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION	UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
					Limestone, nodular, argillaceous, medium hard, thin to thick bedded, light gray. Soft, dark gray, shale seams and interbeds at the following depths: 25.5 to 25.9' 35.4 to 35.9' 36.8 to 37.6'							775
30												770
	C4	100	85									
35												765
40					@ 41.0 to 42.5' - limestone was broken mechanically.							760
	C5	81	56									
45												755
					753.7							
					Alternating shale and limestone interbeds. 47.5 Shale seams and beds at the following depths: 47.5 to 49.9' - unbroken 50.8 to 51.3' - broken 51.6 to 52.0' - broken							
50												

Water Level Surface on

Remarks: Boring gouted upon completion.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. D-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT Rig: CME75

Project No.: SOM00166
Task No.:
Date: 10/10/00
Method: NQ Core

Location: 2193826 East 6776264 North
Surface El.: 801.2' MSL
Total Depth: 130 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION		UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
					52.2 to 52.8' - broken								750
						748.4							
	C6	100	100		Limestone, slightly argillaceous, medium hard, thick bedded, light gray.	52.8							
55													745
60													740
	C7	100	100										
65					@65.8 to 66.3' - mechanical fracture								735
					@ 68.0 to 69.7' - soft, calcareous, light gray shale.								
70													730
						728.2							
	C8	100	88		Limestone, nodular, argillaceous, medium hard, thick-bedded, light gray, with dark gray, medium soft, calcareous, shale interbeds.	73.0							
75													

Water Level Surface on

Remarks: Boring gouted upon completion.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. D-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT Rig: CME75

Project No.: SOM00166
Task No.:
Date: 10/10/00
Method: NQ Core

Location: 2193826 East 6776264 North
Surface El.: 801.2' MSL
Total Depth: 130 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION	UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
80												725
												720
	C9	100	100		@ 83.0' becomes slightly sandy.							
85												715
90					@90.0 to 90.5' - shale seam							710
					@92.0 to 92.5' - shale seam							
	C10	100	100		@93.0' - change from carbide bit to diamond bit.							
95					@93.8 to 94.4' - mottled limestone marker. borderline on calcareous shale @ the following depths:							705
					93.0 to 93.8'							
					94.4 to 97.0'							
					96.0 to 96.3'							
					99.4 to 100.0'							
100												

Water Level Surface on

Remarks: Boring gouted upon completion.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu

LOG OF BORING NO. D-1

Project Description: PALUXY RIVER DIVERSION PROJECT
Project Location: GLEN ROSE, TEXAS
Logged By: JLC
Drilled By: ADT Rig: CME75

Project No.: SOM00166
Task No.
Date: 10/10/00
Method: NQ Core

Location: 2193826 East 6776264 North
Surface El.: 801.2' MSL
Total Depth: 130 Feet

DEPTH, feet	SAMPLE TYPE	SAMPLE RECOVERY (%)	SAMPLE RESISTANCE pp (TSF) RQD	SYMBOL	MATERIAL DESCRIPTION	UNC. COMPRESSIVE STRENGTH (tsf)	WATER CONTENT, %	UNIT DRY WEIGHT, lb/cu ft.	% PASSING NO. 200 SIEVE	LIQUID LIMIT	PLASTIC LIMIT	ELEVATION
												700
	C11	100	96									
105					calcareous soft, slightly sandy shale @ the following depths: 104.8 to 105.4' 106.9 to 107.5' 108.6 to 108.9' 112.4 to 113.0'							695
110												690
	C12	100	88									
115												685
120												680
	C13	100	95									
125												

Water Level Surface on

Remarks: Boring gouted upon completion.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradu