Report on the Expansion of Meadow Park Dam and Lake for the City of Crossville

Interim Release
April 10, 2003

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Engineering ◆ Geotechnical ◆ QA/QC Testing

I. Title Page and Table of Contents

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Title	Section Number

II. Executive Summary

The City of Crossville has participated in several studies that have investigated and researched the water supply issue within Cumberland County, Tennessee in an effort to find, develop, and maintain adequate water volume and quality for the City's customers. In fact, the whole of Cumberland County has been somewhat focused on this issue since at least 1996 when a regional approach or concept was undertaken. Seven years later, the regional approach has not progressed to a point that a project has been moved to conception.

Cumberland County receives an average annual precipitation of 52 inches. The U. S. Geological Survey reports that the water withdrawal from Cumberland County is 7.60 million gallons per day including all ground water and surface water sources and uses. The average precipitation for the County produces an equivalent 225.5 million gallons per day of water. Therefore, approximately 3.37% of this water is used in Cumberland County with the remainder being runoff, evaporation, transpiration, and other natural cycles. This is higher than the Tennessee and Cumberland River Valleys as a whole. However, it is important to understand that based on average consumptive use and renewable water supply estimates from the U. S. Geologic Survey, the Tennessee and Cumberland River Valleys are the second least developed water resource in the country with a Consumptive Use of 0.3 Billion Gallons per day and a Renewable Supply of 41.2 Billion Gallons per day. This constitutes a use rate of only 0.728%; second in the United States only to Alaska.

In order to begin this study, a review of available information was begun as well as obtaining some new information at a minimal cost to the City of Crossville. Environmental & Civil Engineering Services obtained real data in regards to the Meadow Park Lake and Dam by performing on site inspection of both faces of the dam and obtaining cores of the surface concrete of the dam and subsequent analysis.

The tests, inspections, and analysis of the existing dam suggest that it is in need of repair to prevent further severe deterioration of the structure whether the dam is raised or not. The cost estimate to perform this remedial work is estimated to be approximately $1.14 million above feasibility costs.

The purpose of this report was to determine an estimated cost for the most economical height and method by which to raise the Meadow Park Dam to increase the storage volume of water available for treatment. At the current time this report is based solely on known structural factors and issues.

We have reviewed five available options to increase the height of the dam. The five options are:

- Do Nothing
- Backface Expansion
- Frontface Expansion
- Embankment Buttress
- Heightened Section

The Do Nothing Option is not a feasible option since the City has commitments to customers to supply them with water. The City will have to seek other possibilities to meet these obligations if they choose not to use Meadow Park for expansion.

The Backface Expansion option and the Frontface Expansion option both have difficult construction issues that translate into increased construction costs not to mention increased risk. This leads to a more favorable construction environment and cost to raise the dam by embankment buttress or heightened section. The costs to use either of these options is very similar and based on our estimates could lean toward a preference of one or the other based on permitting difficulty. The cost analysis reveals that the cheaper option up to 14.0 feet is the Heightened Section Alternative; however, above 14.0 feet a slight cost advantage could be seen in using an Embankment Buttress. However, the increase in disturbed stream area to construct the embankment buttress could offset any cost advantage as a result of increased permitting cost.

At the current time, there remains a lot of unknown factors that would affect the construction and permitting costs to undertake any of these options. However, it cannot be denied that the environmental costs to raise a dam and the property costs to raise a dam are much less than the costs to construct a new dam; disregarding the construction savings of having a portion of the dam complete.

This study indicates that due to the numerous fixed costs associated with the project, the higher the dam is raised up to the 20.4 foot analyzed by this report, the cheaper the dam is in terms of cost per acre-foot of water storage. The cost can be as low as $660 per acre-foot of additional water storage.

Therefore, we recommend that the City of Crossville pursue the construction and permitting of this project by taking the next step to complete the feasibility study and beginning the permit process based on using Alternative 4 or Alternative 5 to raise the dam from 9 to 14 feet above the current normal pool. In the next phase, hydraulics should be calculated, permit issues fully defined, geotechnical investigations undertaken, additional testing performed so that the costs can be refined and even preliminary designs begun so that property tracts to be acquired could be defined and appraised. The cost to pursue this project can range depending upon the method and timeframe at which the Owner chooses to progress. Following are the estimated costs for the work described above:

Item Description	Estimated Costs
Hydraulic Feasibility	$48,000
Geotechnical Investigations	$260,000
Endangered Species Determination	$14,000
Wetlands Determination	$7,500
Stream Assessments	$35,000
Other Permit Issues	$75,000
Additional Testing	$30,000
Property acquisition and appraisals	$35,000
Topographic mapping of dam site	$7500

III. Situation Definition

The City of Crossville has participated in several studies that have investigated and researched the water supply issue within Cumberland County, Tennessee in an effort to find, develop, and maintain adequate water volume and quality for the City's customers. In fact, the whole of Cumberland County has been somewhat focused on this issue since at least 1996 when a regional approach or concept was undertaken. Seven years later, the regional approach has not progressed to a point that a project has been moved to conception.

The City of Crossville is one of three municipalities within Cumberland County, TN. Data from the U. S. Census Bureau shows that Cumberland County, TN has a land area of 682 square miles with a population (2000) of 46,802 persons or 68.7 persons per square mile. The population change from 1990 to 2000 was 34.7% which is the intial indicator of a significant growth requiring additional water supply development.

Cumberland County was created in 1855 from portions of Bledsoe, Morgan, Rhea, Fentress, and Putnam Counties. The City of Crossville was organized as a municipality and chartered in 1901. Cumberland County is almost entirely located on the Cumberland Plateau in East Tennessee. The Tennessee divide runs through the county such that the eastern half of the county generally drains to the east to the Tennessee River while the western half drains generally to the west to the Caney Fork River and subsequently to the Cumberland River.

Cumberland County receives an average annual precipitation of 52 inches. The U. S. Geological Survey reports that the water withdrawal from Cumberland County is 7.60 million gallons per day including all ground water and surface water sources and uses. The average precipitation for the County produces an equivalent 225.5 million gallons per day of water. Therefore, approximately 3.37% of this water is used in Cumberland County with the remainder being runoff, evaporation, transpiration, and other natural cycles. This is higher than the Tennessee and Cumberland River Valleys as a whole. However, it is important to understand that based on average consumptive use and renewable water supply estimates from the U. S. Geologic Survey, the Tennessee and Cumberland River Valleys are the second least developed water resource in the country with a Consumptive Use of 0.3 Billion Gallons per day and a Renewable Supply of 41.2 Billion Gallons per day. This constitutes a use rate of only 0.728%; second in the United States only to Alaska.

Therefore, there is no shortage of water in Tennessee or Cumberland County; it is only that there is not enough water at the right time due to the ever increasing limitations placed on development of new water resources by regulatory agencies and environmental groups. As the statistic above shows, our water resources have barely been effected by the development of water supplies.

The City of Crossville currently owns and operates two water treatment facilities in order to provide potable water to its customers.

The first plant is Meadow Park Water Treatment Plant that was originally built in the late 1930's after completion of the Meadow Park Dam and Lake in 1938. This plant is located in the southern portion of Cumberland County. The plant has subsequently outlived its usefulness and been replaced by a modern facility in 2001 capable of producing 3.5 million gallons per day (MGD).

The second plant is Lake Holiday Water Treatment Plant located on Lake Holiday within the City Limits of Crossville. This treatment plant was constructed in the 1968, expanded in 1975 to 3.0 MGD, and has been renovated again in the last few years to bring its rated capacity to 4.0 MGD.

In April 1998, Lamar Dunn & Associates prepared a Master Plan for the City of Crossville Water Department. The Master Plan reported that the safe yield of Lake Holiday was 6.0 MGD and the safe yield of Meadow Park Lake was 3.5 MGD.

In December 1998, the United States Army Corps of Engineers (USACE) released a study entitled, Cumberland County Regional Water Supply Study – Preliminary Engineering Report. This report attempted to preliminarily define available options for the expected increase in water demand in Cumberland County. The study put forth some preliminary needs assessments that suggested that the 2050 Demand for Cumberland County could be anywhere from 7.3 MGD to 68.3 MGD. The report did nothing to define a realistic expectation of what the need would be. Therefore, it stated that the additional water supply required could be from no need to 58.3 MGD.

The report defined the safe yield of a reservoir as the "maximum continuous rate water could be drawn from each reservoir during severe drought conditions without lowering the water surface below the sediment storage pool." The report stated that the existing safe yield was 4.0 MGD for Lake Holiday and 3.0 MGD for Meadow Park Lake.

However, the safe yield of a reservoir is dependent on numerous factors all of which are related to the water budget for the reservoir including evaporation, vegetation, losses, springs, seeps, rainfall, and sediment. The analysis of the safe yield for these reservoirs or the concurrence with the USACE's estimates is beyond the scope of this issue of this report. However, the following are the statements as presented by the U.S. Army Corps of Engineers in regards to Meadow Park Lake. Note that all references to figures or photos in the following paragraphs are in reference to the U. S. Army Corps of Engineers' Report.

> Soil erosion in the watersheds upstream of dams is a constant source of sediment deposition in reservoirs. The Corps has set up monitoring programs to measure the amount of sediment buildup in reservoirs within the Cumberland River Basin. Center Hill Reservoir is one of the Corps reservoirs that has an established sedimentation monitoring program. The results from the Center Hill program have shown the rate at which sediments are deposited in the reservoir is approximately 0.5 acre-feet per square mile per year. The 0.5 rate is an average inflow of sediment over several decades, however, most of the sediment enters a reservoir during major flood events. Since several extreme flood events have occurred within the Center Hill basin over the past two decades, this inflow rate should be considered on the conservative side. Due to the close proximity, similar ground cover, land use and soil type, the sediment deposition rate for the modeled water supply reservoirs in Cumberland County should be equivalent to that of the Center Hill reservoir.
>
> Per this review, it was determined that Crossville's annual pan evaporation rate of 34.55 inches was applicable to the study area. In a feasibility-level study, instead of using the annual evaporation rate, the actual evaporation data for each drought year would be used in the yield analysis.
>
> Widely-published research into pan evaporation rates has concluded that seventy percent of the pan value is equivalent ot the evaporation that can be expected in a shallow reservoir. The rate on a deep reservoir would be less. Again, to be conservative, an allowance of seventy percent of the pan evaporation rate, or 24.19 inches per year, was used for the yield analyses... Evaporation was accounted for in the rainfall runoff modeling process by using a starting reservoir water surface elevation equal to the spillway crest elevation minus the anticipated evaporation from the reservoir over the amount of run time the model reflects, which is typically one year.

A constant outflow of three to seven cubic feet per second (cfs) was provided in all the reservoir routing models except the raised Mayland Lake impoundment alternative. For the raised impoundment alternatives, the outflow was based on the size of the existing outlet works.

Meadow Park Lake is an existing water supply reservoir located approximately five miles southwest of Crossville, Tennessee. The existing reservoir has approximately 255 acres of surface area at normal pool (elevation 1817.5 feet NGVD29) and a drainage area of 5.19 mi^2. Refer to Figure 4-8.

Data on the current dam configuration were obtained from the State of Tennessee's Safe Dam Inspection reports and a set of plans on proposed modifications to the reservoir. Photo 4-1 is a picture of the existing Meadow Park Lake Dam. Because Meadow Park Lake is one of two reservoirs currently used to provide water for the City of Crossville, a yield analysis on the existing dam configuration was performed to verify the reservoir's current capacity. An HEC1-API model was created to represent the Meadow Park Lake watershed and existing dam configuration. A yield analysis was performed with the existing condition HEC1-API model and the results indicated the existing dam could provide 3 MGD.

To identify the maximum yield that could be obtained from raising the Meadow Park Lake, the dam configuration was raised as high as the surrounding terrain would permit. The top of the Meadow Park Lake dam can be raised from elevation 1821.5 to 1840.0 feet NGVD29. An HMR52 model was created to determine the Probably Maximum Storm (PMS) for the Meadow Park watershed. An HEC-1 model was then created to utilize the PMS to produce the Probable Maximum Flood (PMF). According to the State of Tennessee's Safe Dam requirements, the raised Meadow Prk Lake dam would need to pass the ½ PMF event (refer to Table A-3 in Appendix A) without overtopping. The HEC-1 model was used to size the spillway of the raised dam in order to meet the Safe Dam requirements. A 125-foot wide spillway with an invert at elevation 1834.0 feet NGVD29 was required.

The HEC1-API model was modified to represent the raised dam and a yield analysis was performed (refer to Section 4.6.5). The yield analysis indicated the raised dam configuration could provide 4 MGD. The reason for the small increase in yield despite the large increase in dam height is the small drainage are of the watershed (5.19 mi^2). The amount of runoff from the watershed is the controlling factor as opposed to the amount of storage provided by the reservoir.

No cost analysis for raising the Meadow Park Dam as described above was put forth in the USACE report. However, the USACE report went on to make the following statements about a water harvesting method utilizing Meadow Park Lake with an estimated cost of $42.66 million dollars.

The second method of water harvesting investigated was pumping water during high-flow events on the Caney Fork and storing it in a raised Meadow Park Lake reservoir. If the exisitng Meadow Park Lake Dam were raised, a substantial additional storage area could be utilized for water supply. This alternative would combine the benefits of both sites: the large drainage area upstream of the Caney Fork site could be utilized without impounding the river and the large storage area upstream of the existing Meadow Park Lake Dam could be utilized for water supply. As designed, harvesting water from the Caney Fork to a raised Meadow Park Lake Reservoir could increase the yield of Meadow Park Lake from 3 MGD (existing yield) to 11 MGD.

Subsequent to this study, Lamar Dunn & Associates, Inc. issued a report in November 1999 entitled Securing Watts-Bar Reservoir Water for Crossville that investigated an alternative to the Meadow Park Lake issue. This report built on a water Master Plan by Lamar Dunn & Associates, Inc. that was prepared and published in April 1998 for the City of Crossville. The Watts-Bar Reservoir report projects a 10 MGD shortfall of water by the year 2025. This report also indicated an estimated project cost of $18.38 million to $20.43 million to complete a raw water supply from Watts-Bar Reservoir to Crossville.

In December 2001, Lamar Dunn & Associates, Inc. issued a report for the City of Crossville entitled Investigating the Feasibility of Constructing Raw Water Impoundments Downstream of Meadow Park Lake in regards to constructing a new impoundment downstream of Meadow Park Dam as an alternative to the options above. The proposal included defining two alternatives for completing such a project.

The first alternate was to build a new dam downstream of the current Meadow Park Lake and the proposed structure would be higher than the current dam and back water over the existing reservoir and over the new impounded area. The report stated that the watershed for this dam would be an additional 1070 acres in addition to the 3300 acres for the existing lake. The report claimed a safe yield of 8.0 MGD with a cost of $18.90 million.

The second alternate was to build a new dam downstream of the Meadow Park Lake that would be completely independent of the existing lake. This lake would provide a watershed of 2830 acres and a safe yield of 8.0 MGD according to the report at a cost of $20.33 million.

In January 2003, the City of Crossville instructed Environmental & Civil Engineering Services to provide a report to document the preliminary structural, financial, and environmental feasibility of raising Meadow Park Lake. Primarily, this report is to define the most economical height that the dam could be raised to for the amount of additional water storage to be obtained. Later versions of this report are to address the hydraulic issues with filling the storage area. The study is to evaluate height increases of 4 to 18 feet inclusively for the proposed additions. We have modified the study heights slightly to be able to correlate the elevations used in various studies and mapping work so that the study actually investigates height increases of 5.38 feet to 20.38 feet.

IV. Contributing Factors

Background Information

In order to begin this study, a review of available information was begun as well as obtaining some new information at a minimal cost to the City of Crossville.

A review of the State of Tennessee, Department of Environment and Conservation, Division of Water Supply, Safe Dams Section file on the Meadow Park Dam revealed the following general data:

State Dam ID Number	18-7001		
Federal Dam ID Number	TN 03501		
Latitude	35o54'09" N	**Longitude**	85o05'49" W
Year Completed	1938		
Engineer	Freeland and Roberts		
Type of Dam	Concrete Arch	**Size Classification**	Intermediate
Downstream Hazard Potential Classification	2		
Structural Height	32 feet		
Hydraulic Height	28 feet		
Crest Length	274 feet including spillways	**Crest Width**	3.5 feet
Upstream Slope	Vertical	**Downstream Slope**	0.2:1
Normal Pool Area	274 Acres	**Maximum Pool Area**	390 Acres
Top of Dam El.	1821.5 feet	**Storage**	4397 Acre-Feet
Normal Pool El.	1817.5 feet	**Storage**	3069 Acre-Feet
Spillway Sizes	49 ft X 4 ft, right	54 ft x 4 ft left	
Drainage Area	5.19 Square Miles	**Curve Number**	66
Time of Concentration	0.73 Hours		

No original plans for the dam were found to exist. However, on October 26, 1989 the City of Crossville was advised that the dam was issued a Notice of Violation. This Notice of Violation stated two points of concern:

First, the trees and brush within 20 feet of the toe of the dam must be removed and the drawdown valve(s) must be opened at least once each year to ensure operability. Second, a professional engineer must be retained to evaluate the structural integrity and stability of the dam under normal and over topping conditions (the dam overtops from a ½ PMP). Plans for correcting all deficiencies must be submitted by April 1, 1990, by the engineer.

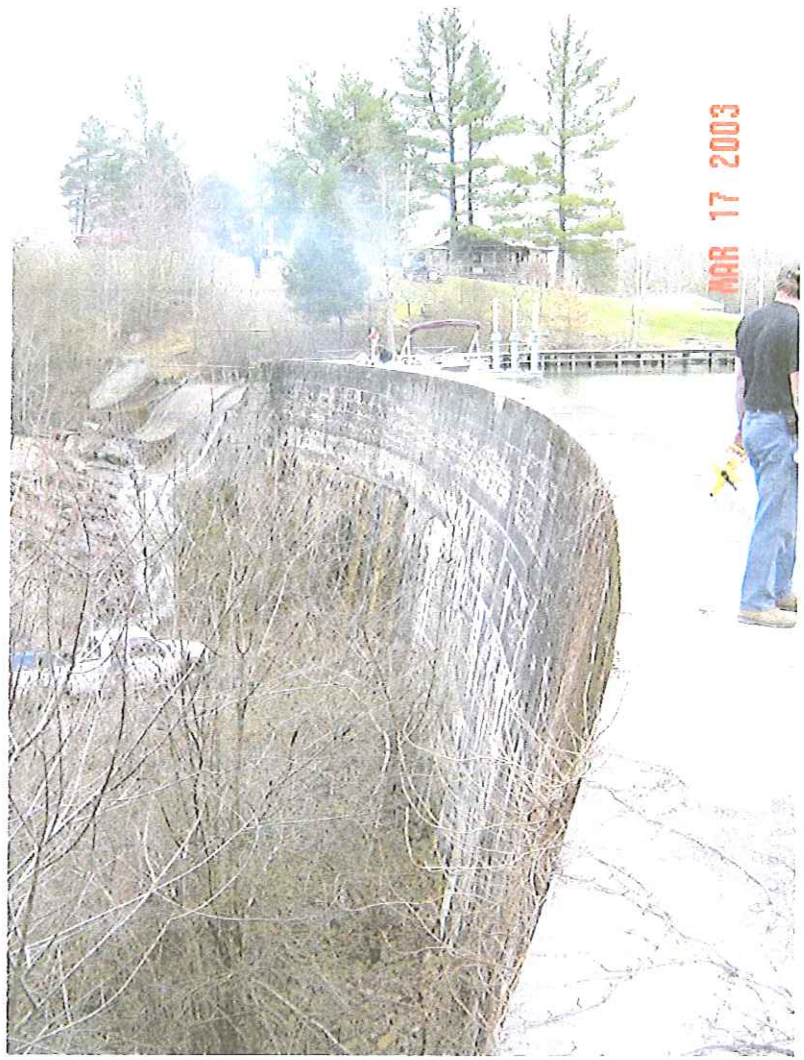
The file also includes substantial inspection reports indicating leakage from construction joints on the backside of the dam. On July 1990, J. R. Wauford & Company responded to the Notice of Violation with an Engineering Report based on newspaper articles, eyewitness accounts, divers, and a survey of the dam structure. This study reported the PMP as 29.2 inches in 6 hours. The full PMP was determined to produce a maximum water level of 1826.26 or 4.76 feet over dam crest with a maximum outflow of 16,185 cfs and 6.42 hours of overtopping. The ½ PMP results were reported as a maximum water level of 1822.5 feet with a maximum depth of 1.00 feet over the dam crest. This still produced 5071 cfs maximum outflow and 3.25 hours of overtopping. The report also included a structural analysis based on normal pool and the dam passing the PMF. The analysis was based on elastic theory of arch dams because "the narrow cross section of the dam indicated the dam should be analyzed as an arch instead of using a standard gravity analysis." The analysis was based on assumptions since no testing was performed on the dam. The report presented a stress analysis of the concrete but did not provide any calculations regarding the overturning stability or sliding stability of the dam; only stating since it had stood for 50 years, then it must be stable.

Environmental & Civil Engineering Services also reviewed newspaper records and did not find any information particularly pertinent to the structure definition.

General

Environmental & Civil Engineering Services obtained real data in regards to the Meadow Park Lake and Dam by performing on site inspection of both faces of the dam and obtaining cores of the surface concrete of the dam and subsequent analysis.

The visual inspection of the dam revealed the obvious as well as some basic measurements of the dam were taken. The dam is a concrete dam constructed in horizontal lifts varying from approximately 8 inches to over 14 inches with a vertical front face and a sloping back face. The dam has a spillway opening at each end of the structure. Minimal abutment footings are observable at the ends. The channel below the dam is unshaped and remains in its natural sandstone with some gravel and soil present. The downstream face of the dam depicts several locations that are leaking; primarily within the horizontal construction joints. The worst leaks are located within the range of the thermocline.



The inspection of the submerged face of the dam was conducted over a four-day period in March 2003 and documented using underwater video technology. Approximately 1 hour and 10 minutes of completed video was obtained viewing the submerged face of the dam. The video reveals a highly spalled concrete surface that has little algae growth on it. The lake bottom at the dam seems relatively undisturbed and without significant silt accumulation. Several significant holes were observed in the upstream face of the dam that were over 2 inches in any one dimension. These holes typically occurred at horizontal construction joint locations and had excessive concrete loss.

The concrete cores recovered from the dam were 4" diameter concrete cores obtained using standard diamond coring technology. A total of 26 cores were cut from 7 different locations, 3 of the locations were on top of the dam, while 4 of the locations were on the back face of the dam. The cores are from 3 distinct construction lifts and extended approximately 12 to 14 inches into the dam concrete. The cores revealed a relatively soft exterior concrete as indicated by the extensive spalling on both faces of the dam. However, the cores also revealed the prolific use of large pieces of sandstone rock in the concrete. Estimates from the cores indicated that sandstone rock from 4 inches to over 16 inches in diameter were used in the construction of the dam. Initially, we located the sandstone rock within the horizontal construction joints and assumed that they may have been used for shear keyways. Later cores revealed however that this assumption was incorrect and that the sandstone may have been used throughout the dam construction. The cores also revealed that wire reinforcement to a limited extent was placed in the dam for reinforcement. Many of the cores separated at the horizontal construction joint locations suggesting little or no shear resistance locally between the monolithic portions of the construction.

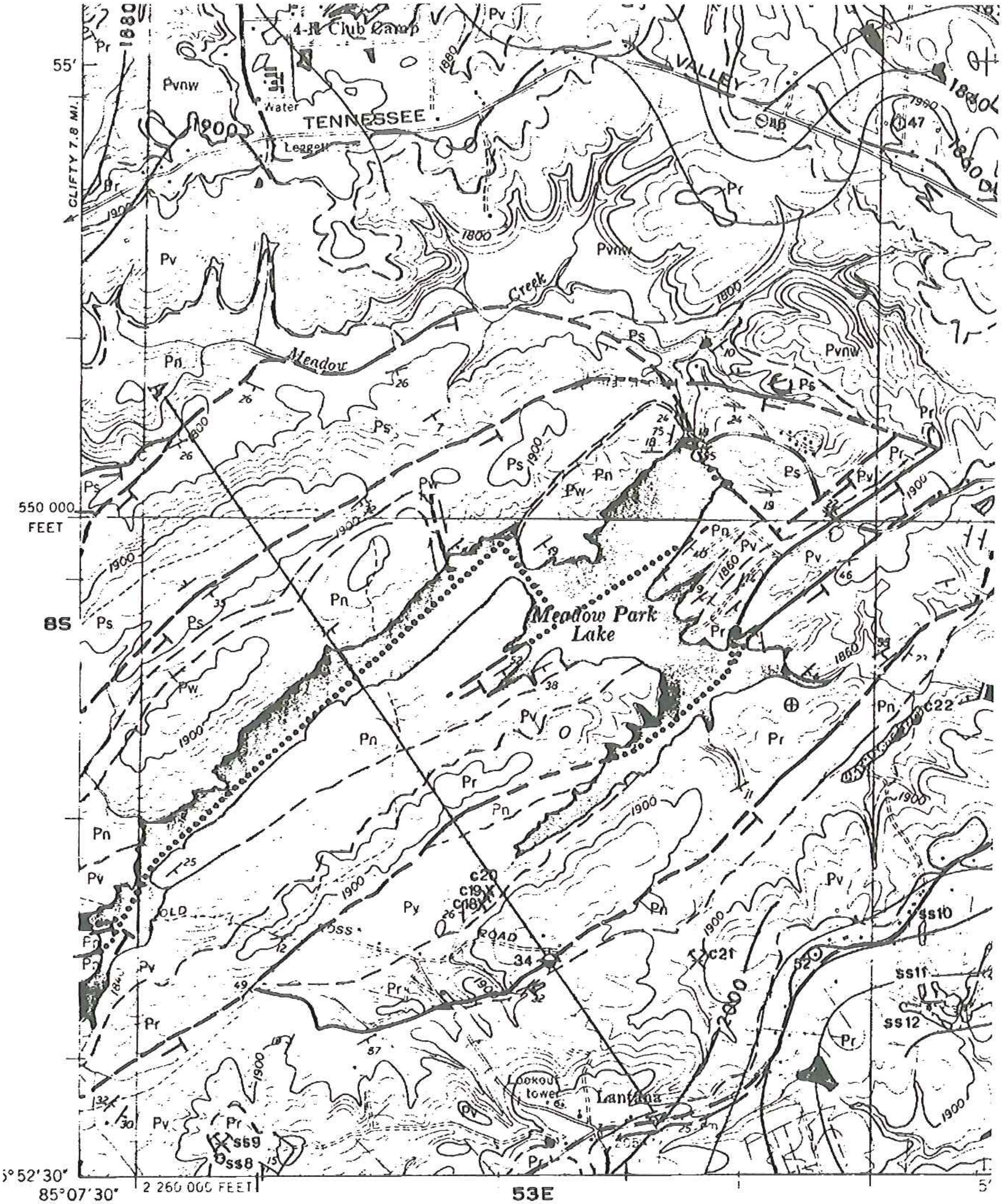
Hydrology

Hydrology is the term used to define the relationship between the structure and its environment in regards to the rainfall and runoff captured by the impoundment. This term is usually applied to all water cycle events that happen to affect the structure. This issue is beyond the scope of this initial version of this report and will be added if selected by the City of Crossville.

Geology

Geology refers to the subsurface environment and conditions in which the lake and dam reside primarily defining the soil and rock structures present within the dam and lake areas. This topic is vitally important in regards to project feasibility as the structure relies upon a solid foundation to resist forces imposed by the water and other loads but also to prevent unusual or excessive leakage as well as provide good drainage to promote efficient gathering of the runoff from the rainfall in the drainage basin. No subsurface investigation has been performed for this initial issue of this report and will be added at a latter date if chosen.

However, the following figure is a portion of the geologic map that shows the dam site and a portion of the lake.



Base topographic map by USGS-TVA, 1966.
10,000-foot grid based on Tennessee rectangular coordinate system.

The geologic map shows formations Pn, Ps, Pw, Pv, and Pr in the vicinity of the lake and the dam. The Pr formation is the Rockcastle Conglomerate which is the uppermost occurring layer. Below this is often the Vandever formation, symbolized as Pv; followed by the Newton Sandstone formation, symbolized as Pn; followed by the Whitwell Shale, symbolized as Pw; followed by the Sewanee Conglomerate; symbolized as Ps. Each of these layers are described in the literature as shown below:

The Rockcastle Conglomerate is up to 165 to 210 feet thick comprised of sandstone, white to light gray; fine to coarse-grained, cross-bedded, silty and micaceous, locally conglomeratic (especially near the base) with rounded and subrounded quartz pebbles as much as ¼ inch long. Base of the formation is commonly cemented with limonite. There are at least three shale "splits" in the formation that are up to 10 feet thick. These shales are commonly medium-gray, silty and sandy, discontinuous lenses that extend over an area of a few tens of acres, and are usually seen only in well cuttings or on geophysical logs.

The Vandever Formation is layer of shale between 140 to 280 feet thick and is described as shale, micaceous and sandy, medium to dark-gray; siltstone, very light to light-gray; sandstone, white to yellowish-gray, very fine to fine-grained, very thin to thin-bedded, micaceous. Although the various facies of this formation are irregular, sandstones and siltstones dominate just above and below the middle of the formation, whereas the shales dominate the top, middle, and base of the formation. The Morgan Springs coal and the Lantana coal are present locally. Mapped with the Newton and Whitwell formations in the western part of the quadrangle, where they thin abruptly.

The Newton Sandstone formation lies beneath the Vandever Formation and is a layer of sandstone varying from 5 to 100 feet thick. Newton Sandstone is a sandstone, white to light-gray and pink, very fine to medium grained, thin to medium-bedded, crossbedded, becoming slightly to highly conglomeratic in the southwestern part of the quadrangle. Occasional thin layers of light to medium-gray, micaceous, silty shale, and siltstone, white to light-gray and sandy, occur throughout the formation. Limonite and limonite cement occur at the base. In the western part of the quadrangle, the Newton thins abruptly, and is mapped with the Vandever and Whitwell formations.

The Whitwell Shale is a 5 to 100 feet thick layer of shale, medium to very dark-gray, silty and micaceous with very thin, discontinuous coal layers; interbedded with sandstone, white to light-gray, fine-grained, micaceous, shaly, and carbonaceous. Sewanee coal seam is nearly continuous just above the base of the formation. The Sewanee is only seen in the subsurface, and to the southeast of the Cumberland Plateau Overthrust. The Whitwell (and especially the Sewanee coal) is moderately to intensively sheared by the major fault decollement. In the western part of the quadrangle, the Whitwell thins abruptly and is mapped with the Vandever and Newton formations.

The Sewanee Conglomerate is a 140 to 230 feet thick layer of sandstone, conglomeratic sandstone and conglomerate, white to light-gray with light shades of pink, medium to very coarse-grained, medium to thick-bedded, crossbedded; contains round quartz pebbles as much as ½ inch long. Formation is slightly to abundantly micaceous, somewhat silty and limonitic; thin, discontinuous layers of medium-gray shale occur throughout the formation.

With such a widely varying published geology, it is difficult to make estimations of the conditions immediately at the dam and near the lake without site specific geologic information. This is beyond the scope of this issue of the report and will be added in the future.

Hydrogeology & Leakage Avoidance/Prevention

Hydrogeology is a specialty area of concern in dams that takes into account the issues associated with the two topics above of hydrology and geology. This topic deals with the flow of water in the subsurface geology. In terms of dams and dam construction this addresses whether the potential exists for leaks, springs, seeps, or subsurface flows that may improve the hydraulic/hydrologic characteristics of the lake or hurt them. Again, this topic is beyond the scope of this version of this report.

Structural Stability

Structural stability refers to the ability of the dam to remain stable when exposed to all forces loaded onto it. This includes a wide range of forces that may be applied to the dam. Stability is usually gauged in three terms: factor of safety against overturning, factor of safety against sliding, and stress transferred to the foundation materials.

Environmental & Civil Engineering Services performed a stability analysis of the existing dam in order to determine the factors of safety in regards to overturning and sliding. No numbers were offered by the earlier report prepared by J. R. Wauford & Co. Data that has been obtained by ECE Services does not include any actual measurements of the dam footing although we have measured the majority of the dam. Also, we have not performed any core drilling of the dam footing or foundation rock to determine the condition of these.

The analysis by Wauford was based on the dam being an arch dam. We feel that this assumption may be grossly in error. The dam has a relatively small amount of curvature in it, is much longer than it is tall, and does not have substantial abutments at the ends of the dam. For these reasons, the dam does not have some structurally significant traits for concrete arch dams. For true arch action to occur, nearly all stresses should be transferred to abutments located at the ends of the dam. The 274-foot length to approximately 32-foot height at maximum produces approximately an 8.56 length-to-height ratio that would make it difficult for stresses to transfer from the central upper heights of the dam to the footings at the dam end. In addition, the spillways located at each end are 4.0 feet below the top of the dam and are taller than the abutments appear to be at each end of the dam. This would prevent any arch action from reaching the abutments if they were present based on the dam configuration. Irregardless, the analysis by Wauford disregarded the significant foundation pressures that would be present in the foundation of a concrete arch dam and did nothing to address this issue for the Meadow Park Dam.

The dam appears to be a hybrid between true arch action and a gravity dam. The presence of apparent shear keys in the dam and wire reinforcement tend to indicate that this may be the case. The dam is assumed to act as a cantilever from the footing for our analysis.

Many dams built during the time that the Meadow Park Dam was built disregarded seismic loadings and buoyancy as loads on the structures. These earlier designs are rarely stable by modern design standards after leakage becomes a major factor and when exposed to seismic loading. Since, Crossville is located in an area with a seismic acceleration typically less tan 0.09; seismic loading is not a significant player in the design of a dam or the analysis. Although, we assume in our analysis, that buoyancy is based on water throughout the dam height since most of our cores revealed a very high moisture content in the dam as well as significant leaks near the top. In addition, we assume that the seismic loading is 10% of the water horizontal force.

The analysis indicates at the tallest section in the dam a factor of safety against overturning of 0.22 and a factor of safety against sliding of 0.59. Both factors of safety should be at least 2.0 for a gravity dam. This analysis further indicates that the dam probably behaves somewhat as a cantilevered design from the foundation with some arch action or the possibility exists that a lack of information in regards to the foundation could be critical to an accurate analysis.

Without more accurate foundation information, our preliminary analysis indicate that the foundation pressures may be in excess of 40,000 psi on the sandstone bedrock that the dam is built into. This high stress level is not problematic in some sandstones but may be in others. No definitive result can be determined without geotechnical and foundation data.

The only way to achieve a more accurate analysis is to obtain real information about the footing and the foundation subsurface and to combine this information with more destructive test results from the dam concrete and surveying dimensions of the subsurface geology to perform a finite element analysis of the structure and the structure-geology interaction.

However, the structure is probably not stable at the PMP flood in consideration of modern loading criteria and the age/condition of the structure.

Structural Strength

The structural strength of the dam is a term used to define the ability of the materials that the dam is constructed of to resist internal stresses in them caused by the application of loads. The inspection of the dam revealed several significant cracks in the top part of the structure that extend vertically from the front face to the downstream face. These cracks appear to be temperature related since the dam contains no allowance for temperature expansion/contraction.

The report by Wauford found that the structure was overstressed during the PMP when the concrete was compared to modern 3000-psi concrete. This condition is made worse by the fact that the sandstone is present in the concrete.

However, our analysis of the structure as a cantilever out of the footing suggests that the structure behaves very similar to this and the coring and inspection results indicate this as well. The dam has vertical wire reinforcing near the upstream face suggesting that this is a minimal amount of reinforcing to prevent tensile cracking although the tensile forces are relatively low. In addition, the inspection revealed that the horizontal construction joints in the upstream face tend to be opening as the structure ages; suggesting that the tension on this face is opening the joints.

Therefore, our findings indicate that the structure is substandard based on modern codes. Improvements in the structural strength of the structure that limited deflections would provide a more stable dam capable of withstanding many more years of service.

Environmental Issues

We preliminarily investigated the environmental issues facing the proposed project of raising the dam. This was done through a phone conversation with Mr. Fran Baker of the Division of Water Pollution Control, a letter to U. S. Fish and Wildlife, and a conversation with an independent consulting biologist. Water Pollution Control will require an individual ARAP permit to raise the dam but felt that this would not be as difficult to obtain as other recently submitted dam construction permits in Cumberland County. The individual ARAP permit will require delineation of wetlands, stream, and evaluation of endangered species as well as documentation that the stream use classification downstream of the dam be unaltered as a result of the project.

Appendix I contains the response to the initial letter to U. S. Fish and Wildlife in regards to the Project. This letter suggests that there are five endangered species that will have to be addressed: the Gray Bat, the Bluemask Darter, the Cumberland Rosemary, the Green Pitcher Plant, and the White Fringeless Orchid.

V. Definition and Evaluation of Alternatives

The goal of this issue of the report is to define the most economical height and manner to increase the dam so as to provide the most storage for the dam height. The study evaluates height increases of 6.5 above normal pool to 22.5 feet above normal pool.

Based on the constraint that the City cannot withstand any decrease in the lake level for construction to occur; all estimates and alternatives are presented and assumed to be performed without lowering the lake level. Any alternative that would require the lowering of the lake level or complete draining of the lake is considered to be non-viable and is not included in this report.

Before any alternative can be implemented on the proposed structure, the structure must be brought into a good condition by performing remedial work. The remedial work is not only needed to bring the structure into a condition to be expanded in height; but is needed for proper maintenance of the structure so that it can be useful to the city for the next 30 to 50+ years.

The full scope of this remedial work is not known at this time. Although, the following estimate includes the most logical approach to bring the structure back to the condition needed. The work included involves grouting the existing structure to the foundation rock using post-tensioned steel cables and buttresses in order to improve the overall stability of the structure and reduce structural stresses. In addition, the downstream face of the dam would be jetted to remove all loose and weakened concrete; then all horizontal joints in the dam would be drilled, cleaned, and epoxy injected to eliminate leakage, reduce buoyancy forces, and improve structural condition of dam. After all grouting is complete, the downstream face of the dam would be repaired/replaced by shotcrete in order to provide a weatherable surface.

The estimate for the remedial work does not include professional fees that are assumed to be necessary to complete this report in regards to hydraulics, hydrology, geology, hydrogeology, and geotechnical issues. However the estimate after the remedial estimate includes the professional fees to complete the feasibility study and the environmental permitting costs that are applicable to any of the chosen alternatives.

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Cost Estimate for Remedial Work to Dam

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$50,000.00	$50,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Drilling of anchorage holes	LF	550	$90.00	$49,500.00
4	Post tensioning	EA	11	$5,000.00	$55,000.00
5	Pressure Jetting to remove weak concrete	SF	7672	$2.90	$22,248.80
6	Drilling of grout holes	EA	600	$40.00	$24,000.00
7	Cleaning of grout holes	EA	600	$52.00	$31,200.00
8	Epoxy grouting of construction joints	SF	7672	$24.00	$184,128.00
9	Shotcreting of back of dam	SF	7672	$3.50	$26,852.00
10	Buttress Construction	EA	5	$45,000.00	$225,000.00
	Total Estimated Construction Cost				$677,928.80
	Construction / Project Contingency	%	20	$135,585.76	$135,585.76
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		0	$0.00	$0.00
	Endangered Species Review & Field Study		0	$0.00	$0.00
	Geotechnical Engineering		1	$45,000.00	$45,000.00
	Special Testing		1	$45,000.00	$45,000.00
	Engineering Design		1	$122,027.18	$122,027.18
	Construction Administration		1	$30,000.00	$30,000.00
	Construction Inspection		1	$55,000.00	$55,000.00
	Construction Testing		1	$20,000.00	$20,000.00
	Project Administration		0	$0.00	$0.00
	Legal		0	$0.00	$0.00
	Property / Easement Acquisition		0	$0.00	$0.00
	Permitting		0	$0.00	$0.00
	Plans Review		0	$0.00	$0.00
	Total Estimated Project Cost				$1,138,041.74

Once the remedial work on the dam has been completed, the City of Crossville has approximately 5 options or methodologies by which to increase the dam height. Each of these options are presented below and detailed in method, permitting difficulty, construction difficulty, and cost. Primarily, for a given increase in height all options have approximately the same permitting difficulties except if discussed in detail in the following paragraphs.

Alternative #1: "Do Nothing" Alternative

This is the standard engineering alternative to do nothing which in and of itself is quite self-explanatory. The City could choose to do nothing in terms of renovation and/or do nothing in terms of increase the dam and lake. The only advantage to this alternative is the low cost involved and the fact that it does not raise any environmental issues. However, due to commitments to provide water, this may not be a feasible option.

Alternative #2: Additional Concrete on Downstream Face

This option would appear to be simple in only adding additional concrete to the downstream face of the dam and additional concrete on top of the dam to increase the height. However, it can be complex during engineering design and construction since the foundation that supports the existing dam will need to be removed; thus requiring an elaborate shoring and bracing system to support the dam through construction. This fact would eliminate the feasibility of using this methodology to increase the normal pool by more than approximately 14 feet.

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Alternative #2: 5.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$45,000.00	$45,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Drilling of anchorage holes	LF	4000	$60.00	$240,000.00
4	Post tensioning	EA	100	$1,200.00	$120,000.00
5	Foundation excavation	CY	700	$25.00	$17,500.00
6	Concrete	CY	1830	$510.00	$933,300.00
7	Drainage System	LS	1	$175,000.00	$175,000.00
8	Spillway Modifications	LS	1	$225,000.00	$225,000.00
	Total Estimated Construction Cost				$1,765,800.00
	Construction / Project Contingency	%	20	$353,160.00	$353,160.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		1	$0.00	$0.00
	Endangered Species Review & Field Study		1	$0.00	$0.00
	Geotechnical Engineering		1	$150,000.00	$150,000.00
	Special Testing		1	$75,000.00	$75,000.00
	Engineering Design		1	$317,844.00	$317,844.00
	Construction Administration		1	$75,000.00	$75,000.00
	Construction Inspection		1	$125,000.00	$125,000.00
	Construction Testing		1	$120,000.00	$120,000.00
	Project Administration		1	$0.00	$0.00
	Legal		1	$0.00	$0.00
	Property / Easement Acquisition		1	$0.00	$0.00
	Permitting		1	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$2,994,304.00

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Alternative #2: 20.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$45,000.00	$45,000.00
2	Clearing and Grubbing	LS	1	$25,000.00	$25,000.00
3	Drilling of anchorage holes	LF	4000	$60.00	$240,000.00
4	Post tensioning	EA	100	$1,200.00	$120,000.00
5	Foundation excavation	CY	5000	$21.00	$105,000.00
6	Concrete	CY	10200	$375.00	$3,825,000.00
7	Drainage System	LS	1	$320,000.00	$320,000.00
8	Spillway Modifications	LS	1	$675,000.00	$675,000.00
	Total Estimated Construction Cost				$5,355,000.00
	Construction / Project Contingency	%	20	$1,071,000.00	$1,071,000.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		1	$0.00	$0.00
	Endangered Species Review & Field Study		1	$0.00	$0.00
	Geotechnical Engineering		1	$150,000.00	$150,000.00
	Special Testing		1	$75,000.00	$75,000.00
	Engineering Design		1	$706,860.00	$706,860.00
	Construction Administration		1	$75,000.00	$75,000.00
	Construction Inspection		1	$150,000.00	$150,000.00
	Construction Testing		1	$150,000.00	$150,000.00
	Project Administration		1	$0.00	$0.00
	Legal		1	$0.00	$0.00
	Property / Easement Acquisition		1	$0.00	$0.00
	Permitting		1	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$7,745,360.00

Alternative #3: Additional Concrete on Upstream Face

This option is simply stated as increase the dam height by pouring additional concrete at the face and effectively continuing the backslope to the desired height. This option is difficult from a construction point of view since all work must be completed on the submerged side of the dam. Therefore, in order to prevent draining of the lake, sheet piling and cutoff trenches would have to be installed first in order to provide a working area in which to begin construction. This option would be expensive for relatively small increases in dam height due to the cost of dewatering the site while it virtually has no limits in the increase of height to the dam except as limited by the terrain of the area.

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Alternative #3: 5.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$75,000.00	$75,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Dewatering	LS	1	$625,000.00	$625,000.00
4	Foundation excavation	CY	500	$75.00	$37,500.00
5	Concrete	CY	1900	$500.00	$950,000.00
6	Spillway Modifications	LS	1	$250,000.00	$250,000.00
	Total Estimated Construction Cost				$1,947,500.00
	Construction / Project Contingency	%	20	$389,500.00	$389,500.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		1	$0.00	$0.00
	Endangered Species Review & Field Study		1	$0.00	$0.00
	Geotechnical Engineering		1	$150,000.00	$150,000.00
	Special Testing		1	$40,000.00	$40,000.00
	Engineering Design		1	$350,550.00	$350,550.00
	Construction Administration		1	$75,000.00	$75,000.00
	Construction Inspection		1	$100,000.00	$100,000.00
	Construction Testing		1	$75,000.00	$75,000.00
	Project Administration		1	$0.00	$0.00
	Legal		1	$0.00	$0.00
	Property / Easement Acquisition		1	$0.00	$0.00
	Permitting		1	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$3,140,050.00

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Alternative #3: 20.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$75,000.00	$75,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Dewatering	LS	1	$950,000.00	$950,000.00
4	Foundation excavation	CY	1550	$75.00	$116,250.00
5	Concrete	CY	8450	$375.00	$3,168,750.00
6	Spillway Modifications	LS	1	$250,000.00	$250,000.00
	Total Estimated Construction Cost				$4,570,000.00
	Construction / Project Contingency	%	20	$914,000.00	$914,000.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		1	$0.00	$0.00
	Endangered Species Review & Field Study		1	$0.00	$0.00
	Geotechnical Engineering		1	$150,000.00	$150,000.00
	Special Testing		1	$40,000.00	$40,000.00
	Engineering Design		1	$603,240.00	$603,240.00
	Construction Administration		1	$125,000.00	$125,000.00
	Construction Inspection		1	$120,000.00	$120,000.00
	Construction Testing		1	$150,000.00	$150,000.00
	Project Administration		1	$0.00	$0.00
	Legal		1	$0.00	$0.00
	Property / Easement Acquisition		1	$0.00	$0.00
	Permitting		1	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$6,684,740.00

Alternative #4: Embankment Buttress

This alternative is the least technical of the options to raise the dam structure. It would simply involve using the existing dam as a face to an earthen fill dam or a roller compacted concrete dam. Vertical extensions of the concrete could be placed to any height and earthen fill placed behind it. Particular attention would have to be given to make sure that any water that penetrated the concrete dam was collected and not allowed to percolate through the soil fill.

This alternative is not limited except by the terrain of the area. The following cost estimates are for 6.5 feet above existing normal pool and 22.5 feet above existing normal pool.

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Cost Estimate for Alternative #4 - 5.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$45,000.00	$45,000.00
2	Clearing and Grubbing	LS	1	$25,000.00	$25,000.00
3	Drainage System	LS	1	$350,000.00	$350,000.00
4	Earth Fill	CY	42500	$6.50	$276,250.00
5	Concrete	CY	350	$275.00	$96,250.00
6	Spillway Modifications	LS	1	$585,000.00	$585,000.00
	Total Estimated Construction Cost				$1,377,500.00
	Construction / Project Contingency	%	20	$275,500.00	$275,500.00
	Surveying / Mapping		1	$25,000.00	$25,000.00
	Wetlands Delineation		0	$0.00	$0.00
	Endangered Species Review & Field Study		0	$0.00	$0.00
	Geotechnical Engineering		1	$70,000.00	$70,000.00
	Special Testing		1	$30,000.00	$30,000.00
	Engineering Design		1	$247,950.00	$247,950.00
	Construction Administration		1	$75,000.00	$75,000.00
	Construction Inspection		1	$125,000.00	$125,000.00
	Construction Testing		1	$120,000.00	$120,000.00
	Project Administration		0	$0.00	$0.00
	Legal		0	$0.00	$0.00
	Property / Easement Acquisition		0	$0.00	$0.00
	Permitting		0	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$2,350,950.00

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Cost Estimate for Alternative #4 - 20.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$45,000.00	$45,000.00
2	Clearing and Grubbing	LS	1	$25,000.00	$25,000.00
3	Drainage System	LS	1	$475,000.00	$475,000.00
4	Earth Fill	CY	124000	$4.75	$589,000.00
5	Concrete	CY	1750	$275.00	$481,250.00
6	Spillway Modifications	LS	1	$425,000.00	$425,000.00
	Total Estimated Construction Cost				$2,040,250.00
	Construction / Project Contingency	%	20	$408,050.00	$408,050.00
	Surveying / Mapping		1	$35,000.00	$35,000.00
	Wetlands Delineation		0	$0.00	$0.00
	Endangered Species Review & Field Study		0	$0.00	$0.00
	Geotechnical Engineering		1	$45,000.00	$45,000.00
	Special Testing		1	$30,000.00	$30,000.00
	Engineering Design		1	$269,313.00	$269,313.00
	Construction Administration		1	$125,000.00	$125,000.00
	Construction Inspection		1	$125,000.00	$125,000.00
	Construction Testing		1	$175,000.00	$175,000.00
	Project Administration		0	$0.00	$0.00
	Legal		0	$0.00	$0.00
	Property / Easement Acquisition		0	$0.00	$0.00
	Permitting		0	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$3,257,613.00

Alternative #5: Heightened Section

This alternative is the "pure" structural approach to raising the dam. It involves devising a concrete structure capable of withstanding the forces and stresses necessary to raise the dam to the desired height. This alternative is not limited except by the terrain of the area, although, it will become progressively more expensive with height as the size of the structure must increase.

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Cost Estimate for Alternative #5 - 5.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$15,000.00	$15,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Concrete	CY	435	$450.00	$195,750.00
4	Spillway Modifications	LS	1	$125,000.00	$125,000.00
5	Concrete Buttresses	EA	1	$45,000.00	$45,000.00
	Total Estimated Construction Cost				$390,750.00
	Construction / Project Contingency	%	20	$78,150.00	$78,150.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		0	$0.00	$0.00
	Endangered Species Review & Field Study		0	$0.00	$0.00
	Geotechnical Engineering		1	$35,000.00	$35,000.00
	Special Testing		1	$30,000.00	$30,000.00
	Engineering Design		1	$70,335.00	$70,335.00
	Construction Administration		1	$75,000.00	$75,000.00
	Construction Inspection		1	$125,000.00	$125,000.00
	Construction Testing		1	$120,000.00	$120,000.00
	Project Administration		0	$0.00	$0.00
	Legal		0	$0.00	$0.00
	Property / Easement Acquisition		0	$0.00	$0.00
	Permitting		0	$0.00	$0.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$936,735.00

City of Crossville
Meadow Park Dam

Engineer's Opinion of Cost
Cost Estimate for Alternative #5 - 20.4 FT Increase

Item No.	Description	Unit	Qty	Unit Price	Item Total
1	Mobilization	LS	1	$15,000.00	$15,000.00
2	Clearing and Grubbing	LS	1	$10,000.00	$10,000.00
3	Concrete	CY	2750	$345.00	$948,750.00
4	Spillway Modifications	LS	1	$650,000.00	$650,000.00
5	Concrete Buttresses	EA	7	$82,000.00	$574,000.00
	Total Estimated Construction Cost				$2,197,750.00
	Construction / Project Contingency	%	20	$439,550.00	$439,550.00
	Surveying / Mapping		1	$7,500.00	$7,500.00
	Wetlands Delineation		0	$0.00	$0.00
	Endangered Species Review & Field Study		0	$0.00	$0.00
	Geotechnical Engineering		1	$85,000.00	$85,000.00
	Special Testing		1	$30,000.00	$30,000.00
	Engineering Design		1	$290,103.00	$290,103.00
	Construction Administration		1	$125,000.00	$125,000.00
	Construction Inspection		1	$125,000.00	$125,000.00
	Construction Testing		1	$175,000.00	$175,000.00
	Project Administration		0	$0.00	$0.00
	Legal		1	$75,000.00	$75,000.00
	Property / Easement Acquisition		1		$0.00
	Permitting		1	$300,000.00	$300,000.00
	Plans Review		1	$5,000.00	$5,000.00
	Total Estimated Project Cost				$3,854,903.00

Based on the above estimates of project cost, we used a straight line interpolation to approximate costs at varying heights of additional dam between the two extremes to produce the following summary of estimated costs. The summary costs do not include any costs to adjust the water plant intake at the Meadow Park Treatment Plant or costs to relocate facilities at the Meadow Park that would be subject to flooding.

Meadow Park Dam and Lake Expansion
Summary of Costs

		Alt #1 "Do Nothing"	Alt #2 Backface Expansion	Alt #3 Front face Expansion	Alt #4 Embankment Buttress	Alt #5 Heightened Section
+5.4 Feet	Additional Storage	1.0	1,615.9	1,615.9	1,615.9	1,615.9
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$130,977	$130,977	$130,977	$130,977
	Land & Environmental Costs	$0	$952,500	$952,500	$952,500	$952,500
	Alternative Est. Cost	$0	$2,994,304	$3,140,050	$2,350,950	$936,735
	Est. Total Cost	$1,588,042	$5,665,823	$5,811,569	$4,797,469	$3,608,254
	Est. Cost per Acre-Foot	$1,588,042	$3,506	$3,597	$2,969	$2,233
	Surface Area	338.5	338.5	338.5	338.5	338.5
+8.4 Feet	Additional Storage	1.0	2,691.2	2,691.2	2,691.2	2,691.2
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$192,570	$192,570	$192,570	$192,570
	Land & Environmental Costs	$0	$1,052,500	$1,052,500	$1,052,500	$1,052,500
	Alternative Est. Cost	$0	$3,944,515	$3,848,988	$2,532,283	$1,520,369
	Est. Total Cost	$1,588,042	$6,777,627	$6,682,100	$5,140,394	$4,353,480
	Est. Cost per Acre-Foot	$1,588,042	$2,518	$2,483	$1,910	$1,618
	Surface Area	380.1	380.1	380.1	380.1	380.1
+10.4 Feet	Additional Storage	1.0	3,471.1	3,471.1	3,471.1	3,471.1
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$222,282	$222,282	$222,282	$222,282
	Land & Environmental Costs	$0	$1,102,500	$1,102,500	$1,102,500	$1,102,500
	Alternative Est. Cost	$0	$4,577,989	$4,321,613	$2,653,171	$1,909,458
	Est. Total Cost	$1,588,042	$7,490,813	$7,234,437	$5,340,995	$4,822,281
	Est. Cost per Acre-Foot	$1,588,042	$2,158	$2,084	$1,539	$1,389
	Surface Area	406.6	406.6	406.6	406.6	406.6
+12.4 Feet	Additional Storage	1.0	4,318.1	4,318.1	4,318.1	4,318.1
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$251,544	$251,544	$251,544	$251,544
	Land & Environmental Costs	$0	$1,466,750	$1,466,750	$1,466,750	$1,466,750
	Alternative Est. Cost	$0	$5,211,463	$4,794,239	$2,774,059	$2,298,547
	Est. Total Cost	$1,588,042	$8,517,799	$8,100,574	$5,855,395	$5,604,882
	Est. Cost per Acre-Foot	$1,588,042	$1,973	$1,876	$1,356	$1,298
	Surface Area	435.4	435.4	435.4	435.4	435.4
+14.4 Feet	Additional Storage	1.0	5,231.4	5,231.4	5,231.4	5,231.4
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$269,370	$269,370	$269,370	$269,370
	Land & Environmental Costs	$0	$1,566,750	$1,566,750	$1,566,750	$1,566,750
	Alternative Est. Cost	$0	$5,844,938	$5,266,864	$2,894,948	$2,687,636
	Est. Total Cost	$1,588,042	$9,269,099	$8,691,026	$6,094,110	$6,111,798
	Est. Cost per Acre-Foot	$1,588,042	$1,772	$1,661	$1,165	$1,168
	Surface Area	465.4	465.4	465.4	465.4	465.4
+20.4 Feet	Additional Storage	1.0	10,422.3	10,422.3	10,422.3	10,422.3
	Feasibility Study Cost	450,000	450,000	450,000	450,000	450,000
	Remediation Cost	$1,138,042	$1,138,042	$1,138,042	$913,042	$1,138,042
	Clearing Cost	$0	$599,400	$599,400	$599,400	$599,400
	Land & Environmental Costs	$0	$1,674,250	$1,674,250	$1,674,250	$1,674,250
	Alternative Est. Cost	$0	$7,745,360	$6,684,740	$3,257,613	$3,854,903
	Est. Total Cost	$1,588,042	$11,607,052	$10,546,432	$6,894,305	$7,716,595
	Est. Cost per Acre-Foot	$1,588,042	$1,114	$1,012	$661	$740
	Surface Area	760.6	760.6	760.6	760.6	760.6

VI. Recommendation

The purpose of this report was to determine an estimated cost for the most economical height and method by which to raise the Meadow Park Dam to increase the storage volume of water available for treatment. At the current time this report is based solely on known structural factors and issues.

We have reviewed five available options to increase the height of the dam. The five options are:

- Do Nothing
- Backface Expansion
- Frontface Expansion
- Embankment Buttress
- Heightened Section

The Do Nothing Option is not a feasible option since the City has commitments to customers to supply them with water. The City will have to seek other possibilities to meet these obligations if they choose not to use Meadow Park for expansion.

The Backface Expansion option and the Frontface Expansion option both have difficult construction issues that translate into increased construction costs not to mention increased risk. This leads to a more favorable construction environment and cost to raise the dam by embankment buttress or heightened section. The costs to use either of these options is very similar and based on our estimates could lean toward a preference of one or the other based on permitting difficulty. The cost analysis reveals that the cheaper option up to 14.0 feet is the Heightened Section Alternative; however, above 14.0 feet a slight cost advantage could be seen in using an Embankment Buttress. However, the increase in disturbed stream area to construct the embankment buttress could offset any cost advantage as a result of increased permitting cost.

At the current time, there remains a lot of unknown factors that would affect the construction and permitting costs to undertake any of these options. However, it cannot be denied that the environmental costs to raise a dam and the property costs to raise a dam are much less than the costs to construct a new dam; disregarding the construction savings of having a portion of the dam complete.

This study indicates that due to the numerous fixed costs associated with the project, the higher the dam is raised up to the 20.4 foot analyzed by this report, the cheaper the dam is in terms of cost per acre-foot of water storage. The cost can be as low as $660 per acre-foot of additional water storage.

Therefore, we recommend that the City of Crossville pursue the construction and permitting of this project by taking the next step to complete the feasibility study and beginning the permit process based on using Alternative 4 or Alternative 5 to raise the dam from 9 to 14 feet above the current normal pool. In the next phase, hydraulics should be calculated, permit issues fully defined, geotechnical investigations undertaken, additional testing performed so that the costs can be refined and even preliminary designs begun so that property tracts to be acquired could be defined and appraised. The cost to pursue this project can range depending upon the method and timeframe at which the Owner chooses to progress. Following are the estimated costs for the work described above:

Item Description	Estimated Costs
Hydraulic Feasibility	$48,000
Geotechnical Investigations	$260,000
Endangered Species Determination	$14,000
Wetlands Determination	$7,500
Stream Assessments	$35,000
Other Permit Issues	$75,000
Additional Testing	$30,000
Property acquisition and appraisals	$35,000
Topographic mapping of dam site	$7500

Appendix I
U. S. Fish and Wildlife Response

United States Department of the Interior

FISH AND WILDLIFE SERVICE
446 Neal Street
Cookeville, TN 38501

March 19, 2003

Mr. Scott J. Christian
Partner
Environmental & Civil Engineering Services
P.O. Box 6
Crossville, Tennessee 38557-0006

Re: FWS #03-0940

Dear Mr. Christian:

Thank you for your correspondence of February 24, 2003, regarding the City of Crossville's proposed Meadow Park Lake Expansion Project in Cumberland County, Tennessee. The City proposes to increase the height of the existing dam by a maximum of 10 feet to utilize the existing drainage basin boundaries for increased water storage as shown on the attachment to your correspondence. Fish and Wildlife Service (Service) personnel have reviewed the information submitted and we offer the following comments.

Information available to the Service does not indicate that wetlands exist in the vicinity of the proposed project. However, our wetland determination has been made in the absence of a field inspection and does not constitute a wetland delineation for the purposes of Section 404 of the Clean Water Act. The Corps of Engineers should be contacted if other evidence, particularly that obtained during an on-site inspection, indicates the potential presence of wetlands.

According to our records, the following federally listed or proposed endangered or threatened species may occur in the project impact area:

Gray bat (*Myotis grisescens*) (E)
Bluemask darter (doration) (*Etheostoma* (*Doration*) sp.) (E)
Cumberland rosemary (*Conradina verticillata*) (T)
Green pitcher-plant (*Sarracenia oreophila*) (E)

You should assess potential impacts and determine if the proposed project may affect these species. A finding of "may affect" could require initiation of formal consultation. Please submit a copy of your assessment and findings to this office for review and concurrence.

The white fringeless orchid (*Platanthera integrilabia*), a candidate species, is also known to occur in the vicinity of the proposed project. Candidate species are not presently listed or proposed for protection pursuant to the Endangered Species Act at this time, but they are under consideration for listing. They are not legally protected currently, but we would appreciate anything you might do to avoid impacting them.

We are concerned about the potential for impacts to Meadow Creek and Caney Fork River from the proposed project. Free-flowing streams are finite resources that the Service places a high priority on protecting. Water impoundments often result in a loss of stream length, elevation of downstream water temperatures, and degradation of water quality both above and below the dams. The consumptive use of water can also result in impacts to aquatic resources within many miles of stream below impoundments. The direct impacts of impoundment cannot be mitigated. The only means to ensure the integrity of these important natural systems is to prevent their further destruction. We recommend that an aquatic survey be conducted on the affected streams to determine their biological diversity. We also recommend that an alternatives analysis be conducted, particularly to address long-term water supply alternatives such as withdrawal from existing Federal reservoirs. The Service will more throughly evaluate the proposal during the Corps of Engineers' Public Notice comment period. However, we do recommend that pre-permit coordination be conducted on this proposal with the regulatory and resource agencies due to its potential sensitive nature.

Thank you for the opportunity to comment on this action. If you have any questions regarding the information which we have provided, please contact Wally Brines of my staff at 931/528-6481, extension 222.

Sincerely,

Lee A. Barclay

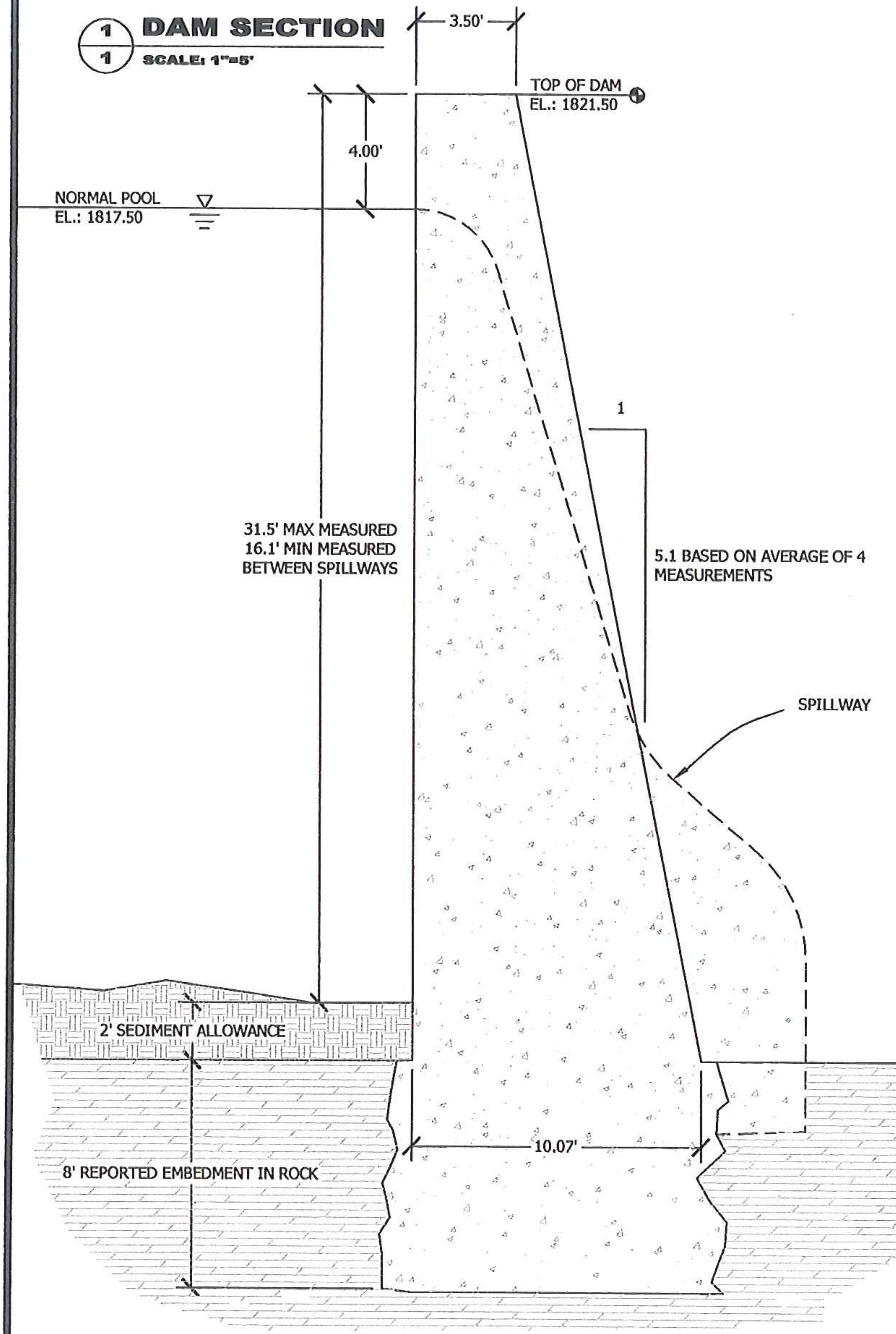
Lee A. Barclay, Ph.D.
Field Supervisor

Appendix II

Drawings/Sketches of Existing Structure and Proposed Alternates for Modification

DAM SECTION

1/1 SCALE: 1"=5'



CHK BY: S.J.C.
DESIGN BY: S.J.C.
DRAWN BY: D.W.B.
DATE: 16 JUNE 2003
PROJECT #3002
DWG #DAM SECTION
REVISION #: 0
SCALE: 1 in = 5 ft
SHEET 1 OF 1

EXISTING DAM SECTION

EXPANSION OF MEADOW PARK DAM & LAKE
CITY OF CROSSVILLE

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ENGINEERING SERVICES

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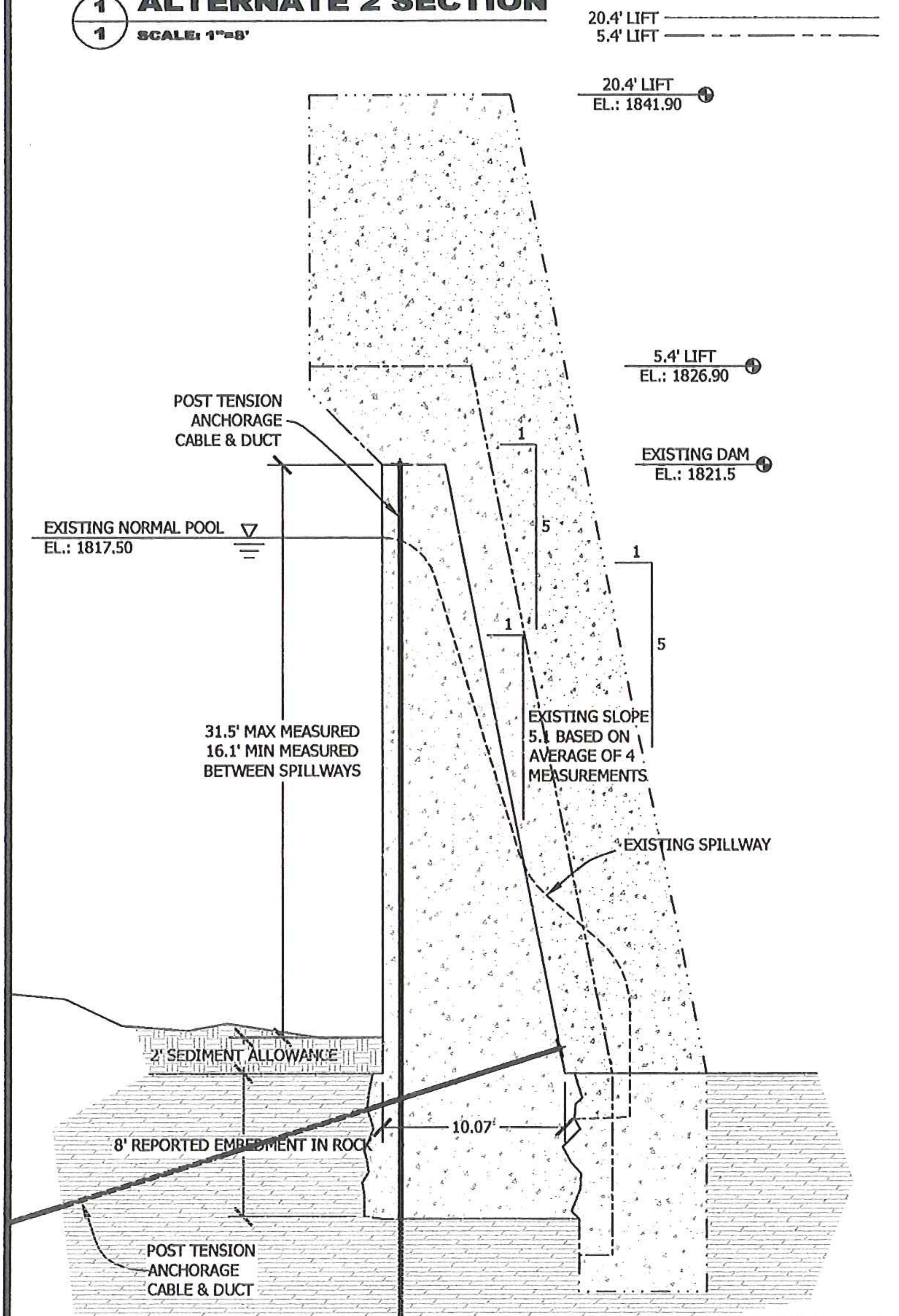
SCOTT J. CHRISTIAN
REGISTERED ENGINEER
AGRICULTURE
COMMERCE
NO. 103039
STATE OF TENNESSEE

1/1 ALTERNATE 2 SECTION

SCALE: 1"=8'



CHK BY: S.J.C.
DESIGN BY: S.J.C.
DRAWN BY: D.W.B.
DATE: 16 JUNE 2003
PROJECT #3002
DWG #DAM SECTION PROP.
REVISION #: 0
SCALE: 1 in = 8 ft
SHEET 1 OF 1

ALTERNATE 2 SECTION

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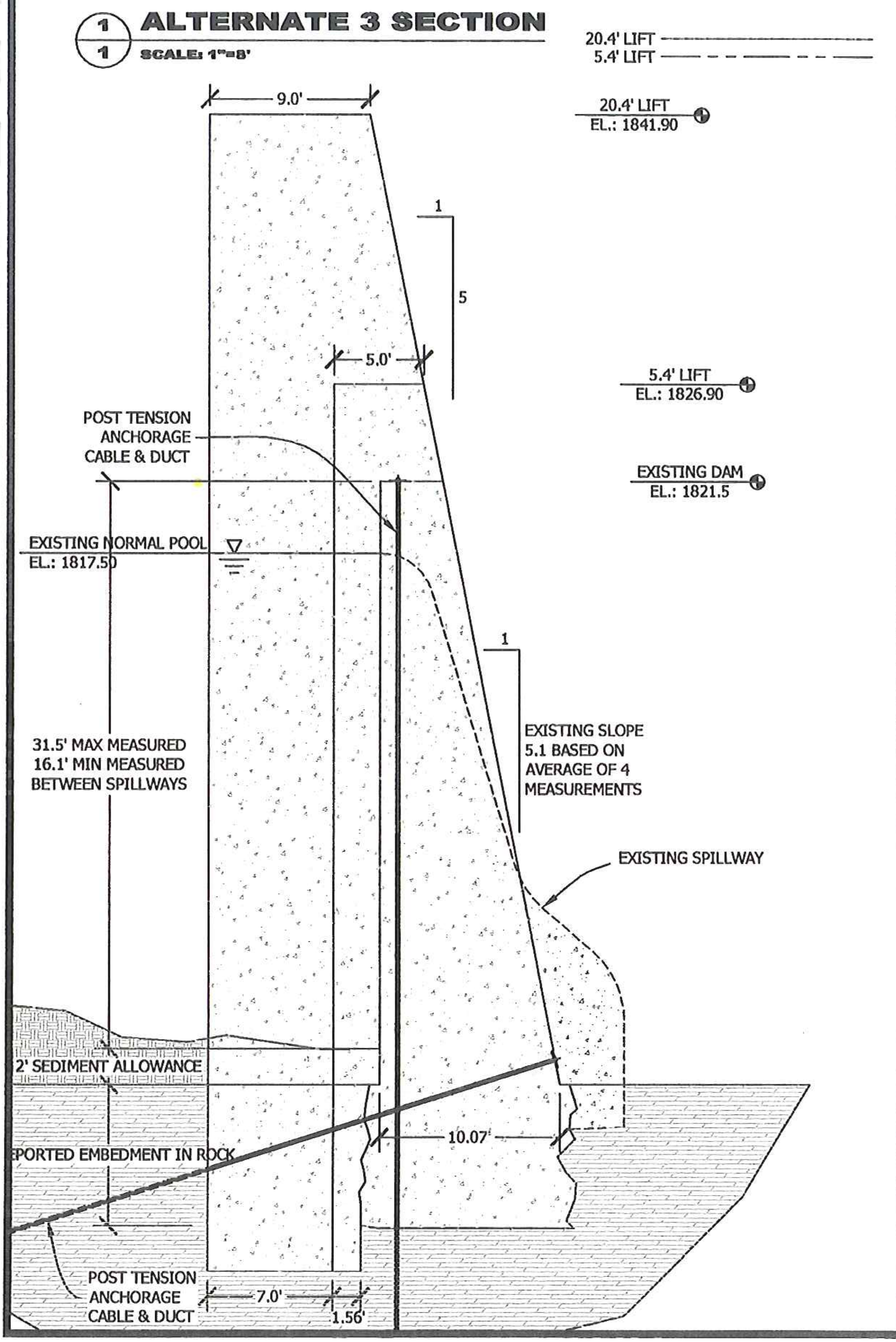

CHK BY: S.J.C.
DESIGN BY: S.J.C.
DRAWN BY: D.W.B.
DATE: 16 JUNE 2003
PROJECT #3002
DWG # ALTERNATE 3 SECT.
REVISION #: 0
SCALE: 1 in = 8 ft
SHEET 1 OF 1

ALTERNATE 3 SECTION

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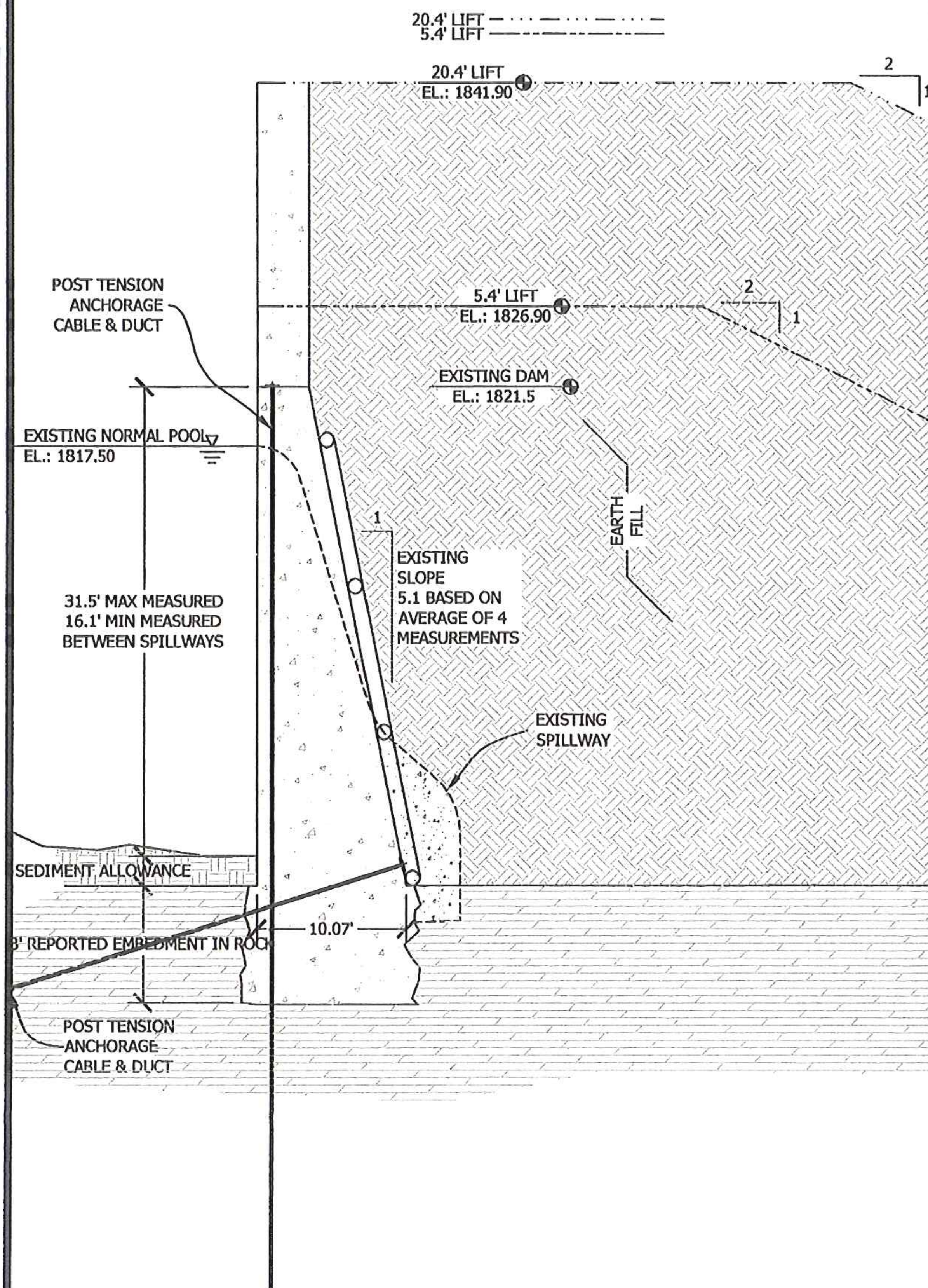
AGRICULTURE COMMERCE
NO. 103039
STATE OF TENNESSEE

1/1 ALTERNATE 4 SECTION

SCALE: 1"=10'



CHK BY: S.J.C.
DESIGN BY: S.J.C.
DRAWN BY: D.W.B.
DATE: 16 JUNE 2003
PROJECT #3002
DWG # ALTERNATE 4 SECT.
REVISION #: 0
SCALE: 1 in = 10 ft
SHEET 1 OF 1

ALTERNATE 4 SECTION

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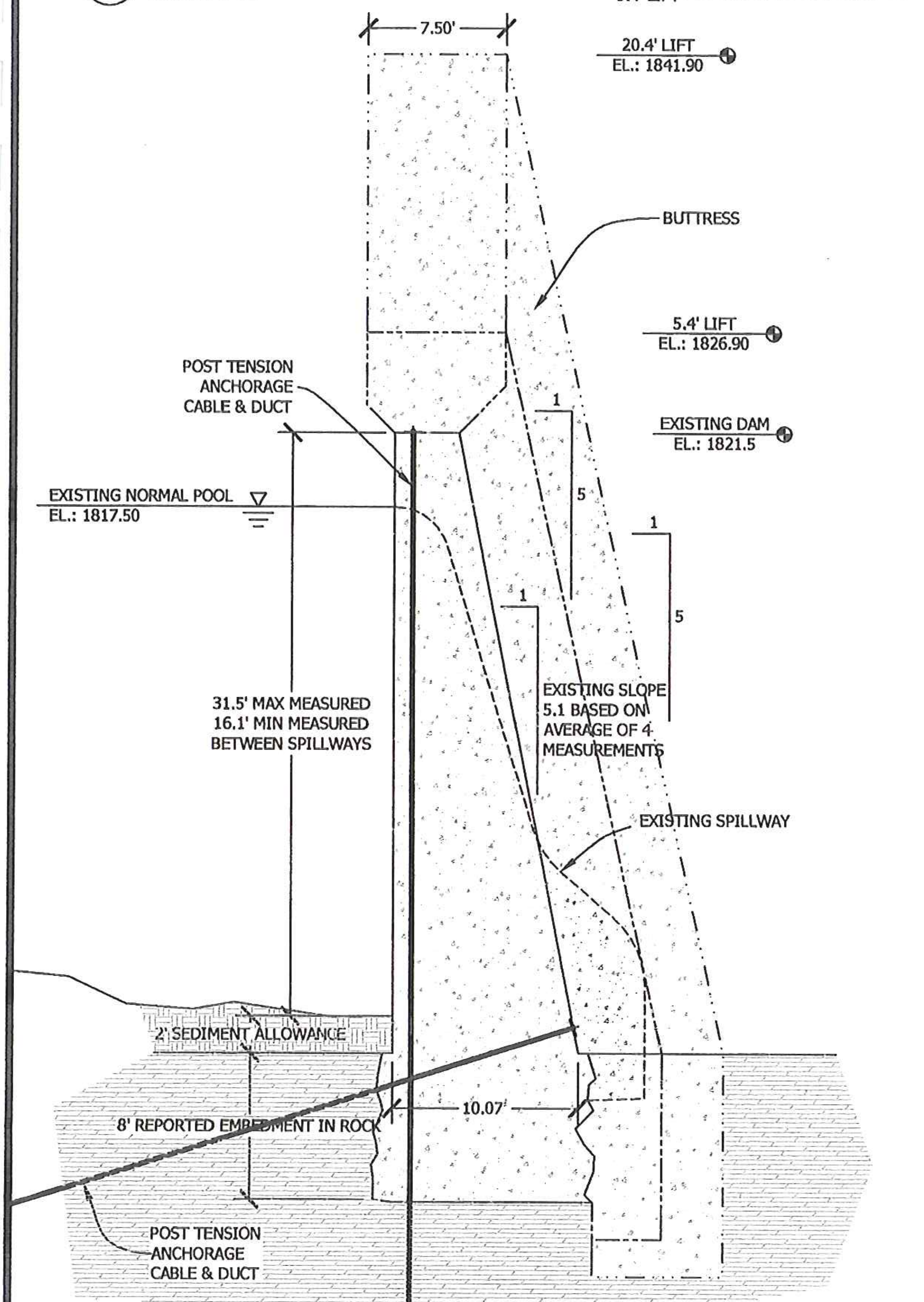
STATE OF TENNESSEE

1/1 ALTERNATE 5 SECTION

SCALE: 1"=8'



CHK BY: S.J.C.
DESIGN BY: S.J.C.
DRAWN BY: D.W.B.
DATE: 16 JUNE 2003
PROJECT #3002
DWG # ALTERNATE 5 SECT.
REVISION #: 0
SCALE: 1 in = 8 ft
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