THE GEOLOGY AND HYDROLOGY OF THE PROPOSED UPPER McCURTAIN
CREEK WATERSHED IMPOUNDMENT CHOCTAW COUNTY, MISSISSIPPI

By
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THE GEOLOGY AND HYDROLOGY OF THE PROPOSED UPPER McCURTAIN CREEK WATERSHED IMPOUNDMENT CHOCTAW COUNTY, MISSISSIPPI

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The McCurtain Creek watershed was proposed for a large reservoir project resulting in the commissioning of this study to assess the site’s geology, hydrogeology, and surface hydrology to find whether or not the site was suitable. Data was collected from 57 geophysical logs from coal exploration boreholes to produce geologic and aquifer cross sections. A program to assess discharge identified surface hydrology characteristics of the stream at five locations. Twenty-seven geotechnical boreholes, 23 standpipe piezometers, and the data from the coal exploration were used to map the water table using ArcGIS 8.3 software. Eighteen piezometers at stream sites, used to measure discharge, assessed groundwater/surface water interactions of the basin. After careful analysis, the results of this study concluded that the geology and hydrology of the basin is sufficient to support the large reservoir although engineering design will be required to mitigate some highly permeable sands for the proposed levee.
DEDICATION

To my wonderful wife, Shelley, and our two darling children, Heather and Olivia,
I dedicate this work to you, for you are the beacons in my life.
ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. Darrel Schmitz, the thesis director, especially for his patience, support, and encouragement to accomplish the thesis process and not become another statistic. I would also like to thank my committee members Dr. John Mylroie and Dr. Brenda Kirkland for all of their recommendations and guidance. I would also like to give a special thanks to Pickering, Inc. and the Choctaw County, Mississippi Board of Supervisors for financial support and project direction, especially Mr. Ron Forsythe of Pickering, Inc, and The North American Coal Corporation for the use of the geophysical logs to characterize the geology for this project and Hayes Mills and Mancel Box, residents of the study area for guidance and assistance. I would like to thank the faculty and staff of the Department of Geosciences. Furthermore, I would like to personally thank, Jay T. McKee, Jason McIlwain, Athena Owen, Jonathan McMillan, and Pieter van Thiel, for their help in collecting field data and Dr. Bill Cooke and Robert Wallace for the 10m DEM used for the GIS models. Finally, I would like to thank my wife and best friend, Shelley, for her continued support in the field and sacrifices at home, without this, none of this would not have been possible.
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CHAPTER I
INTRODUCTION

The purpose of this thesis was to document the subsurface geology and the interactions of surface water and groundwater for a proposed multi-use/multi-purpose reservoir in northwest Choctaw County, Mississippi along the upper reach of the McCurtain Creek, located south of the Natchez Trace. Analysis by Steil and Ballweber (2002) revealed that industrial growth in Choctaw County requires expansion of the available water resources within the county. A 1600 acre (647.5 ha) reservoir, as proposed, would fulfill the requirement. In the watershed, many springs in the Middle Wilcox aquifer (MWA) produce the headwaters of McCurtain Creek at elevations ranging from near 400 ft to 550 ft (122 m – 168 m) above mean sea level (m.s.l.). Preliminary designs of the reservoir south of the Natchez Trace on the creek would place the maximum flood elevation at 440 ft (134 m) m.s.l. at which many of these springs will become inundated if the reservoir is constructed. This evaluation became the framework to determine the hydraulic connectivity of the reservoir to the MWA and provides a basis for an eventual environmental impact study (EIS) to mitigate impacted wetlands and the Tennessee Valley Authority’s (TVA) power infrastructure in the watershed. Thus, this study is comprised of a highly detailed statement of setting, review of literature,
statement of problem, hypothesis, methodology, results, discussion of findings, and a conclusion to help guide the Board of Supervisors of Choctaw County, Mississippi and Pickering, Inc. for further investigation and design of an impoundment for this potential, worthwhile project and the following EIS.
CHAPTER II

SETTING

Location

Choctaw County, Mississippi is located in the northeast region of the state in the North Central Hills physiographic province and has a land area of approximately 417 square miles (1,062 km²) (McMullen, 1986 and Charlton, 1999). Bounded in the north by the Big Black River, the county’s dimensions are 29 miles (46 km) north to south by 21 miles (34 km) east to west which includes the “panhandle” jutting southward (Vestal and McCrutcheon, 1943 and McMullen, 1986). The population 9,758 (U.S. Census, 2003) is stagnant with population hovering around 10,000 during the last century. The town of Ackerman, roughly southeast of the geographic center of the county and the county’s largest town, serves as the County Seat. Ackerman is 108 miles (173 km) northeast of Jackson, the state’s capital, and 26 miles (42 km) southwest of Mississippi State University (McMullen, 1986). Figure 1 is a generalized road map of Choctaw County, Mississippi showing the county’s infrastructure (e.g. primary, secondary, and county roads), streams (including the McCurtain Creek watershed), and towns.
Figure 1. A generalized road map of Choctaw County in relation to the State of Mississippi.
The study area is the upper portion of the McCurtain Creek watershed located in the west-central portion of the county and locally referred to as the Red Hills. The delineated watershed area is near the Red Hills Lignite Mine to the east, depicted by the map in Figure 2. The study area is within latitudes 33° 22’ and 33° 18’ and longitudes 89° 21’ and 89° 17’ and is entirely located on the Weir USGS Topographic Quadrangle. Originating in the Red Hills, McCurtain Creek generally flows northward under the Natchez Trace (which is in the northern portion of the study area) and merges with the Big Bywy Ditch 6.6 miles (10.6 km) north northeast of the Trace. Big Bywy Ditch drains into the Big Black River and ultimately into the Mississippi River. Also, Figure 1 locates the study area in relation to the county’s borders, population centers and county infrastructure. Figure 2 details the project area and the topography associated with the project with the green translucent area representing the delineated watershed.

**Topography**

Choctaw County’s topography is characterized as having hilly, well drained, highly dissected terrain ranging from a high of 660 feet (201 m) at Williams Hill near Bywy to 210 feet (64 m) below Little Mountain (McMullen, 1986) and is characteristic of the North Central Hills province. Area streams thoroughly dissect steep, extensively eroded hills with streams exhibiting dendritic drainage patterns with smaller streams flowing into larger streams that have developed relatively wide, low-gradient floodplains (TVA, 1998). Within the study area, topographic relief
Figure 2. Topographic map of the Upper McCurtain Creek watershed. (Modified from data acquired through MARIS, 2003.)
ranges from a high of 602 feet (183 m) and drops to 385 feet (117 m) at the Trace with total relief of 217 feet (66 m).

**Climate**

The humid subtropical climate averages 57 inches (145 cm) of rain per year with much of the precipitation constant throughout the year. Mean annual temperature is 61º F (16.1º C). Table 1 summarizes climatic data from 1971 through 2000 (30 years) for the Central Mississippi towns of Ackerman, Eupora, and Winona with the study area roughly equidistant from each town (NWS, 2004). Summers are long, hot, and humid due to persistent tropical Gulf air masses with afternoon highs averaging 90º F (32.2º C) and morning lows averaging 68º F (20º C). Winters are short, humid, and mild with afternoon highs averaging 52º F (10.6º C) and morning lows averaging 30º F (-1.1º C). Temperature extremes in the summer can be in excess of 100º F (37.8º C) during heat waves and winters dropping to near 0º F (-17.8º C) (McMullen, 1986; TVA, 1998.) TVA (1998, p. 3-2) cites Hersfield (1961) that precipitation extreme at any “given location in the project area can expect a 1-hour rainfall of about 3.2 inches (8.1 cm) once in 50 years, a 1-hour rainfall of about 3.6 inches (9.1 cm) once in 100 years, a 24-hour rainfall of about 6.2 inches (15.7 cm) once in 10 years, a 24-hour rainfall of about 8.0 inches (20.3 cm) in 50 years, and a 24-hour rainfall of about 8.8 inches (22.4 cm) once in 100 years.” Throughout the year, runoff from precipitation is estimated to be 16-20 inches (41-51 cm) per year with losses mainly due to evapotranspiration and infiltration with sufficient recharge.
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</tr>
<tr>
<td>McCurtain Creek Watershed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>51.6</td>
<td>56.9</td>
<td>65.5</td>
<td>73.4</td>
<td>80.1</td>
<td>86.9</td>
<td>89.6</td>
<td>89.4</td>
<td>84.1</td>
<td>74.7</td>
<td>64.3</td>
<td>56.0</td>
<td>72.6</td>
</tr>
<tr>
<td>Min</td>
<td>29.7</td>
<td>32.6</td>
<td>40.6</td>
<td>48.1</td>
<td>57.1</td>
<td>64.5</td>
<td>68.0</td>
<td>66.6</td>
<td>60.6</td>
<td>48.0</td>
<td>39.7</td>
<td>32.7</td>
<td>49.0</td>
</tr>
<tr>
<td>Mean</td>
<td>40.6</td>
<td>44.8</td>
<td>53.0</td>
<td>60.8</td>
<td>68.6</td>
<td>75.7</td>
<td>78.8</td>
<td>78.0</td>
<td>72.3</td>
<td>61.4</td>
<td>52.0</td>
<td>43.9</td>
<td>60.8</td>
</tr>
<tr>
<td>Precipitation (in)</td>
<td>5.67</td>
<td>4.57</td>
<td>6.47</td>
<td>5.51</td>
<td>5.09</td>
<td>4.29</td>
<td>4.31</td>
<td>3.14</td>
<td>3.69</td>
<td>3.49</td>
<td>5.08</td>
<td>5.82</td>
<td>57.14</td>
</tr>
</tbody>
</table>
to maintain spring flow throughout the year (Charleton, 1999 and Newcome and Bettandorf, 1973).

**Geology and Hydrogeology**

The surficial geology of Choctaw County is mainly composed of the Wilcox Group (Eocene Epoch). The Wilcox Group has an arcuate outcrop that stretches from Tippah County near the Tennessee border south to the Alabama border in Lauderdale County and is depicted by Figure 3, Surficial Geology of Mississippi. The Wilcox is underlain by the Midway Group (Naheola and Porters Creek) which outcrops east and is overlain by the Claiborne Group (Tallahatta/Neshoba Sand and Zilpha/Winona) which outcrops to the west (Figure 3). In the absence of consistent county-wide geological maps for county, Figure 4 is a representation of the Surficial Geology of Choctaw County with the study area outlined in pink and major thoroughfares and population centers depicted. Table 2 presents the lithological units that are used for this study.

**Stratigraphy**

Because the Weir Geologic Quadrangle and the quadrangles to the south and to the west are not publicly available and borings and geophysical logs are proprietary and will be available only for the proposed site, the surficial and structural geology has to be researched for the study area. Several studies have been conducted in the region. Vestal and McCrutcheon (1943) mapped the county noting surficial outcrops
Figure 3. Surficial Geology of Mississippi.
Figure 4. Surficial Geology of Choctaw County.
<table>
<thead>
<tr>
<th>Series</th>
<th>Group</th>
<th>Stratigraphic Unit</th>
<th>Symbol</th>
<th>Thickness (feet)</th>
<th>Lithological Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Alluvium</td>
<td>Qal</td>
<td>-</td>
<td>Varies</td>
<td>Sand, flood plain sands and silts.</td>
</tr>
<tr>
<td>Eocene</td>
<td>Claiborne</td>
<td>Meridian Sand Formation</td>
<td>Tms</td>
<td>-</td>
<td>Sand, buff gray and weathers reddish orange to pale yellow, coarse- to medium grained resembling the Tuscohoma; erodes differently with steeper banks. Expect to find in uppermost hills of the study area at elevations near 550 ft m.s.l. *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tuscohoma Formation</td>
<td>Tu</td>
<td>400</td>
<td>Sand, dark greenish gray to light gray, weathers reddish orange to pale yellow orange, very fine- to coarse-grained, quartzose, micaceous, carbonaceous, glauconitic. Interbedded to interlaminated with clay and silt, light olive gray to brownish black, weathers to various shades of red, gray, brown, or white; lignite, contains Red Hills Mine lignite seams H through L. Basal sandy interval constitutes the Middle Wilcox Aquifer.</td>
</tr>
<tr>
<td>Wilcox</td>
<td>Nanafalia</td>
<td>Formation</td>
<td>Tgh</td>
<td>130</td>
<td>Clay and silt, medium gray to pale green, weathers to various shades of red, brown, and gray, carbonaceous, lignitic, contains Red Hills Mine lignite seams C through G; interbedded to interlaminated with sand, dark greenish gray to medium gray, weathers reddish orange to pale yellowish orange, very fine- to medium grained, quartzose, micaceous, carbonaceous, locally glauconitic. Basal portion is typically sandy.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Paleocene</td>
<td>Naheola Formation - Gravel Creek Sand Member</td>
<td>Tgc</td>
<td>80-110</td>
<td>Sand, medium gray to very light gray, weathers reddish orange to pale yellowish orange, very coarse- to fine-grained, typically fining upward, quartzose, micaceous, clay clast conglomerate; upper portion consists of clay, dark gray to light gray, typically dense, occasionally silty carbonaceous to lignitic. Contains Red Hills Mine lignite seams A and B. Unconformity at base. Basal sandy interval (along with the underlying Coal Bluff sand) constitutes the Lower Wilcox Aquifer.</td>
</tr>
<tr>
<td>Midway</td>
<td>Naheola Formation - Coal Bluff Member</td>
<td>Tcb</td>
<td>70-80</td>
<td>Sand, dark gray to light gray, weathers pale yellowish orange to reddish orange, very fine- to coarse-grained, sometimes pebbly, typically fining upward, quartzose, very micaceous, carbonaceous, clay clast conglomerate; interbedded to interlaminated with clay and silt, dark gray, carbonaceous, lignitic, especially argillaceous at the top. The lower sands may contain kaolinitic to bauxitic clay clasts or beds. Unconformity at base. Along with the overlying Gravel Creek sand, constitutes the Lower Wilcox Aquifer.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Naheola Formation - Oak Hill Member</td>
<td>Toh</td>
<td>100</td>
<td>Clay, brownish black to medium gray, weathers grayish brown to white, silty, carbonaceous, lignitic, kaolinitic to bauxitic; interbedded or interlaminated with sand, dark gray to greenish gray, weathers reddish orange to light yellowish orange, fine- to coarse-grained, glauconitic. The Oak Hill is locally predominantly sandy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Porters Creek Formation</td>
<td>Tpc</td>
<td>500</td>
<td>Clay, grayish black, weathers dusky yellow brown to brownish gray, blocky, typically exhibits conchoidal fracture; upper beds are interbedded with sand, pale yellow to light brown, fine- to very fine-grained, highly micaceous, and often containing sideritic concretions and nodules.</td>
<td></td>
</tr>
</tbody>
</table>

(Descriptions from Thompson and Morse, 2003, 1998a-c, 1997a-b. Meridian sands from personal communication with Schmitz, 2004.)

* Meridian sand member's location and series is currently disputed by geologists in the state.
and used data from borings less than 50 feet (15 m). In the study area, Vestal and McCrutcheon (1943) concluded that the highly dissected region was formed during the Eocene Epoch and identified the unit as the Holly Springs Formation of Wilcox Group separated by an unconformity above with the Meridian Sand Member of the Tallahata Formation of the Claiborne Group in the hilltops. Here, the formation strikes northwestward to southeastward (N 55º W) with a dip to the southwest at 25-30 feet/mile or 0.30º (Vestal and McCrutcheon, 1943). Approximately 40 miles to the south, Lusk (1963) provided more detail to the local stratigraphy of the Selma, Midway, Wilcox, and Claiborne groups by surveying down-dip along Mississippi Highway 25. Lusk’s (1963) findings are consistent with Vestal and McCrutcheon in strike but differ slightly with a regional dip of 30-35 feet/mile or 0.35º south southwestward, and different stratigraphic nomenclature. In a study to investigate water resources of North-Central Mississippi with groundwater being of particular interest to this study, Newcome and Bettandorf (1973) concluded that the Eocene Epoch Wilcox group middle aquifers are locally important sources of water with the Lower Wilcox being the major aquifer in Choctaw County. The depth of the Wilcox averages 400 feet to 500 feet (122 m to 152 m) and Newcome and Bettandorf (1973) provide a north-south trending hydrogeologic cross section, depicted in Figure 5. (Dockery (1981) provides a stratigraphic column for the State of Mississippi, ranging from updip (north, northeast, east) to downdip (south, southwest, and west) and corresponds to the U.S. Geological Survey (USGS, 1997).
Figure 5. North-South cross section through Choctaw County displaying the Lower Wilcox Aquifer (adapted from Newcome and Betandorf, 1973 and TVA, 1998).
Some recent geological studies of Choctaw County (or regional studies including the county) have been completed and centers mainly around the development of lignite seams of the Red Hills. In a master’s thesis, Dueitt (1985) studied the petrography and stratigraphy of the lignite seams of the Wilcox Group. During the initial stratigraphic analysis of Choctaw and Winston Counties, Dueitt (1985) compared the findings of several writers’ differing nomenclature for the formations of the Wilcox ranging from Wilcox Group Undifferentiated, Holly Springs and Ackerman Formations, and Hatchetigbee, Holly Springs, and Ackerman Formations. As presented, the overlying and underlying unconformities correspond, yet thicknesses do not. Furthermore, Dueitt’s work does not follow the nomenclature of the Dockery’s (1981) stratigraphic column. In a master’s thesis, Charleton (1999) gathered baseline information of the shallow groundwater aquifers prior to commissioning the Red Hills Lignite Mine in which the aquifers and stratigraphy of the area are defined. Of special interest in Charleton’s study, he researched the next significant watershed to the east of the study area. Charleton (1999, p6 citing Hosman and Weiss, 1991) describes the portion of the middle and lower Wilcox as the “thin interbedded sands, clays, silts, and lignites compose the Wilcox, and the stratified clays, silts, and lignites retard the vertical movement of water throughout the entirety of the unit.”

Presently, Thompson and Morse (2003, 1998a-c, 1997a-b) have completed six 7.5 minute geologic maps within Choctaw County, and efforts to produce the county’s remaining quadrangles continue. Strikes are consistent and dip in the study
area is to the west southwest at 40 feet/mile or 0.43° (as per conversation with Thompson, 2004). The stratigraphy corresponds to the data presented by the USGS with exception of the Meridian Sands (USGS, 1997). The unit descriptions offered by Thompson and Morse will be used for the remainder of this study with exception of the Meridian Sands of the Claiborne Group. The location and age of deposition of the Meridian Sands is currently disputed by several geologists (as per conversations with Schmitz, 2004). Based upon the geologic descriptions and interpretations by the authors above, Figure 6 represents the geologic cross section (A-A’) of the proposed McCurtain Creek Reservoir located in Figure 2. This cross section has a vertical exaggeration 10 times the horizontal scale. Observation of the strata at the Red Hills Lignite Mine correlates to the cross section as drawn. The Meridian Sands are located in the higher hilltops in the study area and in the western part of the county. Figure 6 is an idealized cross section along dip for the study area.

Structure

The study area is devoid of visible structural features such as faults, joints, folding, etc. Lusk (1963, p 34) describes the “structural condition of the beds (as) homoclinal and primary.” Thus, a review of the literature and aerial photography (Digital Orthogonal Quaterquads) (MARIS, 2003) for the Weir Quadrangle for liniments and other controls were unremarkable. Any evidence of past faulting has been eroded away or is thousands of feet below the surficial depositional strata.
Figure 6. Cross section of the Upper McCurtain Creek watershed perpendicular to strike.
However, recent quarrying at the Red Hills Lignite Mine’s north quarry face reveals of the existence of a large paleochannel and a normal fault (as per conversations with Schmitz, 2005). Yet, significant structures within the county do exist. Vestal and McCutcheon (1943) noted some folding or doming occurring near Ackerman with dips between 30°-40° in an exposed outcrop and reverse dips in the Blantons Gap, 5 miles (8 km) southeast of Williams. Also, Vestal and McCutcheon (1943) notes the existence of a dome near Sturgis with a major fault cutting into Oktibbeha County which is not indicated on the Sturgis Quadrangle (Thompson and Morse, 1997a) and minor faulting and jointing in outcrops east of the study area in which stream flow is controlled by these structural features.

Located approximately 15 miles (24.0 km) to the northwest is the Kilmichael Dome in neighboring Montgomery County. Priddy and McCrutcheon (1943) report that this uplift feature is roughly circular and approximately 8.5 miles (13.6 km) in diameter and is characterized by intense faulting and reverse dips. This dome exposes the strata of the Wilcox and Midway Series with marginal fault blocks creating several sets of horst and graben blocks involving successively younger beds. Furthermore, the authors report that if the normal dip is projected through the dome, they calculate that there has been 800 to 1200 feet (243 to 366 m) of uplift in the area (Priddy and McCutcheon, 1943). Since Priddy’s (1946) explanation, little has been published on the cause of this uplifting, however, several recent proceedings abstracts have been published ranging from an extraterrestrial impact structure to rotational uplifting (Ingram, 1998; Schmitz, 1999; King 2002; and Sloan, 2003).
Soils

The U. S. Department of Agriculture’s Natural Resources Conservation Service (McMullen, 1986) (formerly Soil Conservation Service) and MARIS (2005) shapefiles identifies two relevant soil associations for the watershed area: Smithdale-Ruston-Ora and Smithdale-Sweatman-Providence detailed in Figure 7. They are characterized by gently sloping to steep with moderately- to well-drained silty to loamy soils. Some soils are hydric in the drainage basin including substantial wetland areas.
Figure 7. Soil association map for the Upper McCurtain Creek watershed.
CHAPTER III
REVIEW OF LITERATURE

T. C. Winter has written extensively about the interaction of surface water and groundwater with most of his work concentrating on the interaction of lakes with groundwater, primarily in the northern United States (Winter and others, 2000; Winter and others, 1998; Mau and Winter, 1997, Winter and others, 1988; Winter and Carr, 1980; and Winter, 1984, Winter, 1976). However, very little research has been done in the discipline, and a review of the literature reveals no published work within the discipline performed in the Mississippi Embayment. Thus, this literature review was accomplished by reviewing previously published groundwater/surface water interaction investigations in general and the previous hydrogeologic investigations within northwest Choctaw County.

Previous Water Interactions Investigations

Previous surface water/groundwater interactions studies include Perkins (1999), during dissertation research, provides an algorithm combining elements of SWAT and MODFLOW, computer models, to incorporate RS/GIS data to predict baseflow and aquifer drawdown. Oxtobee (2001, Oxtobee and Novakowski, 2002)
provides a method of locating groundwater discharge points by analyzing deuterium, $\delta^{18}$O, ambient temperature surveys and electrical conductivity within a channel. Nemeth and Solo-Gabriele (2003) modeled channel leakages into an aquifer and provided a numerical model based on derivations of the Darcy and transmissivity equations. Girard and others (2003) conducted interaction studies resulting from a placement of a dam using standpipe piezometers and stream flow stage to determine changes in aquifer levels due to regulated seasonal floodwaters by the structure.

**General Choctaw County Water Resources Investigations**

Prior to the Red Hills Mine coming online in 2000 and their baseline studies taken, little detailed hydrogeologic studies were solely conducted in northern Choctaw County. Rather, regional studies have been performed encompassing several counties, up to the entirety of the Mississippi Embayment, such as the studies of the Regional Aquifer-System Analysis (RASA) Program. No evidence of groundwater/surface water interaction studies were found within the Embayment. Chronologically, the following studies have included the study area.

Lang and Boswell (1960) assessed water resources for Northern Mississippi. Keady (1970) conducted studies on the Wilcox aquifers in Mississippi to determine the geochemistry. Newcombe and Bettandorf (1973) compiled well log data from Mississippi Office of Land and Water Resources that date back to the early 1900’s to provide water resources data for industrial use for eight counties in Central Mississippi that included Choctaw County. Studying the Middle Wilcox Aquifer,
Taylor and Authur (1991) studied the physical and chemical properties that included three wells in northern Choctaw County. Hossman and Wiess (1991) studied the geological units of the Mississippi Embayment and the aquifers associated with the subsurface units while Mallory (1991) focused on the hydrogeology of eastern Mississippi and western Alabama. Oakley and others (1994) compiled a potentiometric map of the Lower Wilcox Aquifer in Mississippi which, among others, used several wells in Choctaw County using data from 1979 to 1988. Charlton (1999; Charlton and Schmitz, 1999) conducted his master’s thesis gathering baseline physical and chemical properties of the ground water resources for a study area that is now the Red Hills Mine. The TVA (1998) published its final environmental impact study (EIS) for the projected mine which duplicates the hydrogeologic data found within Charlton’s thesis. Williamson and Grub (2001) completed a study analyzing the Gulf Coast Regional Aquifer as a part of the RASA Program begun by the USGS in 1978 and included the study area, specifically the Middle and Lower Wilcox. Lockhart (2004) studied geohydrochemical relationships of iron affecting the water quality of the Middle and Lower Wilcox Aquifers. Finally, Schmitz and others (2004; 2005) presented a report to Pickering and Associates detailing the locations of 59 springs, climatological water budgets, chemical and physical properties of the McCurtain Creek Watershed, the study area. This project is associated with this research.
CHAPTER IV

STATEMENT OF PROBLEM

Because a probable location of the impoundment to be constructed has been located in the McCurtain Creek drainage basin, a detailed study of the underlying geology and the hydrogeological characteristics of the units were conducted to determine if the site is suitable. One indigenous resident reported attempting to build a small pond within the proposed area several years ago and to date, this pond fails to hold water at the designed level, probably due to the hydrogeologic characteristics of the underlying sands. It is this concern that has prompted this detailed study to be performed to determine if the geology of the area and the impound structures will support a large reservoir in the proposed area and if the conditions reported by the resident are local or regional.

Hypothesis

The site of the proposed impoundment on McCurtain Creek, Choctaw County, Mississippi is (or is not) suitable based on its geology and hydrogeology.
Objectives

For this reservoir project to be completed, and, to fill and stay filled with water, two things needed to be known. First, the geology of the proposed basin north of the Natchez Trace had to be assessed, and any highly permeable sands and/or aquitards that would pose a problem to the construction of the proposed reservoir had to be mapped. Second, it was necessary to analyze the water resources within the basin to assess whether or not there is sufficient water available to fill and sustain the proposed reservoir. Thus, these objectives established the geology of the proposed site by using selected geophysical logs from borings performed by Phillips Coal Company (provided by The North American Coal Corporation and geotechnical reports provided by Pickering, Inc. from Phase I and II of this project. Once cross sections were developed for the area of concern, a detailed hydrologic study of the watershed and determination of the hydrogeological properties was determined by using a series of standpipe piezometers and the geophysical logs locating the water table that were used to map the piezometric surface of the proposed reservoir site and its watershed.
CHAPTER V

METHODOLOGY

Groundwater/Surface Water Interaction

In a drainage basin, the interaction of groundwater and surface water occurs in several ways. Interactions occur as rain falls on the surface and infiltrates into recharge zones of connected confined and unconfined aquifers. Unconfined aquifers outcropping into slopes or valley bottoms create springs. Interactions occur at streams in all terrains through gaining streams and losing streams to and from hydraulically connected aquifers that are usually unconfined. Thus, groundwater/surface water interactions are affected by topography, geology, hydrogeologic properties, precipitation, and groundwater flow conditions (Cey and others, 1998).

The interaction of surface water and groundwater primarily begins in the unsaturated zone whereby surface water infiltrating the ground surface moves downward from the pull of gravity (Deming, 2002; Winter, 1984). Over time, this water continues to be pulled towards the water table whereby it enters regional flow systems, often referred to as recharge areas and usually found in topographically high places (Fetter, 2001). However, some groundwater percolating through the unsaturated zone begins to move in directions away from topographic highs to lows. This is called interflow and is
acted upon by capillary forces that tend to retain water within the pore spaces. Once the water percolates through to the water table, groundwater flow begins. Figure 8 describes the hydrologic processes occurring in a typical valley profile where a gaining stream is present showing the groundwater divide corresponding to the topographic divide.

Deming (2002, p 158) defines a groundwater divide as “a ridge on the water table that separates areas of lesser head values.”

Figure 8. Graphic representation of ground water divides in relation to continental divides. Also, this figure depicts hydrologic processes including groundwater inflow (Deming, 2002, p 158).

Once water has entered the saturated zone, hydrogeologists can measure subsurface flow using the equation pioneered by Henry Darcy. Darcy, a 19th Century French civil engineer, developed an equation to calculate the flow of water through a sand media. The Darcy equation is represented by the following equation:

\[ \frac{Q}{A} = q = K\left(\frac{h_1 - h_2}{\Delta l}\right) \]  

(1)
where \( q \) is specific discharge in m/sec, which is \( Q/A \), and \( A \) the cross sectional area in m\(^2\), \( K \) is constant of proportionality or hydraulic conductivity in m/sec, and \((h_1 - h_2)/\Delta l\) is the dimensionless hydraulic gradient that represents the change in water level elevation. To find the constant of proportionality that is based on type of media, the following equation can be used:

\[
K = \frac{k \rho_w g}{\mu}
\]  

(2)

where \( k \) is the intrinsic permeability (m\(^2\)), \( \rho_w \) is the density of water, \( g \) is the acceleration due to gravity (9.88 m/sec\(^2\)), and \( \mu \) is the viscosity of water. (Deming, 2002; Fetter, 2001; and Domenico and Schwartz, 1998). However, Equation 1 assumes linear flow two-dimensionally; however groundwater flow typically moves in three dimensions in an anisotropic media which is represented by the following equations:

\[
q_x = -K_{xx}(\partial h/\partial x) - K_{xy}(\partial h/\partial y) - K_{xz}(\partial h/\partial z)
\]  

(3a)

\[
q_y = -K_{yx}(\partial h/\partial x) - K_{yy}(\partial h/\partial y) - K_{yz}(\partial h/\partial z)
\]  

(3b)

\[
q_z = -K_{zx}(\partial h/\partial x) - K_{zy}(\partial h/\partial y) - K_{zz}(\partial h/\partial z)
\]  

(3c)

which describes subsurface flow along the \( x, y, \) and \( z \) axes and is graphically represented in Figure 9.
Related to hydraulic conductivity is transmissivity. Domenico and Schwartz (1998, p 67) define transmissivity as “the rate of flow of water at the prevailing temperature through a vertical strip of aquifer one unit wide, extending the full saturated thickness of the aquifer, under a unit hydraulic gradient.” Transmissivity represented by the following equation:

\[ T = Km \]  \hspace{1cm} (4)

where \( T \) is the coefficient of transmissivity (m\(^2\)/sec), \( K \) is hydraulic conductivity (m/sec), and \( m \) is the formation thickness (m).

Hydrographs are the primary measure of streamflow that graphs changes in volumetric discharge of water over time (Demming, 2002). Following a rainfall event, streams tend to rapidly increase discharge followed by a slow fall that may continue for several months. Thus, hydrographs can be divided into two components. First, quickflow is the flow coincidental with a rainfall event that rapidly rises and then falls
back to a more normal state. Second is baseflow. Baseflow, or seasonal flow, is the portion of stream flow that has a longer duration and declines slowly and is calculated from equation 5:

$$Q = Q_0 e^{-at}$$

(5)

whereby $$Q$$ is the flow at sometime after recession starts, $$Q_0$$ is the flow at the start of the recession, $$a$$ is the recession constant for the basin, and $$t$$ is the time since the start of the recession (Fetter, 2001, p42). Inferring from Deming (2002), baseflow discharge is sustained by water mounded as depicted by Figure 8 discharging into the stream from diffuse effluent groundwater flow or in some cases as separate springs.

In the Red Hills of Choctaw County and the McCurtain Creek watershed in particular, two types of springs are prevalent. They are depression springs and contact springs (Fetter, 2001). Where the water table intersects topography, springs or seeps may be present and are called depression springs. Contact springs occur where a confining layer of low permeability intersects topography and water is transmitted above this layer discharging onto a hillside. With both types of springs, discharges can be constant or intermittent throughout the year with variations in dry periods in relation to the elevation of the water table.

Methods of Investigation

This study was conducted by analyzing the surface and subsurface geology and hydrology of proposed reservoir area and by using the geophysical logs from borings in the area collected during the 1970’s and 80’s by Phillips Coal Company, supplied by The
North American Coal Corporation. These logs were used to determine the geology of the proposed reservoir and the location of the water table when the boreholes were drilled. Specifically, 57 logs of boreholes drilled to 300 feet were analyzed to develop six cross sections of the area. The six cross sections generated were divided into three sections trending down dip and three trending along the strike of the regional geology described in the setting. The logs were cross referenced with the relevant 27 shallow geotechnical logs provided by Pickering, Inc. These cross sections were developed using AutoCAD Lt 98 and used internally within the Department of Geosciences and Pickering, Inc. prior to this study being completed. Cross section geological units are drawn connecting borehole to borehole whereby information is assumed due to lack of information between boreholes.

The second phase of this study analyzed the hydrologic properties of the proposed basin. This was a continuation of the work performed by Schmitz and others (2004; 2005). This work located springs in the proposal site and began to determine the hydrographic stage-discharge relationships using cross-sectional area/velocity measurements at five sites within the basin.

Along with six standpipe piezometers within the basin provided by Pickering, Inc., the study added 17 standpipe piezometers arranged so that four piezometers are located perpendicular to each stream monitoring site (two on each bank of the stream) located at roughly 10-15 foot elevations to assess whether or not that the stream location is a gaining or losing stream. Figure 10 is a representative schematic to show the placement of the peizometers in relation to the stream. At the stream crossing near the
Natchez Trace, this crossing had only two piezometers, because it is below the location of the proposed levee. Data from the standpipe piezometers was analyzed and averaged for wet and dry periods and allowed for the piezometric surface to be mapped using ArcGIS 8.3. Using this program applied a 10-meter DEM (Digital Elevation Model) to model the subdued piezometric surface following a methodology used by Peck and Payne (2003). Peck and Payne (2003) successfully modeled the water table of Georgia and portions of South Carolina and Florida using a 30 meter DEM and the linear regression model between surface elevation and depth to the water table from well data in their large study area. By using these methodologies, this study establishes hydrologic connectivity to the associated Wilcox aquifers in the region.

All maps produced in this study were produced using ArcGIS 8.3 and were projected in Mississippi Transverse Mercator (MSTM) North American Datum 1983 (NAD83). Base data shapefiles were downloaded from the Mississippi Automated Resource Information System (MARIS) which provides a GIS data warehouse of relevant information for the state of Mississippi (MARIS, 2003).
CHAPTER VI
RESULTS

Between October 2003 and April 2005, several phases to this study were conducted and reported to Pickering, Inc. and their client, the Board of Supervisors of Choctaw County, Mississippi. In this chapter, these phases are organized chronologically based on task completion and reporting even though most of the tasks were performed simultaneously. The tasks included a spring inventory, surface water monitoring, geological cross sections, piezometric surface model, and groundwater/surface water interactions. Large data sets are tabularized and presented in the appendixes.

Spring Inventory

A spring inventory was conducted in the upper McCurtain Creek basin for the proposed reservoir between October and December 2003 under the direction of Dr. Darrell Schmitz. A total of 58 spring heads were located by a physical survey in the basin with grid coordinates (latitude and longitude) recorded with Global Position System (GPS). Once found, the springs were identified with three alphanumeric digits followed by four digit numeric sequence such as SPF 1001. “SP” designates a spring followed by an “F” for locations in Township 9E or “G” for locations in Township 10E in the basin
duplicating the method used by the State and the U. S. G. S. The four digit number assigned to each spring also corresponds to Township. Sequences in the 1000 range correspond to Township 9E while sequences in the 1100 range correspond to Township 10E. For springs whose discharge was sufficient, discharge was estimated using the velocity–area method and their water quality parameters were measured using a Yellow Springs International (YSI) environmental sonde. The water quality parameters collected were temperature, pH, specific conductivity, dissolved oxygen, and turbidity (Schmitz and others, 2004). These data are tabularized in Appendix A. Using the data in Appendix A, the latitude/longitude data were imported and mapped using ArcGIS 8.3. Figure 11 is a map locating of the 58 spring heads which is overlaid on the basin’s topographic map with the watershed delineated in translucent green.

**Surface Water Monitoring**

Surface water monitoring within the basin was conducted from September 2003 to April 2005 at five sites within the upper reach of McCurtain Creek. They were designated SW-1, SW-2, SW-3, SW-4 and SW-5 and are depicted in Figure 12. A total of 71 events of data were collected at these five sites. Four of the sites, SW-1, SW-2, SW-4, and SW-5, were on road crossings over McCurtain Creek and another site, SW-3, was on a road crossing over an unnamed tributary near Pisgah Church. These events of collected data at the five crossing in which base flow data and high flow discharge events were calculated using the velocity-area method and the subsequent calculations are included in Appendix B. From these events, stage versus discharge hydrographs were
Figure 11. Spring inventory for the proposed reservoir on McCurtain Creek.
Figure 12. Map of the surface water monitoring stream crossings.
created at each of these crossings utilizing the acquired data which are presented in Figures 13 through 17.

Along with the discharge data, water quality parameters were measured using the YSI sonde and included temperature, pH, specific conductivity, dissolved oxygen, and turbidity. These data are tabularized in Tables 3 through 7 and summarizes the event discharge. While the YSI environmental probe is a good indicator of water quality, a potable water chemical analysis was taken at each monitoring site. In a Mississippi Chemical Laboratory report dated February 15, 2005, initial chemical analysis data at base flow (Appendix C is complete report and analysis components) reveals that all monitoring locations meet minimal contaminant levels (MCL) except for higher than normal levels of iron and manganese noted in Table 8 with values highlighted in red indicating value of MCL. Thus, the analyses show that high background levels of iron are present at four of the five crossings, whereas, high background levels of manganese are present at three of the four crossings.
Hydrograph for SW-1

\[ y = 22184 \ln(x) - 131942 \]

\[ R^2 = 0.9964 \]

Figure 13. Stage/discharge hydrograph for site SW-1.

Hydrograph for SW-2

\[ y = 21439 \ln(x) - 127989 \]

\[ R^2 = 0.9699 \]

Figure 14. Stage/discharge hydrograph for site SW-2.
Figure 15. Stage/discharge hydrograph for site SW-3.

Figure 16. Stage/discharge hydrograph for site SW-4.
Figure 17. Stage/discharge hydrograph for site SW-5.

Table 3. Water Quality and Hydrologic Data for SW-1

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<th>D.O.mg/l</th>
<th>Stage</th>
<th>Discharge (ft³/sec)</th>
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<td>N/A</td>
<td>N/A</td>
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<td>N/A</td>
<td>N/A</td>
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<td>7.16</td>
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<td>10.93</td>
<td>437.80</td>
<td>1.378</td>
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</table>

Table 8. Selected Constituents Showing Higher than MCL.

<table>
<thead>
<tr>
<th>Site</th>
<th>Iron</th>
<th>MCL (FE)</th>
<th>Manganese</th>
<th>MCL (Mn)</th>
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</thead>
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<td>SW-1</td>
<td>0.47</td>
<td>0.30</td>
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<td>SW-2</td>
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<td>0.30</td>
<td>0.062</td>
<td>0.05</td>
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<td>SW-3</td>
<td>0.52</td>
<td>0.30</td>
<td>0.098</td>
<td>0.05</td>
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<tr>
<td>SW-4</td>
<td>0.32</td>
<td>0.30</td>
<td>0.034</td>
<td>0.05</td>
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<td>SW-5</td>
<td>0.22</td>
<td>0.30</td>
<td>0.023</td>
<td>0.05</td>
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Geological Cross Sections

Geophysical logs from 57 boreholes dating from 1976 through 1980 were provided by the North American Coal Corporation (NACC) and were analyzed to develop six geological cross sections (Appendix E). Two sets of the cross sections (Appendixes E and F) were developed to locate the strata of the basin down to approximately 300 feet (92.6 m) below the surface and to locate the aquifers and aquitards of the Middle Wilcox Aquifer (MWA). Several coal seams in the area were used to correlate the strata but are not included in the cross sections as per agreement with NACC. The cross sections were for greater clarity using AutoCAD Lt 98. Figure 18 locates boreholes associated with the cross sections used in this study. Strata within the cross sections were assigned permeabilities based on grain size summarized in Table 9 (modified from Domenico and Schwartz, 1998) and later converted to the aquifer/aquitard cross sections (Appendix F).

Table 9. Hydraulic Conductivity of Strata

<table>
<thead>
<tr>
<th>Strata</th>
<th>Permeability</th>
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<tr>
<td>Coarse Sand</td>
<td>$10^{-5}$ to $10^{-1}$ cm/s</td>
</tr>
<tr>
<td>Sand</td>
<td>$10^{-3}$ to $10^{-7}$ cm/s</td>
</tr>
<tr>
<td>Sandy-Silt</td>
<td>$10^{-6}$ to $10^{-2}$ cm/s</td>
</tr>
<tr>
<td>Silt</td>
<td>$10^{-7}$ to $10^{-5}$ cm/s</td>
</tr>
<tr>
<td>Silty-Clay</td>
<td>$10^{-9}$ to $10^{-4}$ cm/s</td>
</tr>
<tr>
<td>Clayey-Silt</td>
<td>$10^{-9}$ to $10^{-6}$ cm/s</td>
</tr>
</tbody>
</table>

Piezometric Surface Model

A model of the piezometric surface was constructed using ArcGIS 8.3 to locate the water table within the upper McCurtain Creek watershed. This model is depicted by
Figure 19 and was comprised of the 57 boreholes from NACC, 21 geotechnical boreholes from contracted from Pickering, Inc., and 17 boreholes near the surface monitoring sites for this study. Of the 21 boreholes from Pickering, Inc, 6 were fitted with piezometers. All 17 hand-augered boreholes were fitted with piezometers for a total of 23 monitored piezometers used for this study. All other boreholes utilized the depth to the water table encountered during the borings as reported by the geotechnical firms or the geophysical logs from the NACC boreholes (see Appendix D). Figure 19 is a contour map of the model depicted in Figure 20 which is the raster model of the piezometric surface in elevation. Figure 21 is the same model depicted as departure from the surface elevation.
Figure 18. Map locating the boreholes used to create cross sections.
Figure 19. Contour map of the water table in the Upper McCurtain Creek drainage basin.
Figure 20. 10 meter DEM model of the water table.
Figure 21. 10 meter DEM of the water table's departure from the surface DEM.
**Groundwater/Surface Water Interactions**

A total of 17 shallow monitoring wells were hand-augered in the right-of-way of the county roads adjacent to each of the surface monitoring sites to assess groundwater/surface water interactions. Specifically, at crossing SW-1, two wells were set in the flood plain adjacent to McCurtain Creek. At crossings SW-2, SW-4, and SW-5 a series of four wells set, arranged so that one well was placed on either side of the creek in the floodplain and two were set approximately 10 to 15 feet in elevation above the floodplain. At SW-3, only three were set similar to crossings SW-2, SW-4, and SW-5, however, since B-19 had already been set by contract through Pickering, Inc. and was near the creek (unnamed tributary). SW-4 also had borehole B-1 set by contract in the floodplain, and was used in the analysis. This gave a total of 19 shallow monitoring wells which were used to analyze the interactions of the five sites. The results of the analyses are that at each surface monitoring site, the creek is gaining water from the bottom surface of the creek. Furthermore, observation at each site during surface monitoring events indicates that during base flow conditions, all year long, that the banks are wet above the water surface in the creek. In Figures 22 through 26, the water table in relation to the base flow conditions and are schematically represented. At site SW-3, a sandstone layer several inches thick is present and its location is represented.
Figure 22. Interactions schematic for site SW-1.
Figure 23. Interactions schematic for site SW-2.
Figure 24. Interactions schematic for site SW-3.
Figure 25. Interactions schematic for site SW-4.
Figure 26. Interactions schematic for site SW-5.
CHAPTER VII

DISCUSSION

Geology

The geology of the proposed site is situated on the Wilcox Group which is characterized by its fluvial-deltaic deposits of the Tuscohoma Formation from the Pliocene Epoch. The meandering streams of the McCurtain Creek basin drains the densely vegetated, highly dissected, hilly terrain and form the rich Quarternary alluvial flood plains made up of interbedded sands, clays, and silts interpreted from the boreholes in the field. The geophysical logs from the 57 boreholes provided by NACC that were drilled to depths of 300 ft (92.6 m) below the surface, clearly indicates Tuscohoma Formation’s micaceous sands, the Nanafalia Formation, Grapian Hills Member’s clays and silts at lower depths. It is the Grapian Hills Member that forms an aquitard boundary between the Middle and Lower Wilcox Aquifers (LWA). Several coal prospecting geophysical logs taken at lower surface elevations in the basin penetrate the Gravel Creek Member of the Nanafalia Formation which is also characterized by micaceous sands and is part of the LWA. At elevations higher than 570 ft (173.7 m) and observed at Hilltop 602 in the higher, southern portions of the study area, the Meridian Sand Member of the Claiborne Group is present and is characterized by its coarse- to medium-grained
micaceous sands. These controversial sands closely resemble the Tuscohoma sands which are nearly eroded from this area of Choctaw County. Thus, the Tuscohoma-Meridian sand contact on Hilltop 602 is at an elevation of approximately 580 ft (176.8 m) outcropping with a lignitic sandstone layer approximately 1.5 ft (0.5 m) thick.

The geological cross sections (Appendix E) indicate the possibility of normal faulting within the basin. However, due to the spacing of the geophysical logs used for the analysis, there is no clear, overwhelming evidence of faulting and three-dimensional seismic records are not available. Yet, at the nearby Red Hills Lignite Mine, quarrying has unearthed a normal fault with a throw large enough to completely offset one coal seam to another. Thus, the disjointed strata shown in the cross sections could be evidence of some normal faulting.

**Hydrogeology**

The six aquifer/aquitard (Appendix F) cross sections show the relative locations of the MWA, and at some locations at lower elevation, the LWA is indicated. These cross sections resulted from an analysis of the hydraulic conductivity of the strata based on Table 10. This table resulted from modifying a table by Domenico and Schwartz (1998). For the purposes of the cross sections, coarse sand, sand (fine-grained), sandy-silt and silt were considered aquifers while silty-clay, clayey-silt, and clays were considered aquitards. The coal seams in the area, which are not plotted on the cross sections as per agreement with The North American Coal Company, would be considered aquicludes and are present within the strata. The observed water table of the unconfined
aquifers is plotted on the cross sections mimicking the topography in which the piezometric surface model (Figures 19, 20 and 21) clearly shows with the water table data that was available from the geophysical logs.

Observed in the basin, coarse- to medium-grained, micaceous sands associated with the Tuscohoma Formation have high permeabilities approaching free flowing conditions. Specifically, these sand lenses were observed near site SW-5 at well 5-1 and at Pickering’s BH-18 (Figure 27) located below the levee of a local resident’s pond that will not hold water. The geophysical logs for the 57 NACC boreholes and the resulting cross sections revealed the locations of the sands with high permeabilities. These sands could be remnant paleochannels from Pliocene/Eocene ancestral river systems draining the Appalachian Mountains and are similar to the one unearthed at the Red Hills Mine. When matching the locations of the sand lenses to the topography where the lenses outcrop, springs are generally present. These springs will feed the proposed reservoir.

**Levee Site**

At the location near the proposed levee site on the west abutment (see Figure 28 for the proposed levee and reservoir footprint), a coarse- to medium-grained, micaceous sand lens was identified by borehole BH-22 (Pickering, 2004) and geophysical log CH 904 from geologic cross section A-A’ (Appendix E). This sand lens could possibly cause piping under the proposed levee through the hill on the northwest abutment of the proposed structure. Figure 29 is a detail of the cross section A-A’ depicting the sand
Figure 27. Map indicating the locations of boreholes within the study area.
Figure 28. Map showing the proposed levee and reservoir footprint.
lens. The geotechnical report for BH-22 indicates that the sand lens has a permeability of $1.8 \times 10^{-4}$ cm/sec (Schmitz and others, 2005). The existence of this lens could undermine the integrity of the levee and will require an engineering solution to mitigate potential piping under the proposed levee.

Figure 29. Detail of geologic cross section A-A' indicating sand lens at the proposed levee.

To assess the magnitude of the problem, the high permeability of $1.8 \times 10^{-4}$ cm/sec (Schmitz and others, 2005) was used to calculate seepage using Darcy’s Law assuming the leak point was at the base of the levee and the levee design was 100 ft (30.5 m) wide at the base and at the contact of the sands in question:

$$Q/A = -k \left( \frac{\Delta h}{l} \right)$$

$Q/(50 \text{ ft} \times 100 \text{ ft}) = 0.5102 \text{ ft/day (50 ft/100 ft)}$

$Q = 1403 \text{ ft}^3/\text{day}$
Thus, a discharge of 1403 ft$^3$/day (39.7 m$^3$/day) represents 1.62% of the base flow discharge from the northern most monitoring site, SW-1, in the project area and could be considered equivalent to a large spring. However, this could be a dangerous condition that would affect the integrity of the levee.

Calculating the seepage through the hill, the Darcy’s Law equation assumes the leak point through the ridge of approximately 750 ft (228.6 m) as measured on a topographic map where the proposed abutment will be located. Using the coarse-grained sand lens depicted in Figure 28 above, the rate of seepage is:

\[
\frac{Q}{A} = -k \frac{\Delta h}{l} \\
\frac{Q}{(50 \text{ ft} \times 100 \text{ ft})} = 0.5102 \text{ ft/day (55 ft/750 ft)}
\]

\[
Q = 187 \text{ ft}^3/\text{day}
\]

Thus, 187 ft$^3$/day (5.3 m$^3$/day) represents only 0.04% of the base flow discharge from site SW-1 in the project area. Restating, the expected leakage is compared to one of the small springs found within the watershed. While these are approximate numbers to estimate leakages within an order of magnitude they should be used with caution and this leakage will need to be addressed in the design phase of the levee. In addition, the design should consider the shallow locations of the coal and clay layers in the creek bottom at the proposed levee alignment which is also indicated by the geotechnical report for BH-22. Thus, the geology of the McCurtain Creek basin is favorable for the reservoir as proposed. Furthermore, all earth materials (low permeable clayey-silts for the levee’s core and sand for general fill) needed to build the levee are present and reasonably accessible within the vicinity of the proposed levee alignment.
Water Resources

Surface Water Monitoring

Surface water monitoring indicates that base flow in the basin is sufficient to sustain the proposed reservoir. Data collected from 12 to 16 events at each of the five sites (see Figure 12 for crossing locations) produced the stage/discharge hydrographs which are depicted in Figures 13 through 17. The stage/discharge relationships incorporated data collected ranging from base flow conditions to high flow events during the course of three storm events. However, more high flow data including flooding conditions are needed to provide for more accurate hydrographs. Analysis of each hydrograph reveals:

Crossing SW-1  This road crossing site is located on McCurtain Creek in the northernmost part and the lowest elevation of the reach approximately 2500 ft (762 m) northeast of the proposed levee site. This portion of the creek is situated on a relatively broad flood plain. There were 16 stage/discharge measurements taken at this site (Table 3) to produce the hydrograph in Figure 13. Stage was taken from a known location on the bridge above creek at an elevation of 397 ft (121.0 m). Base flow is at ~382.6 ft (116.6 m). Three elevated stages were measured above 384 ft (117.0 m), however, no bank full or flood conditions were measured at this site. The May 15, 2004 event was near bank full. Discharge was measured in a bend approximately 300 ft (91.4 m) upstream (south) of the bridge except for the May 15, 2004 event that was taken from the bridge. Base flow discharge at
this crossing is ~5.1 ft³/s (0.2 m³/s) and a measured peak flow of 328.5 ft³/s (9.3 m³/s) was recorded on May 15, 2004. Using MS Excel, the graph in Figure 13 plots the stage versus discharge points with a logarithmic trendline added to model the hydrographic curve for this site. This trendline indicates an excellent fit with a correlation of $R^2 = 0.9964$ and a curve equation of $y = 22,184 \ln(x) - 131,942$ establishes the rating curve for this site.

**Crossing SW-2.** This road crossing site is the second crossing on McCurtain Creek and is located approximately 1700 ft (518 m) southwest of the proposed levee site. This portion of the creek is situated on a relatively narrow flood plain with a relatively deep incised creek. There were 15 stage/discharge measurements taken (Table 4) to produce the hydrograph in Figure 13. Stage was taken from a known location on the bridge above creek at an elevation of 401 ft (122.2 m). Base flow is at ~391.4 ft (119.3 m). Two elevated stages were measured above 393 ft (119.8 m), however, no bank full or flood conditions were measured at this site. Discharge was measured just downstream (north) of the bridge in front of a small beaver dam except for the May 15, 2004 event that was taken from the bridge. Base flow discharge at this crossing is 4.5 ft³/s (0.1 m³/s) and a measured peak flow of 230.8 ft³/s (6.5 m³/s) recorded on May 15, 2004. Using MS Excel, the graph in Figure 14 plots the stage versus discharge points with a logarithmic trendline added to model the hydrographic curve for this site. This trendline indicates an excellent fit with a correlation of $R^2 = 0.9699$ and a
curve equation of \( y = 21,439\ln(x) - 127,989 \) establishes the rating curve for this site.

**Crossing SW-3**  This site is a road crossing of an unnamed tributary draining into the McCurtain Creek and is located approximately 2000 ft (608.6 m) south of the Pisgah Church and Cemetery. This portion of the tributary is situated on small flood plain and has a shallow creek. There were 13 stage/discharge measurements taken (Table 5) to produce the hydrograph in Figure 15. Stage was taken from a known location on the bridge above tributary at an elevation of 407 ft (124.1 m). Base flow is at stage ~397.1 ft (121.0 m). Discharge was measured just upstream (north) of the bridge except for the May 15, 2004 event that was taken from the bridge. Two elevated stages were measured above 399 ft (121.6 m), showing overbank flood conditions. Another observation (February 5, 2004) was made whereby discharge measurements were not taken and the tributary had flowed over the road and bridge. A culvert was added sometime afterwards to relieved the road overflow problem due to the improper size of the bridge over the stream. On March 22, 2005, the creek overflowed its banks, but there was little measurable discharge evidenced of ponding due to a stream crossing for logging activities downstream of the measuring site. Base flow discharge at this crossing is 0.8 ft³/s (0.02 m³/s) and a measured peak flow of 95.5 ft³/s (2.7 m³/s) recorded on May 15, 2004. Using MicroSoft Excel, the graph in Figure 15 plots the stage versus discharge points with a logarithmic trendline added to model the
hydrographic curve for this site. This trendline indicates an excellent fit with a correlation of $R^2 = 0.9913$ and a curve equation of $y = 9,953.4\ln(x) - 57,266$ establishes the rating curve for this site.

**Crossing SW-4** This site is the third road crossing on McCurtain Creek in the study area. This portion of the creek is situated on a relatively wide flood plain. There were 13 stage/discharge measurements taken at this site (Table 6) to produce the hydrograph in Figure 16. Stage was taken from a known location on the bridge above creek at an elevation of 411 ft (125.3 m). Base flow stage is at ~403.1 ft (122.9 m). Two elevated stages were measured above 404 ft (123.1 m), however, no bank full or flood conditions were measured at this site. Discharge was measured just upstream (south) of the bridge. No bridge discharge measurements were made. Base flow discharge at this crossing is ~3.0 ft$^3$/s (0.1 m$^3$/s) and a measured peak flow of 37.5 ft$^3$/s (1.1 m$^3$/s) recorded on March 22, 2005. However, using MicroSoft Excel, the graph in Figure 17 plots the stage versus discharge points with a logarithmic trendline to model the hydrographic curve for this site. This trendline indicates a good fit with a correlation of $R^2 = 0.9003$ and a curve equation of $y = 9,656.1\ln(x) - 57,924$ establishes the rating curve for this site. This site needed additional elevated flow data to strengthen the stage/discharge curve for the hydrograph.
Crossing SW-5. This site is the forth road crossing on McCurtain Creek in the study area and consists of one three foot (0.9 m) diameter main culvert and three smaller relief culverts. This portion of the creek is situated on a fairly wide flood plain. There were 12 stage/discharge measurements taken (Table 7) to produce the hydrograph in Figure 18. Stage was taken from a known location which was a grader blade set perpendicular to the road next to the culvert at an elevation of 441 ft (134.4 m). Base flow is ~437.6 ft (133.4 m) in elevation. One elevated stage at over bank flood conditions was measured above 440 ft (123.1 m) whereby all four culverts had measurable discharge. Discharge was measured just upstream (south) of the main culvert and at any culvert that had flow. Base flow discharge at this crossing is 1.0 ft³/s (0.03 m³/s) and a measured peak flow of 31.1 ft³/s (0.9 m³/s) was recorded on February 5, 2004. Using MS Excel, the graph in Figure 17 plots the stage versus discharge points with a logarithmic trendline added to model the hydrographic curve for this site. This trendline indicates a good fit with a correlation of $R^2 = 0.9003$ and a curve equation of $y = 9,656.1 \ln(x) - 57,924$ establishes the rating curve for this site. Erosion at the culvert contributes to the skew in the point plot. In December 2004, it was noticed that the main culvert was about to blow out and the stage datum was leaning. In addition, the site needed additional elevated flow data to strengthen the hydrograph, but data collection stopped waiting on the County to fix the culvert. As of April 2005 erosion continued at the site with under piping of the culvert and road bed.
Thus, the surface water monitoring program provided stream crossing data showing that at crossing SW-1, base flow is ~5.1 ft$^3$/s (0.03 m$^3$/s) which is equal to 3.3 mgd. Thus, this base flow was used in the construction of the climatological model that indicates that the reservoir and can support the maximum withdrawal from the climatological model of 5.5 mgd (see Storage Capacity below) (Schmitz and others, 2004; 2005). As a result during drought conditions with fluctuating winter/summer pool management practices, 5.5 mgd may be sustained (Schmitz and others, 2004; 2005) providing for an alternative water supply and greatly diminished stream flow below the proposed levee.

**Storage Capacity**

Schmitz and others (2004, 2005) evaluated the proposed reservoir’s ability to fill and stay filled. The authors found that given a reservoir of an estimated 1280 acres (518.0 ha), at a pool elevation of 440 ft (134.1 m) (see Figure 29), and a drainage basin of 5800 acres (2347.3 ha) that the lake would not only fill, but could withstand withdrawal of 5.5 million gallons per day (20,819.8 m$^3$/day). Once filled, the reservoir as proposed could not only be used for recreational purposes, but could also be used as an alternate water supply for the industrial and residential needs for the county. Furthermore, when factoring in the driest period on record in 1964 using climatological records from 1961 to 2002, a model shows that the stage would have dropped approximately 6 feet (1.9 m). Factoring in the leakage rates from above, the model did not change within three significant digits (Schmitz and others, 2005).
Piezometric Surface

In the Upper McCurtain Creek Watershed, the piezometric surface was modeled with impressive results. This study combined the elevations of the observed water table for the 57 geophysical logs from the 1970’s and 1980’s, the 27 geotechnical boreholes, and the 17 thesis boreholes all located in Figure 27. A linear regression of the observed water table versus the surface elevation at each of the boreholes was performed. Due to questionable methods in waiting for the water table to rebound from boring, six of the geotechnical boreholes were omitted from the models when nearby boreholes clearly showed the presence of the water table. The result of the linear regression is represented in Figure 30 which models 95 borehole data points produced the linear regression of \( y = 0.9286(x) + 23.976 \). The correlation for the regression was \( R^2 = 0.9907 \) or a perfect fit given the dataset. Thus, this model strongly indicates that in the McCurtain Creek basin and probably the Wilcox Group, the water table mimics the topography whereby at the lower elevations the water table is near the surface and in the hills the water table is slightly subdued.

The piezometric surface model was built using ArcGIS 8.3 by taking a 10 m DEM and subsetting the DEM to the watershed with a 1 mile (1.6 km) buffer. This created a DEM of the watershed in which the linear regression equation was applied using the Map Algebra function. Thus, the equation for the raster map became:

\[
\text{Piezometric Surface} = 0.9286(\text{McCurtainDEM}) + 23.976
\]
Figure 30. Linear regression model of the water table elevation versus surface elevation.

Regression Analysis of Elevation vs. Water Table

\[ y = 0.9286x + 23.976 \]

\[ R^2 = 0.9907 \]
which produced the piezometric surface map represented in Figure 19. This model was then contoured to produce a vector-based contour map of the water table represented in Figure 20. To test the model against the known elevations of the water table from the boreholes in the field, the boreholes were brought into the model and manually spot tested to the thesis boreholes, which were within summer/winter fluctuations of the dataset. Thus, this is a credible model for the average between wet and dry months that all of the boreholes together represent. At that point, a second view of the model was made to represent the departure of the water table from the surface DEM (Figure 21) by using the Map Algebra function to subtract the surface DEM from the piezometric surface DEM.

The flaws of this model are that the DEM is not pulled to the borehole inventory, spring inventory, or the streams in the model. When this was attempted, only the particular cell at the borehole, spring, or creek location moved and did not smooth the model. However, at these elevations, the model still fell within the average fluctuation of the boreholes and near (below) the springs and the creeks. Yet, this method offers a far better model than just contouring the wells due to the dissected topography in the basin.

**Groundwater/Surface Interactions**

At the five surface water monitoring sites, a series of hand augered monitoring wells made of PVC pipe were set. The piezometers were arranged so that two piezometers were on each side of the stream crossing, one in the floodplain and the other roughly 10 to 15 foot in elevation above the floodplain for a total four piezometers. The
elevations and distances were noted and the water depths were measured. Figures 22 through 26 documents the location of the water table in relation to the surface and the stream at base flow. According to schematics drawn with a vertical interval of 10 times the horizontal difference, all stream crossings are considered gaining streams, or receiving spring water from stream’s perimeter below the surface of the water. Thus, in the drainage basin, it is probable that all reaches of McCurtain Creek and its tributaries are gaining streams. Balancing the spring inventory of 2.7 ft³/s (0.03 m³/s) with the base flow at stream crossing SW-1 of 5.1 ft³/s (0.03 m³/s), there is a positive balance 2.4 ft³/s (0.03 m³/s), thus providing further evidence that the streams are gaining almost half of its base flow from the perimeter of the steam as spring flow. Furthermore, rainwater that does not runoff infiltrates the Tuscohoma Sands in the hills providing the base flow seen in the schematics.

**Water Quality Analysis**

Chemical data was recorded in the basin, however little analysis was performed. This data will become baseline data for any future projects in the basin. Lockhart (2004) and Charleton (1999) in their theses noted high iron content in the MWA and in the adjacent drainage basin where the Red Hill Lignite Mine and is located. Consistent with their theses, chemical analysis from of base flow at the five stream crossing analyzed by the Mississippi State Chemical Laboratory (Appendix C), also noted high background levels of iron and manganese. Overall, in initial testing, the water quality of the basin is good for the proposed reservoir.
CHAPTER VIII

CONCLUSIONS

Because of the possibility of locating a large multi-use/multi-purpose reservoir in the Upper McCurtain Creek Watershed, a study to determine whether or not the geology and hydrology of the watershed would support the large reservoir was undertaken. The results indicate that this reservoir is ideally suited for this location because spring flow into the McCurtain Creek is ample to provide good quality water year around draining the basin’s sandy hills. Initial chemical analysis testing indicates that water quality is good. Furthermore the springs in the basin will support a reservoir capable of being an alternate water source capable of providing 5.5 mgd of water while maintaining a pool elevation of 440 ft (134 m). Fill materials are available near the vicinity of the proposed levee. While several coarse- to medium grained sand lenses are present in the basin, most provide good aquifer material and spring flow to McCurtain Creek. However, one such coarse-grained sand lens located in the abutments at the proposed levee will be prone to leak at a rate equivalent to a single small spring in the drainage basin. This leak, however, will require mitigation from an engineering design team prior to constructing a levee.

Recommendations for further study should include conducting another round of test borings along the alignment of the proposed levee to get a better understanding of the
sand lens and the stability of the soils and slopes at the proposed abutments. Continuous flow monitoring devices should be installed on several stream crossings to calculate base flow recession and aquifer properties. High flow discharge measurements should be taken to strengthen the hydrographs especially flows above bank full. And, more water quality sampling of base flow and high flow stream conditions and shallow aquifer samples need to be obtained to assess potable water constituents to include fecal coli form.
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APPENDIX A

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APPENDIX B

DISCHARGE CALCULATIONS
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**Total Discharge in ft³/sec** 5.111

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**Total Discharge in ft³/sec** 5.581
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**Total Discharge in ft$^3$/sec**

1.199

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**Total Discharge in ft$^3$/sec**

4.391
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**Total Discharge in ft³/sec** 5.031

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**Total Discharge in ft³/sec** 0.775
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**Total Discharge in ft³/sec**: 3.015

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Total Discharge in ft³/sec 2.998
### SW-5 10/9/2003

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**Total Discharge in ft$^3$/sec** 0.871

### SW-1 11/4/2003

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**Total Discharge in ft$^3$/sec** 4.501
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**11/4/2003**

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Total Discharge in ft³/sec: **5.257**

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**11/4/2003**

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**Total Discharge in ft$^3$/sec** 30.489

### SW-2 11/18/2003

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**Total Discharge in ft$^3$/sec** 19.433
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**Total Discharge in ft^3/sec**: 13.119

### SW-4 11/18/2003

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**Total Discharge in ft^3/sec**: 14.205
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**Total Discharge in ft³/sec**: 4.381

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**Total Discharge in ft³/sec**: 8.033
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#### Total Discharge in ft²/sec 12.675

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#### Total Discharge in ft²/sec 1.384
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**Total Discharge in ft$^3$/sec** 4.422

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**Total Discharge in ft$^3$/sec** 1.283
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**Total Discharge in ft³/sec**: 10.930

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**Total Discharge in ft³/sec**: 9.843
### SW-3 12/23/2003

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Total Discharge in ft³/sec: **3.546**

### SW-4 12/23/2003

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Total Discharge in ft³/sec: **8.197**
### SW-5 12/23/2003

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**Total Discharge in ft³/sec:** 2.762

Stage at 13:30 (initial obs @ 10:30) is 2.77 and believed to be at crest.

### SW-5 2/5/2004

#### Main flow

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<th>Width (ft)</th>
<th>Depth (ft)</th>
<th>Observation depth (ft)</th>
<th>Revolutions</th>
<th>Time in Seconds</th>
<th>Velocity at pt. (fps)</th>
<th>Area (ft²)</th>
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**Total Discharge in ft³/sec:** 27.142
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**Total Discharge in ft$^3$/sec**: 3.482

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**Total Discharge in ft$^3$/sec**: 0.459

Discharge measurements for other sites were not made due to missing piece of equipment.
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**3/29/2004**

**1st Overflow**

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**Total Discharge** in ft$^3$/sec

0.043

**Main Flow**

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**Total Discharge** in ft$^3$/sec

1.419

**SW-5 Total Discharge** in ft$^3$/sec

1.462
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Total Discharge in ft³/sec: 8.985

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Total Discharge in ft³/sec: 6.699
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Total Discharge in ft$^3$/sec 1.624

### SW-4  4/7/2004

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Total Discharge in ft$^3$/sec 4.916
### SW-5 4/7/2004

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**Total Discharge in ft³/sec** 1.463

### SW-1 5/12/2004

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<th>Area</th>
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**Total Discharge in ft³/sec** 6.331
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- Dist. From initial pt: Distance from the initial point.
- Width: Width of the channel.
- Depth: Depth of the channel.
- Observation depth: Depth at the observation point.
- Revolutions: Number of revolutions.
- Time in Seconds: Time taken.
- Velocity at pt.: Velocity at the point.
- Area: Cross-sectional area.
- Discharge: Discharge at the point.
### SW-4
5/12/2004

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**Total Discharge in ft³/sec** 4.748

### SW-5
5/12/2004

1st Overflow

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**Discharge** 0.096
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Total Discharge in ft³/sec 1.561

SW-5

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Total Discharge in ft³/sec 1.657

### SW-1 5/15/2004

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Total Discharge in ft³/sec 328.535
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**5/15/2004**

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**Total Discharge in ft$^3$/sec** 230.888

### SW-3
**5/15/2004**

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**Total Discharge in ft$^3$/sec** 95.514
### Overflow Culvert

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SW-3 Total Discharge in ft³/sec

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8/28/2004

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| Total Discharge in ft³/sec | 4.755 |
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#### 9/17/2004

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**Total Discharge in ft$^3$/sec** 6.516

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### SW-1
#### 12/21/2004

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**Total Discharge in ft$^3$/sec** 11.128
## Table 1: Discharge Measurements

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**Total Discharge** in ft$^3$/sec **1.190**

### SW-3 12/21/2004

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**Total Discharge** in ft$^3$/sec **0.966**
### SW-4 8/28/2004

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**Total Discharge in ft³/sec** 3.734

### SW-4 12/21/2004

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**Total Discharge in ft³/sec** 4.569
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**Total Discharge in ft³/sec**: 1.378

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**Total Discharge in ft³/sec**: 37.494
### SW-2

**3/22/2005**

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**Total Discharge in ft$^3$/sec** 65.902

### SW-1

**3/22/2005**

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<th>Revolutions</th>
<th>Time in Seconds</th>
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<th>Area</th>
<th>Discharge</th>
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**Total Discharge in ft$^3$/sec** 111.934
APPENDIX C

POTABLE WATER RESULTS
February 15, 2005

Analysis No. 32,562-566
Analysis of Water
Received on 1-4-05
Address P.O. Box 5448 Miss. State, MS 39762

Marked: from MSU Dept. of Geosciences
ATTN: Darrel Schmitz

RESULTS:

<table>
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<th>MSCL No.</th>
<th>Sample Identification</th>
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</tr>
<tr>
<td>32,563</td>
<td>SW-2</td>
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<td>32,564</td>
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<td>SW-4</td>
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<td>32,566</td>
<td>SW-5</td>
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</table>

Results are presented in attached reports from our analysis of the above water samples for analytes required by the Mississippi State Department of Health.

State Chemist

PLEASE GIVE NUMBER WHEN REFERRING TO THIS ANALYSIS

042790/5-03
### WATER QUALITY ANALYSES FOR BOTTLED WATER
REQUIRED BY MS STATE DEPARTMENT OF HEALTH

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#### PHYSICAL DETERMINATIONS

| Turbidity, NTU | 5.5 |

#### INORGANICS

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Parts Per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicarbonate Alkalinity as CaCO₃</td>
<td>7.3</td>
</tr>
<tr>
<td>Total Alkalinity as CaCO₃</td>
<td>8.0</td>
</tr>
<tr>
<td>Free Carbon Dioxide</td>
<td>2.1</td>
</tr>
<tr>
<td>Sodium</td>
<td>2.9</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.69</td>
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<tr>
<td>Calcium</td>
<td>2.0</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.1</td>
</tr>
<tr>
<td>Total Hardness as CaCO₃</td>
<td>9.3</td>
</tr>
<tr>
<td>Fluoride</td>
<td>&lt;0.1 (&lt;0.4)</td>
</tr>
<tr>
<td>Chloride</td>
<td>3.1</td>
</tr>
<tr>
<td>Sulfate</td>
<td>1.9</td>
</tr>
<tr>
<td>Nitrate Nitrogen</td>
<td>&lt;0.1 (&lt;1)</td>
</tr>
<tr>
<td>Nitrite Nitrogen</td>
<td>&lt;0.1 (&lt;0.2)</td>
</tr>
<tr>
<td>Total NO₃+NO₂-Nitrogen</td>
<td>&lt;1 (&lt;1)</td>
</tr>
<tr>
<td>Total Dissolved Residue</td>
<td>63</td>
</tr>
<tr>
<td>Cyanide</td>
<td>&lt;0.2 (&lt;0.3)</td>
</tr>
<tr>
<td>Phenol</td>
<td>&lt;0.001 (&lt;0.002)</td>
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*Maximum Contaminant Level for Secondary Contaminants

#### METALS

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Parts Per Million</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>&lt;0.006 (&lt;0.12)</td>
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<tr>
<td>Antimony</td>
<td>&lt;0.001 (&lt;0.01)</td>
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<tr>
<td>Arsenic</td>
<td>&lt;0.001 (&lt;0.05)</td>
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<tr>
<td>Barium</td>
<td>0.020 (&lt;0.09)</td>
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<tr>
<td>Beryllium</td>
<td>&lt;0.002 (&lt;0.005)</td>
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<tr>
<td>Cadmium</td>
<td>&lt;0.001 (&lt;0.005)</td>
</tr>
<tr>
<td>Chromium</td>
<td>&lt;0.01 (&lt;0.05)</td>
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<tr>
<td>Copper</td>
<td>&lt;0.03 (&lt;0.05)</td>
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<tr>
<td>Iron</td>
<td>0.47 (&lt;1.0)</td>
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<tr>
<td>Lead</td>
<td>&lt;0.001 (&lt;0.005)</td>
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<tr>
<td>Manganese</td>
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<tr>
<td>Mercury</td>
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<tr>
<td>Nickel</td>
<td>&lt;0.01 (&lt;0.1)</td>
</tr>
<tr>
<td>Selenium</td>
<td>&lt;0.003 (&lt;0.01)</td>
</tr>
<tr>
<td>Silver</td>
<td>&lt;0.01 (&lt;0.05)</td>
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<tr>
<td>Thallium</td>
<td>&lt;0.001 (&lt;0.002)</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.019 (&lt;0.5)</td>
</tr>
</tbody>
</table>

*MCL = Maximum Contaminant Level for Primary or Secondary Contaminants
Those values preceded by a "less than" sign (\(<\)) indicate "None Detected" at the reported lower level of detection.
Parts Per Million = Milligrams Per Liter.
### Water Quality Analyses for Bottled Water

**Required by MS State Department of Health**

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#### Physical Determinations

- **Turbidity, NTU**: 4.0

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<td>Total Alkalinity as CaCO₃</td>
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<tr>
<td>Free Carbon Dioxide</td>
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<td>Potassium</td>
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<td>Calcium</td>
<td>2.1</td>
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<tr>
<td>Magnesium</td>
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<tr>
<td>Total Hardness as CaCO₃</td>
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<tr>
<td>Fluoride</td>
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<tr>
<td>Chloride</td>
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<tr>
<td>Sulfate</td>
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<tr>
<td>Nitrate Nitrogen</td>
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<td>Nitrite Nitrogen</td>
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<td>Total NO₃/NO₂ Nitrogen</td>
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<td>Cyanide</td>
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<td>Phenol</td>
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*Maximum Contaminant Level for Secondary Contaminants

#### Metals

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<tr>
<td>Barium</td>
<td>0.019</td>
</tr>
<tr>
<td>Beryllium</td>
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<tr>
<td>Cadmium</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chromium</td>
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<td>Mercury</td>
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<tr>
<td>Selenium</td>
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<tr>
<td>Silver</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Thallium</td>
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<tr>
<td>Zinc</td>
<td>0.021</td>
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</table>

*Maximum Contaminant Level for Primary or Secondary Contaminants

Those values preceded by a "less than" sign (<) indicate "None Detected" at the reported lower level of detection.

Parts Per Million = Milligrams Per Liter.
WATER QUALITY ANALYSES FOR BOTTLED WATER
REQUIRED BY MS STATE DEPARTMENT OF HEALTH

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PHYSICAL DETERMINATIONS
- Turbidity, NTU: 5.2

INORGANICS

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<tr>
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<td>Fluoride</td>
<td>&lt;0.1</td>
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<tr>
<td>Chloride</td>
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<tr>
<td>Sulfate</td>
<td>2.3</td>
</tr>
<tr>
<td>Nitrate Nitrogen</td>
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</tr>
<tr>
<td>Nitrite Nitrogen</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Total NO₃/NO₂ Nitrogen</td>
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*Maximum Contaminant Level for Secondary Contaminants

METALS

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<tr>
<td>Barium</td>
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<tr>
<td>Beryllium</td>
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<tr>
<td>Cadmium</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chromium</td>
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</tr>
<tr>
<td>Copper</td>
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<tr>
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<tr>
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<td>&lt;0.003</td>
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<td>Silver</td>
<td>&lt;0.01</td>
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<td>Thallium</td>
<td>&lt;0.001</td>
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<tr>
<td>Zinc</td>
<td>0.021</td>
</tr>
</tbody>
</table>

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Parts Per Million = Milligrams Per Liter.
# Water Quality Analyses for Bottled Water

**Required by MS State Department of Health**

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## Physical Determinations

- Turbidity, NTU: 2.5

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<td>Total Alkalinity as CaCO(_3)</td>
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<td>Free Carbon Dioxide</td>
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<td>Sodium</td>
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<tr>
<td>Chloride</td>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
<td>Total Dissolved Residue</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Cyanide</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Phenol</td>
<td>&lt;0.001</td>
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</table>

\(^*\)Maximum Contaminant Level for Secondary Contaminants

## Metals

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<tr>
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</tr>
<tr>
<td>Beryllium</td>
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<tr>
<td>Cadmium</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chromium</td>
<td>&lt;0.01</td>
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</tr>
<tr>
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<td>Zinc</td>
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\(^*\)MCL = Maximum Contaminant Level for Primary or Secondary Contaminants

Those values preceded by a “less than” sign (<) indicate “None Detected” at the reported lower level of detection.

Parts Per Million = Milligrams Per Liter.
### WATER QUALITY ANALYSES FOR BOTTLED WATER
REQUIRED BY MS STATE DEPARTMENT OF HEALTH

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#### PHYSICAL DETERMINATIONS
- Turbidity, NTU: 1.8

#### INORGANICS

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<td>Sodium</td>
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<td>Potassium</td>
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<td>Total Hardness as CaCO₃</td>
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<tr>
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<td>Chloride</td>
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<td>Nitrite Nitrogen</td>
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<tr>
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*Maximum Contaminant Level for Secondary Contaminants

#### METALS

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<td>Barium</td>
<td>0.011</td>
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<td>Beryllium</td>
<td>&lt;0.002</td>
</tr>
<tr>
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<td>Chromium</td>
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<td>Copper</td>
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*MCL = Maximum Contaminant Level for Primary or Secondary Contaminants

Those values preceded by a "less than" sign (<) indicate "None Detected" at the reported lower level of detection.

Parts Per Million = Milligrams Per Liter.
APPENDIX D

BOREHOLE DATA
<table>
<thead>
<tr>
<th>Boring</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Elevation</th>
<th>Observed Depth to Water</th>
<th>Water Table Elevation</th>
<th>Remarks</th>
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<td>B-1</td>
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<th>Longitude</th>
<th>Latitude</th>
<th>Elevation</th>
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<th>Water Table Elevation</th>
<th>Remarks</th>
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### Pickering Piezometers Average Depth

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### Hand-Augered Standpipe Piezometers

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<th>Elevation (Map Spot)</th>
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<th>Depth to Water Table</th>
<th>Water Table Elevation</th>
<th>Length of Pipe</th>
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## North American Coal Corporation Borehole Data

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<th>Depth to Water Table</th>
<th>Water Table Elevation</th>
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APPENDIX E

GEOLOGICAL CROSS SECTIONS
DETAILED CROSS SECTIONS OF THE PROPOSED McCURTAIN CREEK RESERVOIR

MISSISSIPPI STATE UNIVERSITY
DEPARTMENT OF GEOSCIENCES

SCALE
VE = x10

PERMEABILITY OF STRATA
- Coarse Sand
  \[ K = 10^9 \text{ to } 10^{11} \text{ cm/s} \]
- Sand
  \[ K = 10^9 \text{ to } 10^{10} \text{ cm/s} \]
- Sandy-Silt
  \[ K = 10^5 \text{ to } 10^6 \text{ cm/s} \]
- Silt
  \[ K = 10^5 \text{ to } 10^6 \text{ cm/s} \]
- Silty-Clay
  \[ K = 10^6 \text{ to } 10^7 \text{ cm/s} \]
- Clayey-Silt
  \[ K = 10^9 \text{ to } 10^{10} \text{ cm/s} \]

Hydraulic parameters adapted from Domenico and Schwartz (1998).
DETAILED CROSS SECTIONS OF THE PROPOSED McCURTAIN CREEK RESERVOIR

MISSISSIPPI STATE UNIVERSITY
DEPARTMENT OF GEOSCIENCES

SCALE
VE = x10

PERMEABILITY OF STRATA

- Coarse Sand: $K = 10^4$ to $10^5$ cm/s
- Sand: $K = 10^5$ to $10^6$ cm/s
- Sandy-Silt: $K = 10^2$ to $10^3$ cm/s
- Silt: $K = 10^2$ to $10^3$ cm/s
- Silty-Clay: $K = 10^4$ to $10^5$ cm/s
- Clayey-Silt: $K = 10^6$ to $10^7$ cm/s

Hydraulic parameters adapted from Domenico and Schwartz (1998).
AQUIFER CROSS SECTIONS OF THE PROPOSED MCCURTAIN CREEK RESERVOIR

MISSISSIPPI STATE UNIVERSITY
DEPARTMENT OF GEOSCIENCES

SCALE
VE = x10

LEGEND
- AQUIFER
- AQUIFER
- WATER TABLE
AQUIFER CROSS SECTIONS OF THE PROPOSED MCCURTAIN CREEK RESERVOIR

MISSISSIPPI STATE UNIVERSITY
DEPARTMENT OF GEOSCIENCES