Tennessee Valley Authority Kingston Fossil Plant Harriman, Roane County, Tennessee	**Perimeter Containment** **North Dredge Cell (Dike C) Segment 1** **Sta. A161+50 to A179+50**

Document Control Number	RDP-0113-E
Calculation Package	FPGKIFFESCDX00030020100006

Exhibit 3
Geology and Project Materials

Purpose:

- Document and describe the site geology.
- Identify the primary ash and soil materials.
- Estimate unit weights for each material, for use in subsequent analyses.

Methods:

- Review of published literature and site-specific test data.

Results:

- Narrative description.
- Table of material unit weights.

Calculation Performed by: Stantec Consulting Services, Inc.	
Prepared by: YW and AFR, Nov2010	*Reviewed by:* Multiple reviews of prior drafts
Revisions:	

Geology and Project Materials

1. Geologic Setting

The Kingston Fossil Plant is located within the Tennessee River valley, near Harriman, Tennessee. The site is about 30 miles west of Knoxville, in the Valley and Ridge physiographic province of eastern Tennessee. The coal ash dredge cell at the Kingston plant is located within a former oxbow of the Emory River, about two miles upstream of where the Emory discharges into the Clinch River. Water levels in this area are controlled by Watts Bar Dam, which is over 30 miles downstream on the Tennessee River.

Geologic mapping of the area, developed by Moore et al. (1993), is provided in Appendix A. The structural geology of the area is characterized by a series of thrust faults, which strike to the northeast. Older rock units have been forced over younger formations toward the northwest. The Kingston dredge cell is underlain by the Conasauga Shale formation and the deeper Rome Formation. Both are sedimentary rocks of the Cambrian period. Moore et al. (1993) provide these geologic descriptions:

- *Conasauga Shale:* "Shale, gray, red, light-green, and dull purple; argillaceous and silty; zones of shaly, gray limestone, somewhat oolitic, as much as 100 feet thick scattered throughout. Formation contorted, brecciated, and sheared throughout."

- *Rome Formation:* "Shale and siltstone, with lesser thicknesses of sandstone and dolomite. Shale, variegated, reddish- and greenish-gray, olive-green, light-green, and brown, micaceous, and generally arenaceous; siltstone layers as much as a few inches thick, medium-gray, and in part glauconitic; sandstone beds generally fine-grained, thin- to medium-bedded, as much as 2 feet thick. Formation characterized by abundance of ripple marks, mud cracks, and irregularly oriented markings (tracks, trails, etc.) on bedding planes; typically underlies sharp-crested ridges. Base nowhere exposed."

As indicated on the geologic mapping (Appendix A), the surface contact between these two formations strikes to the northeast, and roughly coincides with the railroad tracks and Swan Pond Road where they border the dredge cell. The contact appears to dip 10º to 15º to the southeast, with the exposed Conasauga Shale eroded to a roughly horizontal surface across the site. The Chattanooga Fault, an inactive thrust fault that strikes in a northeasterly direction, is located about 3,000 ft northwest of the Kingston dredge cell.

Within the footprint of the dredge cell, bedrock (Conasauga Shale) is overlain with up to about 65 feet of natural, alluvial deposits that formed within the floodplain of the Emory River and its tributaries. The lower unit of the alluvium consists of a heterogeneous, interbedded deposit of granular soils that generally grade from sandy silt to silty sand. Coarser gradations tend to be found toward the bottom of this deposit. A fairly thick, floodplain deposit of lean, silty clay covers the silts and sands over most of the site. At the top of this material are thin, lacustrine deposits of clay, silt, and ash, which were deposited after Watts Bar Lake was impounded (in 1942) and during the early development of the Kingston ash pond.

The Kingston ash pond was formed in the 1950s by construction of perimeter dikes. Coal ash was hydraulically sluiced to the pond, where ash deposits gradually accumulated. Over the ensuing years, the height of the dredge cell was raised in stages, using upstream construction of new perimeter dikes. Compacted soil fill is found within the constructed embankments along defined alignments. Most of the dredge cell footprint is currently covered with loose deposits of coal ash remaining after the December 2008 failure. Toward the southern end of the dredge cell, intact deposits of sluiced ash are found beneath areas that were not mobilized in the failure.

2. Project Materials

Explorations in the area of the Kingston Fossil Plant Dredge Cell have typically encountered saturated fly ash, alluvial soils (clays to silty sands), and weathered shale bedrock. The soil and rock materials selected for inclusion in the stability and seismic analyses are identified and described in Table 2.1.

2.1. Soil and Ash Deposits

The loose, hydraulically-placed, ash deposits are almost entirely fly ash, but coarser material (bottom ash, clinkers, etc.) is sometimes found mixed with the fly ash in some samples. Over much of the project site, ash in the dredge cell was displaced and disturbed to varying degrees by the December 2008 failure. Toward the southwest side of the site (unfailed end of the dredge cell), thick deposits of ash in the remnant dredge cell are generally intact and exhibit thin, horizontal bedding planes.

Detailed investigations of the dredge cell failure by AECOM (2009) have suggested that a root cause was a thin layer of stratified, sensitive silt (ash) and clay at the base of the ash deposits. Laboratory test data show significant sensitivity in this material, referring to the loss of shear resistance when a soil fails without drainage past the peak strength. AECOM (2009) referred to this material as “slimes”; here, to better reflect the constituents and behavior, this same material is identified as a “sensitive silt/clay”.

The natural soils under the dredge cell are soft to loose, alluvial deposits of lean clay and silty sand to sandy silt. These materials are interbedded across the site, with a tendency for the sandier soils to occur at greater depth. Thin layers of dense sands were encountered just above the bedrock in some borings. These natural, sedimentary soils would have been deposited in an alluvial, and possibly lacustrine, environment prior to development of the site by TVA. Initially normally consolidated to perhaps slightly over consolidated, these soils are now over consolidated where the recent failure removed the overburden ash deposits.

2.2. Stabilized Soils

The closure plan includes construction of a perimeter earthen berm around the failed dredge cell. The ash and alluvial foundation soils beneath the perimeter berm will be stabilized using deep mixing technology. Cementitious grout will be mixed with the ash and soil deposits, forming panels of stabilized ground.

The treated foundation will be modeled as three soil zones: stabilized foundation ash, stabilized foundation clay, and stabilized foundation sand. Within these strata under the berm footprint, appropriate properties will be used to represent the composite behavior of the treated and untreated soil (the cement-stabilized panels and the untreated soil between the panels). Properties of the cured soil-cement within each subsurface stratum, and the composite properties of the stabilized foundation zone, are addressed in Exhibit 14.

2.3. Embankment Materials

Following construction of the stabilized perimeter, the failed fly ash will be excavated, transported, and placed in a landfill embankment inside of the perimeter. The restored fly ash embankment or landfill will be compacted to at least 90% of its standard Proctor maximum dry density.

The dredge cell perimeter will be defined by an earthen berm built atop the stabilized foundation. Based on the locally available borrow materials, the earthen berm is expected to be constructed of silty to sandy clay, which will be compacted to at least 95% of its standard Proctor maximum dry density. The particular borrow area for the embankment has not been identified.

The design materials list also includes stone aggregates, which will be used to build working platforms, rock berms, and slope protection:

- Coarse stone, which is assumed to be a clean, coarse, uniform stone aggregate (coarse sand to gravel) that would classify as a poorly graded sand or gravel.

- Shot rock, which can be obtained from local quarry operations. Shot rock is an ungraded, heterogeneous, and highly variable mix of stone sizes with particle sizes ranging from coarse sand up to 2.5-ft boulders.

Stone rip rap, which will be used as slope protection in selected locations along the shoreline of Watts Bar Lake, consists of large stones. For the design analyses, rip rap can be assumed to have the same design properties as the shot rock.

2.4. Bedrock

Beneath the alluvial soils, the site is underlain by shale bedrock of the Conasauga Shale formation. Based on the geologic section in Figure 2.1 (after Moore et al. 1993), the Conasauga shale appears to vary in thickness under the dredge cell from zero along northwest side (under the railroad) to maybe 400 ft on the southeast (under the ash pond).

From rock cores taken at the site, this material can be described as a gray, very fine grained, soft to very soft, thinly bedded shale that is occasionally interbedded with a fine to medium grained, hard limestone. The bedding planes dip between 15˚ to 20˚ from horizontal. The top of rock elevation ranges from approximately El. 700 to El. 714 across the site. Rock cores have been advanced up to 20 feet into the shale.

The upper surface of the shale bedrock is highly weathered. Data from 79 borings across the site indicate that the highly weathered shale can vary in thickness from about 0 to 10 feet, with a median thickness of 1.5 feet. Here, the thickness of the highly weathered zone is assumed to equal the refusal depth for an SPT split spoon minus the depth to the top of rock, as reported on the field boring logs. The strength of the shale rock is characterized in Exhibit 17.

Table 2.1. Identification of Materials for the Analysis of the Closed Kingston Dredge Cell

Material Name	Material Characterization
Earthen Berm	Compacted embankment of silty to sandy clay in the perimeter berm
Landfilled Ash	Compacted embankment of fly ash, consisting of material recovered from the failed dredge cell
Hydraulically Placed Ash	Existing deposits of fly ash, including failed and unfailed ash within the dredge cell
Sensitive Silt/Clay	Stratified, lacustrine layer of silt and clay above natural soil
Lean Clay Foundation Soil	Natural, alluvial deposits of silty clay under the dredge cell
Sandy Silt to Silty Sand	Natural, alluvial deposits of silty sand to sandy silt under the dredge cell
Stabilized Foundation Ash	Composite zone of treated, stabilized ash and untreated, hydraulically placed ash beneath the berm foundation*
Stabilized Foundation Clay	Composite zone of treated, stabilized clay and untreated, lean clay foundation soil beneath the berm foundation*
Stabilized Foundation Sand	Composite zone of treated, stabilized silty sand and untreated, sandy silt to silty sand beneath the berm foundation*
Shale	Weathered shale bedrock, with dipping beds and occasional layers of limestone, thickness up to 400 feet
Coarse Stone	Clean, coarse, uniform stone aggregate (coarse sand to gravel)
Shot Rock	Highly variable mix of stone sizes, with boulders up to 2.5-feet in size

** Details of foundation treatment will be developed during the design process.*

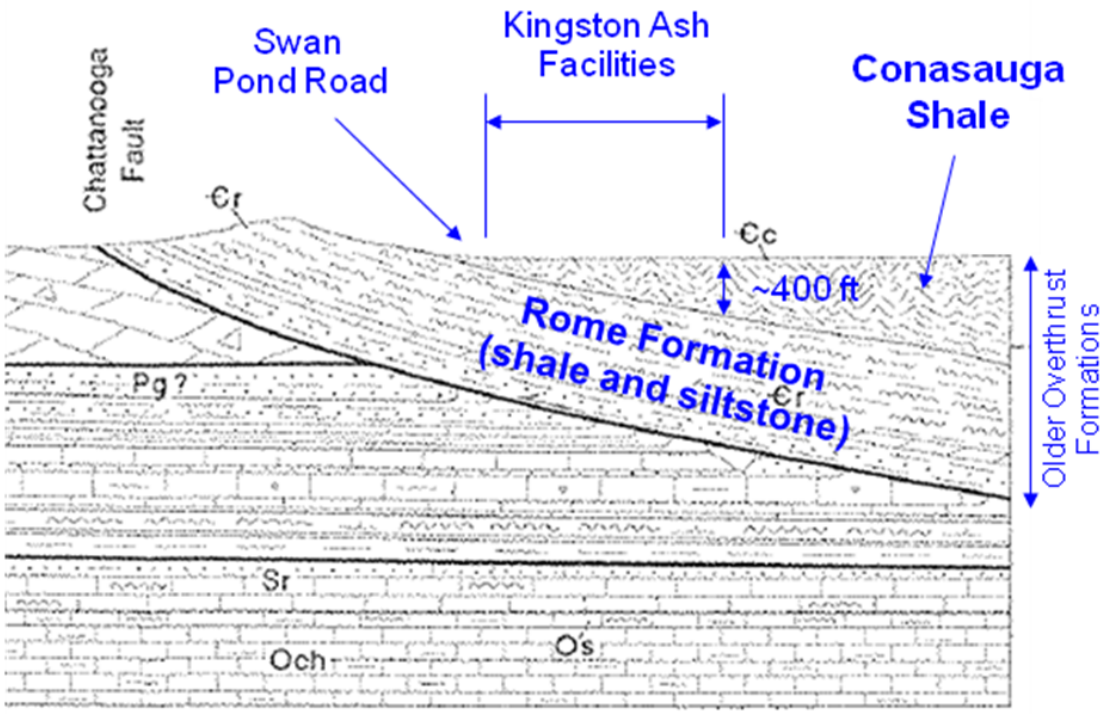


Figure 2.1. Geologic Cross Section under the Kingston Dredge Cell (after Moore et al. 1993).

3. Unit Weights

The various stability and seismic analyses require unit weights (densities) for each soil material or zone that is modeled. Estimated unit weights for the Kingston dredge cell materials are summarized in Table 3.1.

The unit weight of a given soil varies with water content, with different values in a deposit above or below the water table. Unit weights for various moisture conditions can be computed as follows:

- Dry unit weight $$\gamma_d = \frac{G_s}{1+e}\gamma_w \qquad 3.1$$
- Moist unit weight $$\gamma_m = \gamma_d(1+w) \qquad 3.2$$
- Saturated unit weight $$\gamma_{sat} = \frac{G_s + e}{1+e}\gamma_w \qquad 3.3$$

where G_s is the specific gravity of the solids, e is the void ratio, w is the moisture content, and γ_w is the unit weight of water (62.4 pcf).

Stantec and AECOM performed laboratory tests (Appendix B) on samples of the Kingston fly ash obtained from the failed dredge cell. A specific gravity test (Stantec, ASTM D 854) indicated that the fly ash has a G_s of 2.31. Results from five standard Proctor compaction tests (ASTM D 698) indicated an average maximum dry unit weight of 83.7 pcf (void ratio of 0.72) at an average optimum moisture content of 24 percent.

Field data on the compacted density of the Kingston ash was obtained from the first stage of the 2009 test embankment, which was constructed of recovered ash in the area of failed dredge cell. Thirty-nine drive cylinder tests were conducted in the test embankment between August 12 and October 8, 2009. The measured dry unit weight of the compacted ash varied between 75 and 97 pcf, or 90 to 116% of the standard Proctor maximum density. Based on the average measurements from the field tests, the compacted Kingston ash will have a dry unit weight of about 87 pcf at an average moisture content of 25%. For a specific gravity of 2.31, the void ratio is then 0.67, with moist and saturated unit weights of 109 and 111 pcf, in the ash embankment (Table 3.1).

For the existing hydraulically-placed ash material, laboratory results from AECOM (Appendix C) indicate specific gravities ranging from 2.25 to 2.35 and void ratios ranging from 0.7 to 1.4. AECOM concluded that the void ratios do not decrease with depth. The average void ratios for the failed and unfailed ash are 0.82 and 0.89, respectively. Assuming these averages reflect the true average void ratios in each material, this may indicate that some compression has occurred within the sheared ash. Based on the logs provided by AECOM, the average moisture content of the existing ash above the groundwater level is about 28%. Assuming a specific gravity of 2.31 and an average void ratio of 0.85, the dry, moist, and saturated unit weights of the existing hydraulically-placed ash would be 78, 100, and 107 pcf, respectively (Table 3.1).

The University of Massachusetts (UMass) Amherst performed consolidation and shear tests on samples of the sensitive silt/clay layer collected with a thin-walled piston sampler. The measured total unit weight of 25 test specimens varied widely, from 82 to 128 pcf, as tabulated in the UMass report (see Exhibit 13). For the stability analyses, this soil was assumed to have a saturated unit weight of 107 pcf, the same as in the overlying ash. The sensitive silt/clay is found in a very thin layer within the cross section, so the unit weight assigned to this material will have no discernible effect on the results of the stability analyses.

Because the alluvial lean clay and silty sand/sandy silt are below the groundwater level, only saturated unit weights are needed for the stability analyses. Void ratios presented on the AECOM triaxial compression test reports (Exhibit 13) were used to calculate the unit weights of these two materials. Assuming a specific gravity of 2.7 for both (the AECOM data indicates that the specific gravity of the lean clay ranges from 2.65 to 2.72), the saturated unit weights of the lean clay and silty sand/sandy silt soils were then estimated at 130 and 128 pcf, respectively (Table 3.1).

The saturated and moist unit weights of the earthen berm were assumed to be 128 and 125 pcf, respectively. This corresponds to an assumed specific gravity of 2.7, void ratio of 0.62, and moisture content (unsaturated) of 20%.

The stone aggregate materials were conservatively assumed to have a total unit weight of 115 pcf and a saturated unit weight of 128 pcf. Higher densities may be achieved if these materials are compacted in place. Assuming a specific gravity of 2.65, the void ratio would be 0.64 and, when unsaturated, the water content would be 14%.

The saturated unit weight of the shale bedrock was assumed to be 140 pcf.

Table 3.1. Representative Material Unit Weights

Material Name	Void Ratio, e	γ_d (pcf)	γ_m (pcf)	γ_{sat} (pcf)
Earthen Berm	0.62	104	125	128
Landfilled Ash	0.67	87	109	111
Hydraulically Placed Ash	0.85	78	100	107
Sensitive Silt/Clay	0.85	78	100	107
Lean Clay Foundation Soil	0.58	107	--	130
Sandy Silt to Silty Sand	0.62	104	--	128
Shale	--	--	--	140
Coarse Stone	0.64	101	115	128
Shot Rock	0.64	101	115	128

4. References

AECOM (2009). “Root Cause Analysis of TVA Kingston Dredge Pond Failure on December 22, 2008.” Four volumes, June 25.

Moore, J. L, Finlayson, S. P., and Milici, R. C. (1993). “Geologic Map of the Harriman Quadrangle, Tennessee.” *GM 123-NE*, Tennessee Division of Geology.

Appendix A

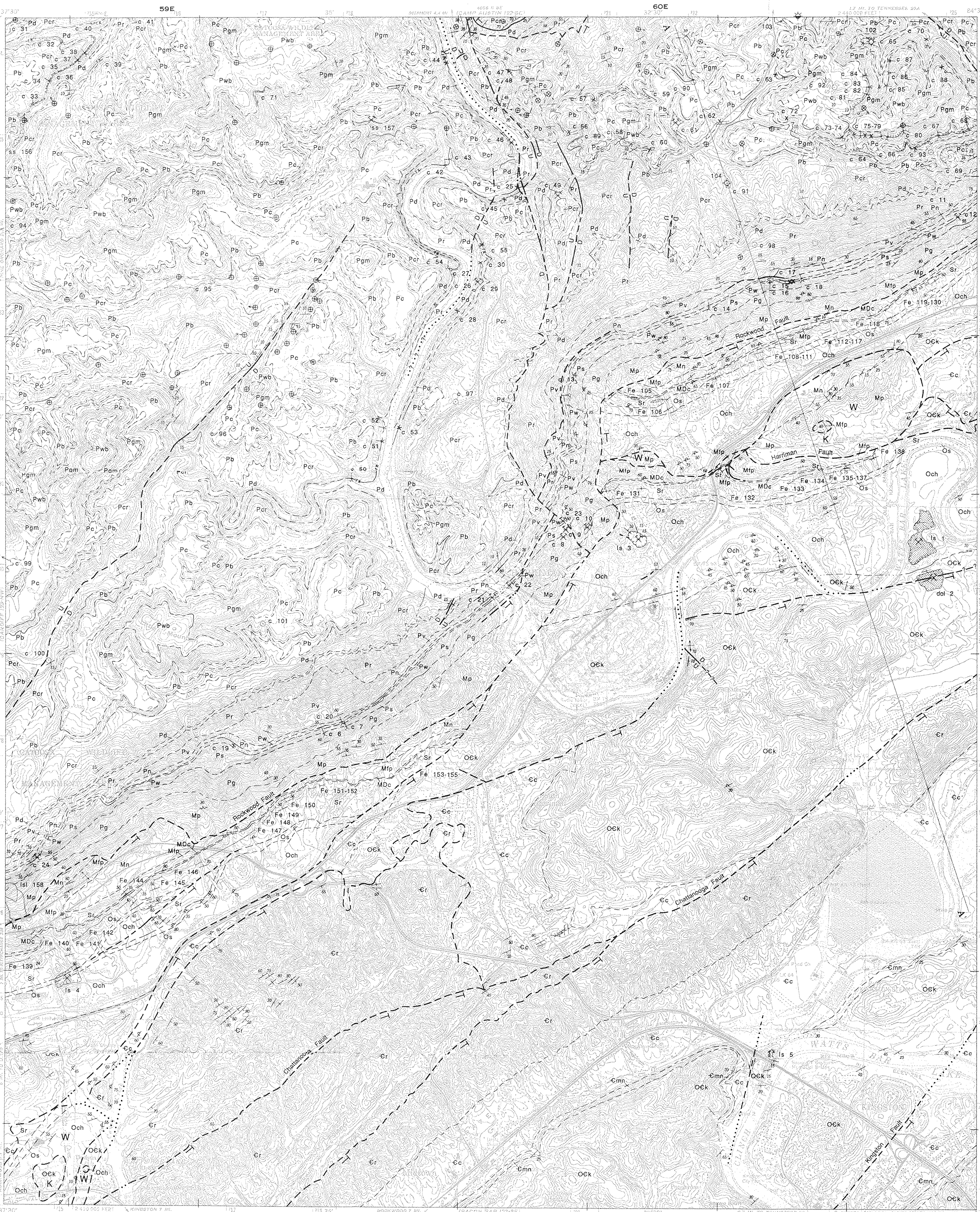
Geologic Map of the Harriman Quadrangle, Tennessee

By Moore, Finlayson, and Milici (1993)

GEOLOGIC CARTOGRAPHY BY
THE TENNESSEE DIVISION OF GEOLOGY

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF GEOLOGY
Edward T. Luther, *State Geologist*

GEOLOGIC MAP
HARRIMAN QUADRANGLE
TENNESSEE
GM 123-NE



Base topographic map by USGS, 1980.
10,000-foot grid based on Tennessee rectangular coordinate system.

Field and compilation sheets are on open file at Nashville, Tennessee.

The Carter Coordinate System letters and numbers used to designate five-minute divisions of latitude and longitude are shown along the margins; tick marks indicate one-minute divisions.

UTM GRID AND 1980 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

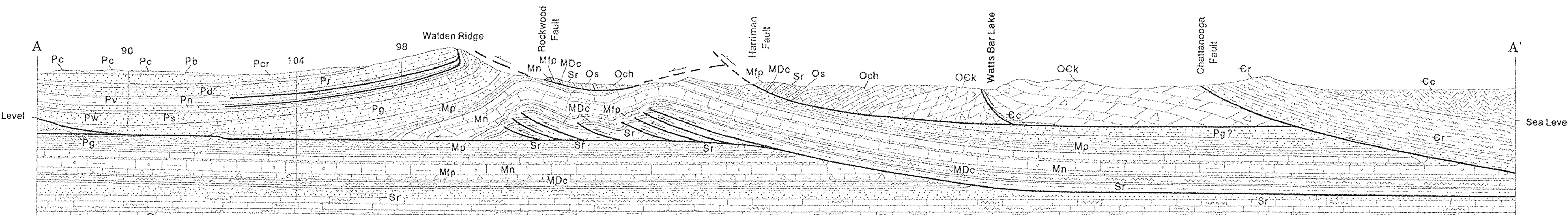
CONTOUR INTERVAL 20 FEET
DASHED LINES REPRESENT HALF INTERVAL CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Mineral Resources mapped by James L. Moore, Albert B. Horton, C. Pratt Finlayson, and Robert C. Milici.

Compilation and editing by James L. Moore, Albert B. Horton, Christopher K. Moxon, Edward T. Luther, Ronald P. Zurawski, and Doris E. Noble.

Authorization No. 327018-48.



SECTION ALONG A-A'
No vertical exaggeration

GEOLOGIC MAP OF THE HARRIMAN QUADRANGLE, TENNESSEE

By
James L. Moore, C. Pratt Finlayson, and Robert C. Milici
1993

SYSTEM AND SERIES	GROUP, FORMATION, AND BED	THICKNESS IN FEET
PENNSYLVANIAN, Lower Pennsylvanian, Crooked Fork Group	Wartburg Sandstone	Up to 120
	Glenmary Shale (unnamed coal)	120-260
	Coalfield Sandstone	30-60
	Burnt Mill Shale, Hooper coal	50-100
	Crossville Sandstone	120-220
	Rex coal, Dorton Shale, Christmas coal	15-110
Crab Orchard Mountains Group	Nemo coal, Rockcastle Conglomerate	160-290
	Morgan Springs coal, Vandever Formation, #12 coal, Lantana coal	210-410
	Newton Sandstone	10-120
	Sewanee coal, Whitwell Shale, Richland coal	30-100
	Sewanee Conglomerate	130-240
	Gizzard Group, Bon Air coals	200-280
MISSISSIPPIAN, Upper Mississippian	Pennington Formation	400
	Newman Limestone	570

LEGEND

Pwb

Wartburg Sandstone

Sandstone, light- to medium-gray, fine- to medium-grained, thin- to thick-bedded; partings and intervals of shale, olive-gray to olive-black; locally carbonaceous.

Pgm

Glenmary Shale

Shale, olive-gray to olive-black and medium-gray, silty to sandy, with thin beds of sandstone, medium light-gray, fine- to medium-grained, crossbedded; thin, unnamed coal seams separated by thin intervals of olive-gray, sandy shale locally in upper part of formation in northeast and north-central parts of quadrangle.

Pc

Coalfield Sandstone

Sandstone, light-gray to medium light- and olive-gray, very fine- to medium-grained, thin- to medium-bedded, silty; commonly interbedded with olive-gray to olive-black shale and sandy siltstone laminae and beds; typically poorly cemented.

Pb

Burnt Mill Shale

Shale, silty, dark-gray to olive-black, locally interbedded with laminae of sandstone and thin beds of sandstone, light-gray, very fine-grained, medium light-gray, very fine- to fine-grained with shale laminae; Hooper coal and associated seat earth, dark-gray to olive-gray, rooted, locally near base.

Pcr

Crossville Sandstone

Sandstone, light-gray, weathers yellowish-gray, very fine- to fine-grained, very thin- to medium-bedded; thin-bedding predominant in upper third. Lower third typically thin- to medium-bedded, crossbedded, and locally conglomeratic; intervals throughout interbedded and flasered with shale, olive-gray to olive-black, silty; shale locally near middle (well exposed along highways east and west of Oakdale), olive-to dark-gray with thin interbeds of sandstone. Where faulted, sandstone microfractured into white, dense orthoquartzite.

Pd

Dorton Shale

Shale, silty to sandy and with a few layers of ironstone, medium dark- to dark-gray and olive-gray, with laminae and beds of sandstone, light-gray, very fine-grained, flasered and burrowed; Rex coal with associated seat earth at or near top except approximately 40-50 feet below top to northwest; thin Christmas coal at base locally in northeast corner of quadrangle.

Pr

Rockcastle Conglomerate

Sandstone, light-gray, fine- to medium-grained, medium- to thick-bedded, some very thick-bedded, generally crossbedded, locally conglomeratic, predominates in the lower part. Unit locally interbedded with partings and thin beds of medium dark-gray shale. Upper part in western part of quadrangle silty, dark-gray shale interbedded with sandstone, medium light-gray, very fine- to fine-grained. Top of formation marked by persistent thin bed of sandstone and/or seat earth seen only in core logs. To the east, upper shale facies is replaced by sandstone similar to unit at base of formation to west. Persistent Nemo coal near base of upper shale unit. Interval between Rex coal and Nemo coal consistent 140±5 feet throughout quadrangle.

Pv

Vandever Formation

Shale, silty, medium dark-gray to olive-gray, persistent at top, middle, and base of formation; sandstone, very fine- to fine-grained, light-gray, flasered with irregular partings of medium dark-gray shale, persistent just above and below middle; shale and sandstone irregularly interlaminated with sandstone, very fine- to fine-grained, light-gray and medium- to medium dark-gray shale, rippled, flasered, and burrowed; thin Morgan Springs coal locally at or near top, with #12 coal in upper sandstone unit and Lantana coal near base; commonly split into several thin seams.

Pn

Newton Sandstone

Sandstone, light- to medium-gray, fine- to coarse-grained, thin- to thick-bedded, with a few shale and coal laminae; sandy shale, dark-gray, with a few sandstone laminae; siltstone, medium-gray.

Pw

Whitwell Shale

Shale, medium dark-gray to grayish-black and black, silty, with plant fossils and ironstone nodules scattered throughout, carbonaceous adjacent to coals; interlaminated with sandstone, very fine-grained, light-gray, and shale, medium dark-gray, flasered, and burrowed. Thin Sewanee coal locally just above middle and Richland coal throughout quadrangle at or near base with both coals underlain by seat earth, rooted siltstone, medium-gray, and siltstone, dark-gray to olive-black.

Ps

Sewanee Conglomerate

Sandstone, medium- to medium light-gray, fine- to coarse-grained, medium- to thick- and very thick-bedded, crossbedded, sparsely to strongly conglomeratic; thin, silty shale interval near middle, locally.

Pg

Gizzard Group

Shale, medium- to very dark-gray, silty, with interbedded laminae of silty sandstone and ironstone nodules; sandstone, medium light-gray, very fine- to fine-grained, thin- to medium-bedded; siltstone, medium-gray, mottled and shaly; Bon Air coal locally in two to three thin seams; several shale and sandstone horizons sheared and shattered by décollement of Cumberland Plateau Overthrust Fault.

Mp

Pennington Formation

Shale, grayish-red, light olive- to greenish-gray, silty; sandstone, light- to medium-gray and yellowish-gray, very fine- to fine-grained; limestone, medium-gray to light olive-gray, very fine-grained; and dolomite, light olive-gray. Formation only locally exposed, but invariably crumpled where seen.

Mn

Newman Limestone

Limestone, light- to medium-gray, very fine- to medium-grained, generally thick-bedded, locally oolitic. No complete section of the Newman (equivalent to all Mississippian limestone formations extending from the Bangor down through the Warsaw) in this quadrangle because of faulting. Upper 160 feet equivalent to the Bangor Limestone, medium- to dark-gray, medium-grained; zones of shale, medium-gray to light olive-gray. Hartselle Formation equivalent to sandstone, light-gray to light olive-gray, very fine-grained, calcareous; and shale, calcareous; approximately 70 feet thick. Monteagle Limestone equivalent, 220 feet thick, light- to medium-gray and light olive-gray, fine- to medium-grained; some scattered oolitic and shaly zones. St. Louis Limestone equivalent, 80 feet thick, medium-gray, some light-gray, very fine- to fine-grained, dolomitic, with medium- to dark-gray chert. Warsaw Limestone equivalent, 40 feet thick, light- to medium-gray, fine- to medium-grained, sandy with crinoidal chert. Individual formations not mappable in this area because of scarcity of exposures due to heavy colluvial cover.

SYSTEM AND SERIES	GROUP AND FORMATION	THICKNESS IN FEET
MISSISSIPPIAN, Lower Mississippian	Fort Payne Formation	150
MISSISSIPPIAN AND DEVONIAN, Lower Mississippian and Upper Devonian	Chattanooga Shale	25
SILURIAN, Lower and Middle Silurian	Rockwood Formation	As much as 760
ORDOVICIAN, Upper Ordovician	Sequatchie Formation	100
ORDOVICIAN, Middle Ordovician	Chickamauga Limestone	1250
ORDOVICIAN, Lower Ordovician / CAMBRIAN, Upper Cambrian	Knox Group	Approximately 2600
CAMBRIAN, Upper Cambrian	Maynardville Limestone	200-400
CAMBRIAN, Middle Cambrian	Conasauga Shale	Approximately 2000
CAMBRIAN, Lower Cambrian	Rome Formation	Approximately 1500

LEGEND

Mfp

Fort Payne Formation

Siltstone, yellowish-gray, dolomitic, siliceous; weathers to medium-bedded layers of chert. Thin green shale with phosphatic nodules (Maury Shale) at base.

MDc

Chattanooga Shale

Shale, very dark-gray to black, carbonaceous, commonly chevron-folded.

Sr

Rockwood Formation

Upper 160 feet predominantly shale, medium-gray, yellowish-brown, reddish-brown and grayish-red, argillaceous, ferruginous; with numerous 1- to 2-inch layers of yellow-brown to gray siltstone and thin layers of bedded hematite, reddish-brown to red, oolitic, submetallic luster where fresh; generally less than 2 feet thick, mostly in zone 100 to 150 feet below top of formation; middle unit with approximate thickness of 220 feet predominantly sandstone, light brownish-red, light-gray, light-green, and reddish-brown, very fine- to fine-grained, thin- to medium-bedded, calcareous; interbedded with siltstone and limestone, very sandy; may be equivalent to the Clinch Sandstone to north and east. Limestone, lower 400 feet of formation, yellowish-gray to medium-gray with scattered reddish-brown specks, fine-grained to cryptocrystalline, silty; interbedded with siltstone, medium dark-gray.

Os

Sequatchie Formation

Limestone, mottled shades of red and green, medium-gray and brownish-gray, very silty and argillaceous, medium-bedded; interbeds of olive-gray to dark-red, calcareous shale.

Och

Chickamauga Limestone

Limestone, light- to medium-gray and dark-gray, cryptocrystalline to coarsely crystalline, thin- to medium-bedded; fossiliferous; argillaceous shale beds present locally; shaly limestone abundant. Two or more 1- to 3-foot layers of bentonite in upper half.

O€k

Knox Group

Dolomite, siliceous, light- to dark-gray and olive-gray, very fine- to medium-grained, generally medium-bedded; a few limestone layers in upper part; scattered thin (generally less than 5 feet thick) quartz sandstone beds and lenses; commonly weathered to thick residuum of reddish-orange soil containing chert fragments.

€mn

Maynardville Limestone

Dolomite approximately upper third, light- to medium-gray, fine-grained, laminated to thinly bedded; distinguished from overlying Knox Group by lack of chert; limestone below, medium-gray, fine-grained, thin- to very thick-bedded; characteristically ribboned with shale seams and dolomite laminae.

€c

Conasauga Shale

Shale, gray, red, light-green, and dull purple; argillaceous and silty; zones of shaly, gray limestone, somewhat oolitic, as much as 100 feet thick scattered throughout. Formation contorted, brecciated, and sheared throughout.

€r

Rome Formation

Shale and siltstone, with lesser thicknesses of sandstone and dolomite. Shale, variegated, reddish- and greenish-gray, olive-green, light-green, and brown, micaceous, and generally arenaceous; siltstone layers as much as a few inches thick, medium-gray, and in part glauconitic; sandstone beds generally fine-grained, thin- to medium-bedded, as much as 2 feet thick. Formation characterized by abundance of ripple marks, mud cracks, and irregularly oriented markings (tracks, trails, etc.) on bedding planes; typically underlies sharp-crested ridges. Base nowhere exposed.

Contact, dashed where approximate, dotted where concealed.
Thrust fault, on upper plate, dashed where approximate, dotted where concealed.
Tear fault, arrows indicate relative movement, dashed where approximate, dotted where concealed.
Fault, U on upthrown side, D on downthrown side dashed where approximate, dotted where concealed.
K Klippe
W Window
Strike and dip of beds
Normal
Vertical
Overturned
Crumpled
Dip less than 5°
Horizontal

Active quarry showing extent.
Abandoned quarry or mine showing extent.
Abandoned mine
Abandoned strip mine
Coal cropline, dashed where approximate.
Prospect or exposure
Abandoned adit
Trench
Dry hole (oil and gas shows)
Dry hole (gas show)
Dry hole
Mineral test hole
42 Map numbers refer to descriptions in Mineral Resources Summary.

c Coal
dol Dolomite
ls Limestone
ss Sandstone
Fe Iron
lsl Landslide

u unnamed coal
h Hooper coal
rx Rex coal
n Nemo coal
r Richland coal

Many geologists have contributed work on this quadrangle over the years. Contributors other than the three principal authors include: James L. Harding, Albert B. Horton, John W. Jewell, Edward T. Luther, R. Alan Mebane, Robert M. Mitchum, Jr., John Rodgers, William D. Rose, George D. Swingle, Herbert A. Tiedemann, and Charles W. Wilson, Jr. Credit must also be given to the two core-drilling projects and three oil and gas tests (see Mineral Resources Summary) that made possible the final correlation of Pennsylvanian units in this quadrangle.

References

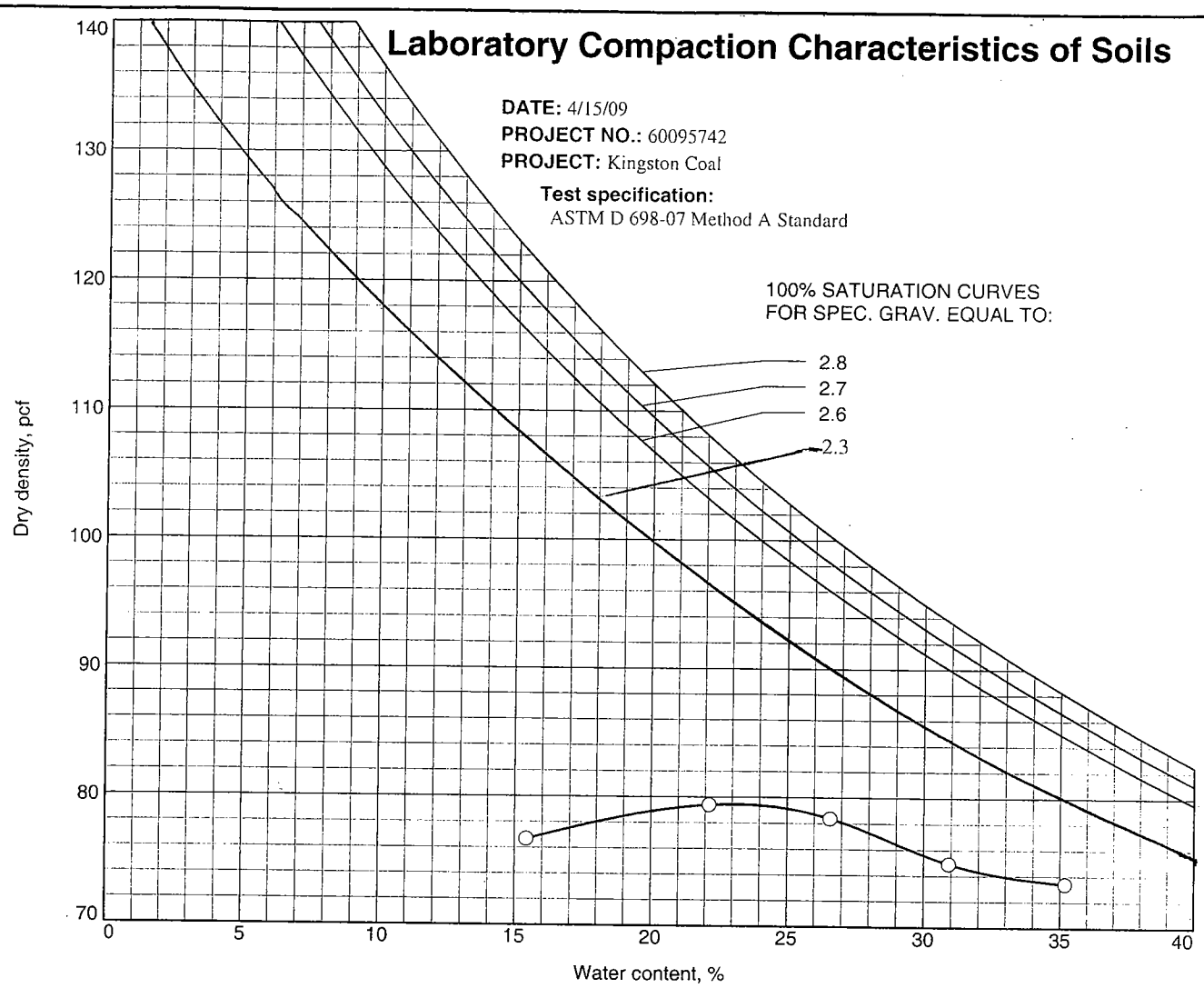
Harding, James L., (1957) *The geology of Emory Gap, Roane County, Tennessee:* University of Tennessee, unpublished Master's thesis.
Mebane, R. Alan, (1957) *The geology of the South Harriman area, Roane County, Tennessee:* University of Tennessee, unpublished Master's thesis.
Milici, Robert C., (1955) *The structural geology of the Harriman corner, Roane County, Tennessee:* University of Tennessee, unpublished Master's thesis.
Rodgers, John, (1953) *Geologic map of East Tennessee with explanatory text:* Tennessee Division of Geology Bulletin 58, Part 2, 168 p.
Tiedemann, Herbert A., (1956) *The geology of the Postoak window, Roane County, Tennessee:* University of Tennessee, unpublished Master's thesis; (abs.) Geological Society of America Bulletin, v. 67, p. 1760.

Appendix B

Test Data – Landfilled Ash

Laboratory Compaction Characteristics of Soils

DATE: 4/15/09
PROJECT NO.: 60095742
PROJECT: Kingston Coal
Test specification:
ASTM D 698-07 Method A Standard



	Sample No.	Elev. or Depth	Material Description	Specific Gravity	LL	PL	Oversize	% < #200
○	SC-18		COAL ASH - DARK GRAY	2.33	N/A	N/P		

Sample No.	SC-18			
Natural water content, percent	16.3			
Optimum water content, percent	23.0			
Max dry density, pcf	79.4			

Remarks: TEST PERFORMED ON 4/12/09.
NATURAL MOISTURE AS RECIEVED.

Project: Kingston Coal
Project No.: 60095742

Location: TN

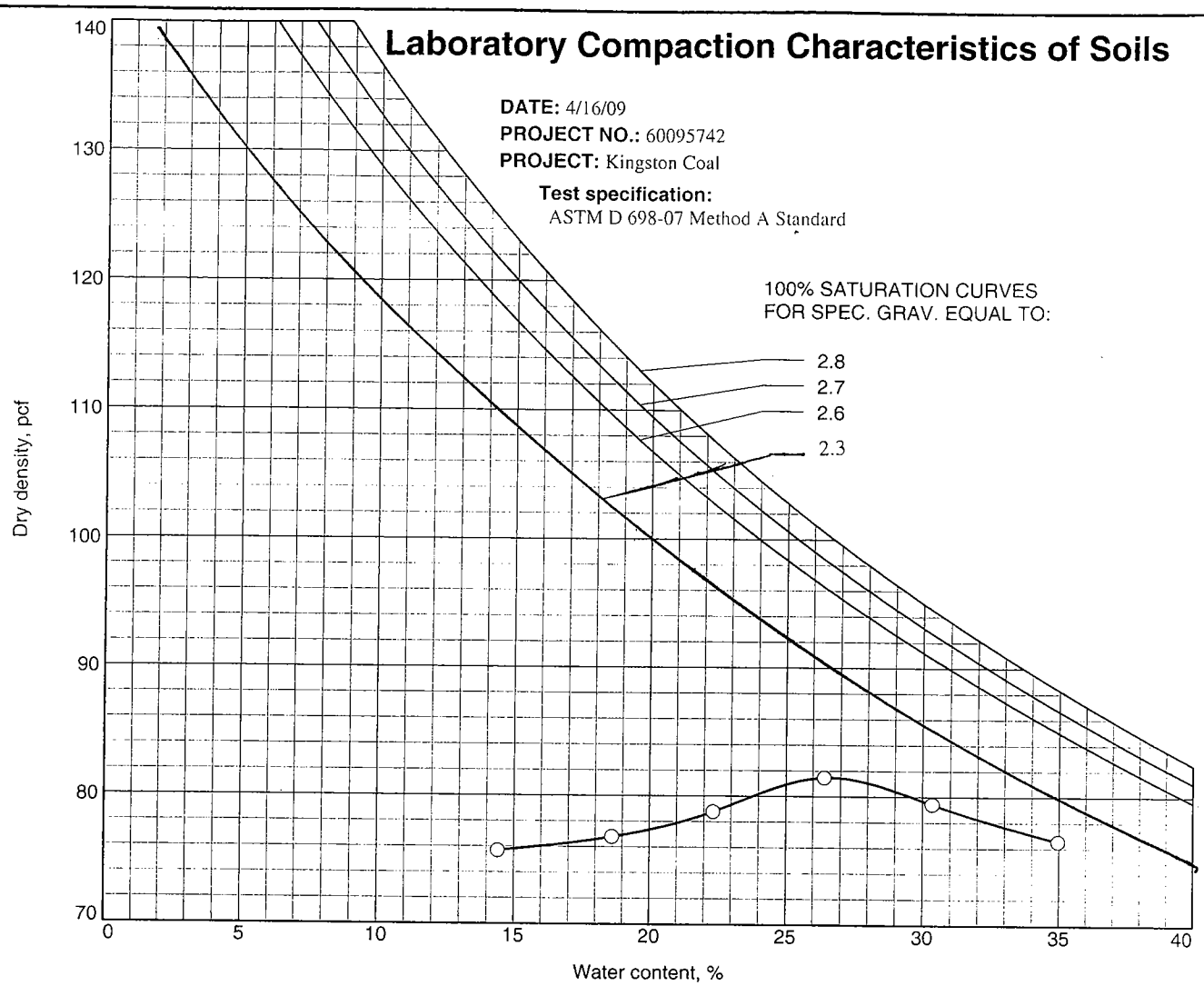
Source: Bulk Samples

STS

Tested By: MM **Checked By:** WPQ

Laboratory Compaction Characteristics of Soils

DATE: 4/16/09
PROJECT NO.: 60095742
PROJECT: Kingston Coal
Test specification:
ASTM D 698-07 Method A Standard



	Sample No.	Elev. or Depth	Material Description	Specific Gravity	LL	PL	Oversize	% < #200
○	SC-26		COAL ASH - DARK GRAY	2.33	N/A	N/P		

Sample No.	SC-26			
Natural water content, percent	24.6			
Optimum water content, percent	26.6			
Max dry density, pcf	81.5			

Remarks: TEST PERFORMED ON 4/12/09.
NATURAL MOISTURE AS RECIEVED.

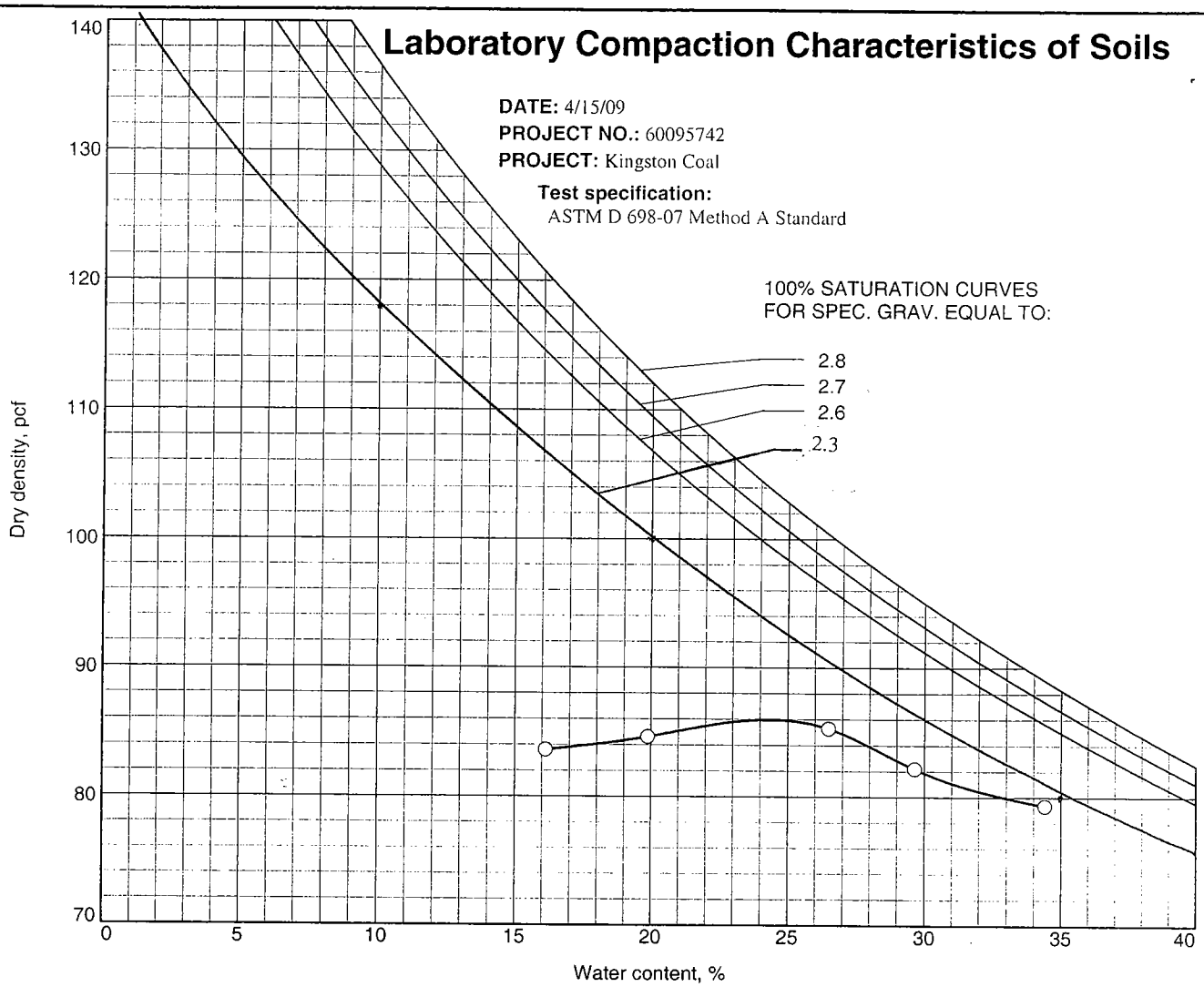
Project: Kingston Coal
Project No.: 60095742
Location: TN
Source: Bulk Samples

STS

Tested By: MM **Checked By:** WPQ

Laboratory Compaction Characteristics of Soils

DATE: 4/15/09
PROJECT NO.: 60095742
PROJECT: Kingston Coal
Test specification:
ASTM D 698-07 Method A Standard



	Sample No.	Elev. or Depth	Material Description	Specific Gravity	LL	PL	Oversize	% < #200
○	SC-34		COAL ASH - DARK GRAY	2.33	N/A	N/P		

Sample No.	SC-34			
Natural water content, percent	21.2			
Optimum water content, percent	24.3			
Max dry density, pcf	86.0			

Remarks: TEST PERFORMED ON 4/12/09.
NATURAL MOISTURE AS RECIEVED.

Project: Kingston Coal
Project No.: 60095742

Location: TN

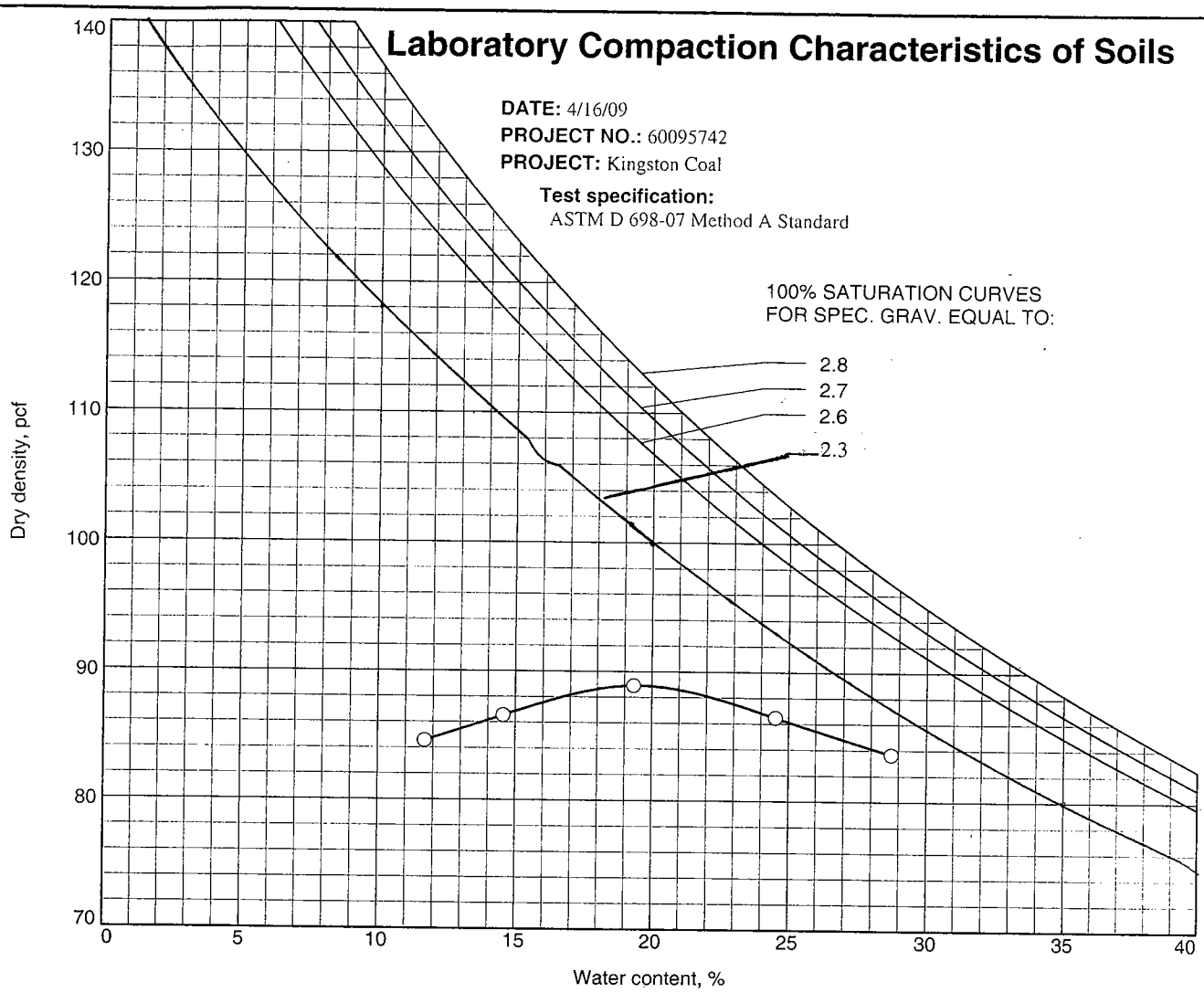
Source: Bulk Samples

STS

Tested By: MM **Checked By:** WPQ

Laboratory Compaction Characteristics of Soils

DATE: 4/16/09
PROJECT NO.: 60095742
PROJECT: Kingston Coal
Test specification:
ASTM D 698-07 Method A Standard



	Sample No.	Elev. or Depth	Material Description	Specific Gravity	LL	PL	Oversize	% < #200
○	SC-40		COAL ASH - DARK GRAY	2.33	N/A	N/P		

Sample No.	SC-40			
Natural water content, percent	20.5			
Optimum water content, percent	19.4			
Max dry density, pcf	88.9			

Remarks: TEST PERFORMED ON 4/12/09.
NATURAL MOISTURE AS RECIEVED.

Project: Kingston Coal
Project No.: 60095742

Location: TN

Source: Bulk Samples

STS

Tested By: MM **Checked By:** WPQ

Stantec

Summary of Soil Tests

Project Name	TVA Kingston Plant Dike Failure	Project Number	171468117
Source	Kingston Fly Ash	Lab ID	30
County	N/A	Date Received	3-5-09
Sample Type	Bag	Date Reported	3-18-09

Test Results

Natural Moisture Content

Test Method: ASTM D 2216

Moisture Content (%): 24.5

Particle Size Analysis

Preparation Method: ASTM D 421

Gradation Method: ASTM D 422

Hydrometer Method: ASTM D 422

Particle Size		%
Sieve Size	(mm)	Passing
3"	75	
2"	50	
1 1/2"	37.5	
1"	25	100.0
3/4"	19	99.2
3/8"	9.5	96.5
No. 4	4.75	93.7
No. 10	2	88.3
No. 40	0.425	81.8
No. 200	0.075	59.1
	0.02	29.6
	0.005	7.6
	0.002	3.0
estimated	0.001	1.0

Plus 3 in. material, not included: 0 (%)

Range	ASTM (%)	AASHTO (%)
Gravel	6.3	11.7
Coarse Sand	5.4	6.5
Medium Sand	6.5	---
Fine Sand	22.7	22.7
Silt	51.5	56.1
Clay	7.6	3.0

Atterberg Limits

Test Method: ASTM D 4318 Method A

Prepared: Dry

Liquid Limit: ---

Plastic Limit: Non Plastic

Plasticity Index: ---

Activity Index: N/A

NOTE: Assumed

Moisture-Density Relationship

Test Method: ASTM D 698 Method B

Maximum Dry Density (lb/ft^3): 82.8

Maximum Dry Density (kg/m^3): 1326

Optimum Moisture Content (%): 24.9

Over Size Correction %: N/A

California Bearing Ratio

Test Not Performed

Bearing Ratio (%): N/A

Compacted Dry Density (lb/ft^3): N/A

Compacted Moisture Content (%): N/A

Specific Gravity

Test Method: ASTM D 854

Prepared: Dry

Particle Size: No. 10

Specific Gravity at 20° Celsius: 2.31

Classification

Unified Group Symbol: ML

Group Name: Sandy silt

AASHTO Classification: A-4 (0)

Comments: Atterberg Limit Test not performed.

Reviewed by:

Appendix C

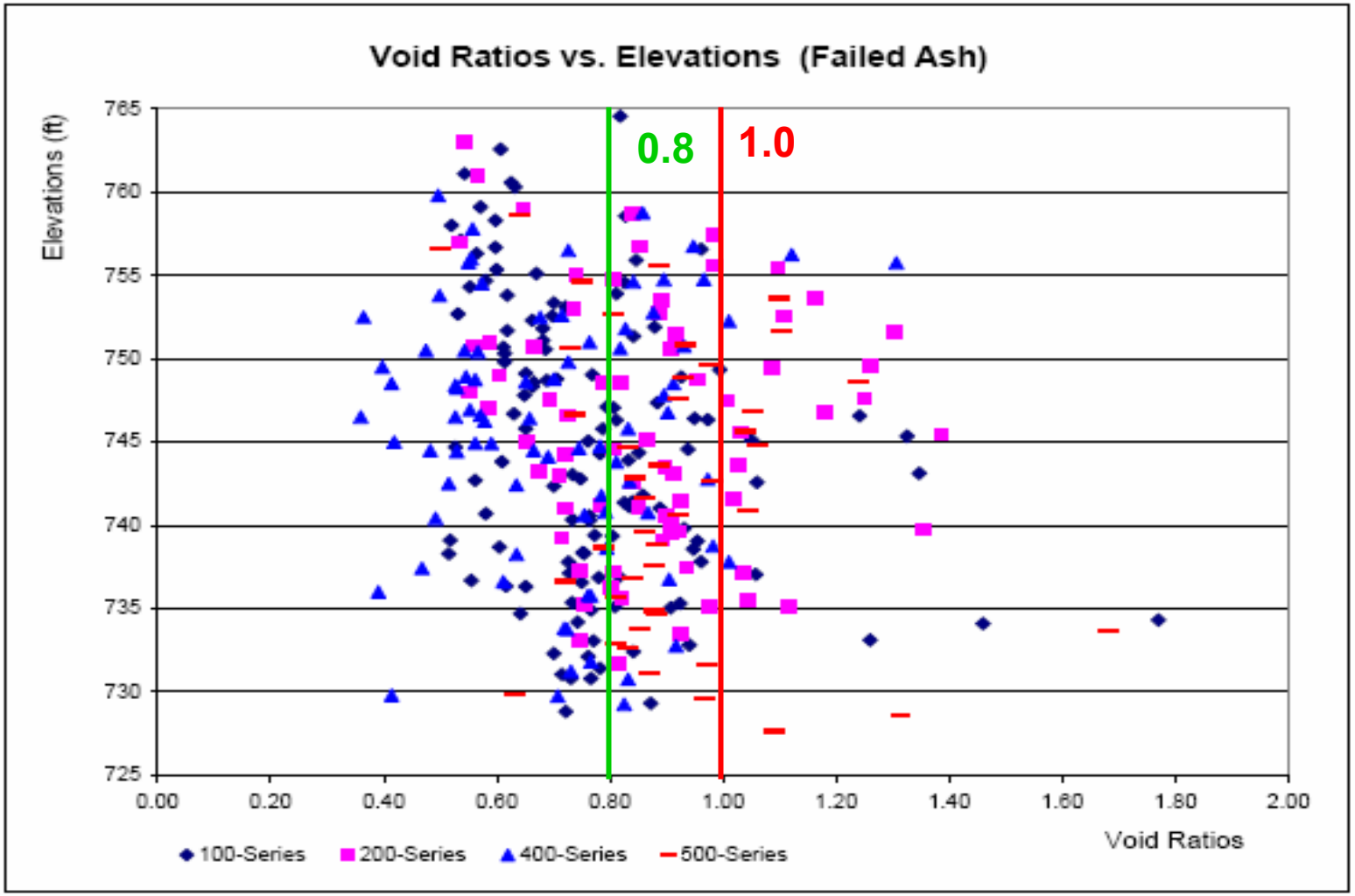
Test Data – Hydraulically Placed Ash

Sluiced Loose Ash Properties

- Sluiced Ash under Dredged Cells
- Thin Laminates of Ash and Red Silt at base
- Void Ratios (e = 0.7 to 1.4)
- Specific Gravity Gs = 2.25 to 2.35
- Void Ratios do not Decrease with Depth
- Contractive Undrained Behavior
- Triaxial CIU' and CKU' Shear Behavior (A_f>1.0)
- Low Undrained Steady State Shear Strength
- Drained Friction Angle 28 to 40 degrees

Work in-Progress

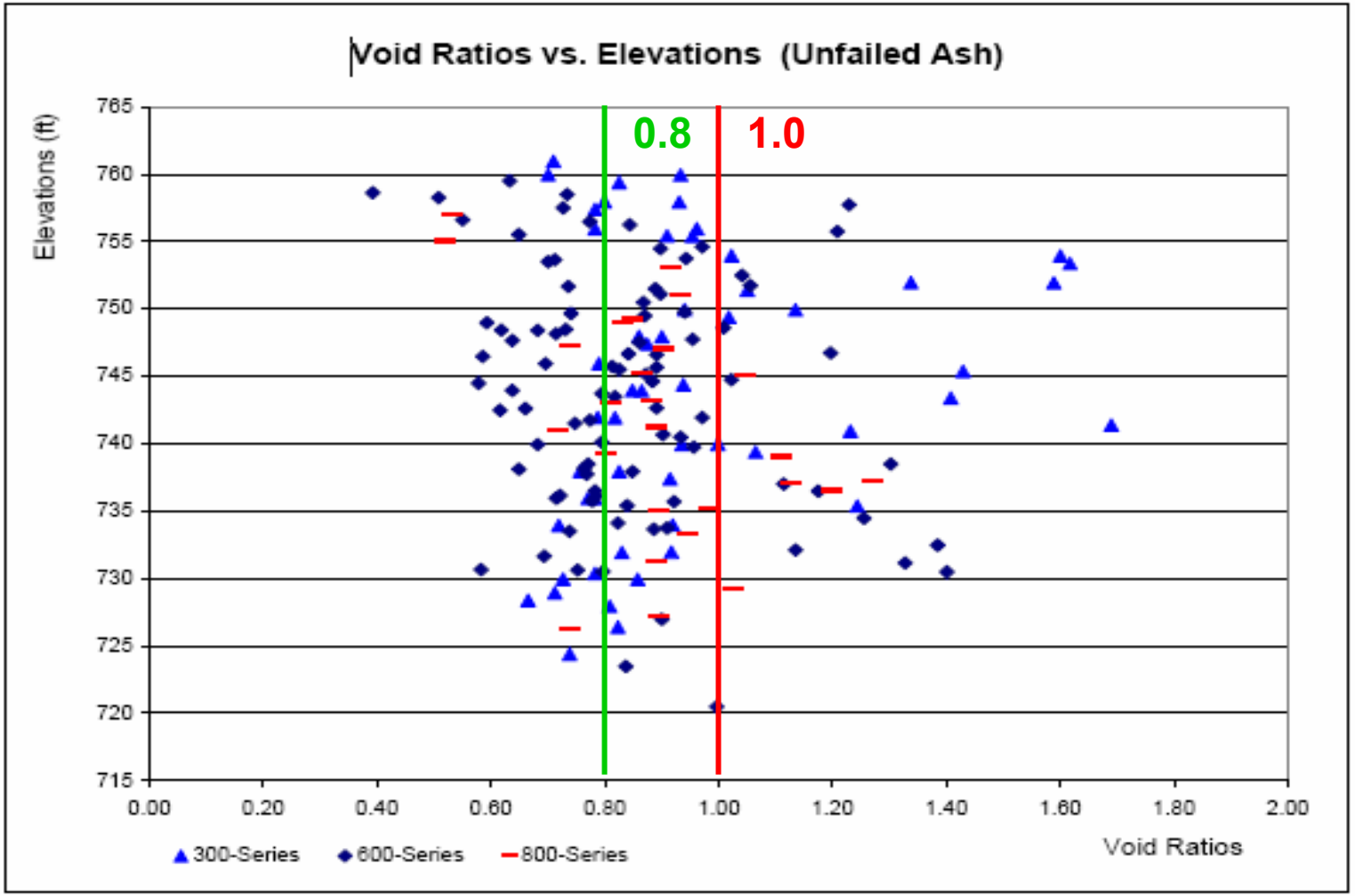
Failed Ash Void Ratios



Failed Ash Average: 0.82

Note: 1. Only ash below Elev. 760 ft. In 100- and 200-Series, ash below water table
2. Assuming G_s=2.35 and 100% saturation
3. Failed Ash in 100-, 200-, 400- and 500-Series boirngs

Unfailed Ash Void Ratios



Unfailed Ash Average 0.89

Note: 1. Only ash below Elev. 760 ft.
2. Assuming G_s=2.35 and 100% saturation
3. Unfailed Ash in 300-, 600- and 800-Series Borings