November 10, 1995

Cheri Miller
Tennessee Valley Authority
Fossil Fuels Group
1101 Market Street
Chattanooga, Tennessee 37402-2801

Subject: **FINAL REPORT TRANSMITTAL**
Fly Ash, Bottom Ash and Scrubber Gypsum Study
Contract No. TV-92657V, Phase 1
Law Engineering - Knoxville Project No. 50385-5-0400 (Phase 1)
Law Engineering - Atlanta Project No. 5810860101

Dear Cheri:

I've sent a special messenger (courier) to deliver this final report. The package consists of five final report letters (for distribution to all who received the five sets I brought up last month) and the original test reports for all the work performed in this test phase. I've also copied the Excel spreadsheet files that you may find helpful. They are: Prgrm.xls - *contains all the information you see in the 11x17 fold-out sheets*; and 29 additional .xls files which contain a summary of results for each individual material/source tested, which are shown in each of the sections following a colored sheet of paper.

In speaking with Don Armour, he made a lot of sense when describing why the gypsums, a water soluble material, behaved the way they did. Essentially, the air-dry method of achieving an air-dried condition most certainly chemically altered the material. Additionally, because of the water soluble nature of the material, he recommends using gypsum saturated water when performing the saturation steps for the majority of the geotechnical tests performed. There is apparently some literature available in the Electric Power Research Institute (EPRI). I suggest that if we research the gypsum materials further, we retain Mr. Armour as a technical consultant to help us understand what is going on.

Thank you for the opportunity to be of service to you on this project. If you have any questions or require any additional information, please contact me.

Sincerely,
LAW ENGINEERING, INC.

Rich

Richard L. Boudreau, P.E.
Senior Materials Engineer

LAW
ENGINEERING AND ENVIRONMENTAL SERVICES

November 7, 1995

Tennessee Valley Authority
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Dear Sir/Madam:

Law Engineering has completed the testing program outlined in the Scope of Work - Phase 1 of Contract TV-92657V. This letter provides a brief background of the test program. In addition, a descriptive summary of the test procedures used is presented. The summary provides discussion pertaining to clarifications or deviations from the procedures. Finally, general observations made while preparing samples or performing tests that are not represented on the test reports are discussed, and the results of the test program are presented.

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Based on our years of experience with the testing of geotechnical materials and our experience derived from this test program, we have highlighted some instances in which these materials behaved differently than others, either visually or by test results that varied significantly from results calculated for similar materials.

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Law Engineering has completed the testing program outlined in the Scope of Work - Phase 1 of Contract TV-92657V. This letter provides a brief background of the test program. In addition, a descriptive summary of the test procedures used is presented. The summary provides discussion pertaining to clarifications or deviations from the procedures. Finally, general observations made while preparing samples or performing tests that are not represented on the test reports are discussed, and the results of the test program are presented.

BACKGROUND

The purpose of this laboratory testing program was to provide classification and engineering properties characterization of several of the Tennessee Valley Authority's (TVA) sources of fly ash, bottom ash, boiler slag and scrubber gypsum. Twenty-nine materials from eleven coal burning power generation steam plants were included in this study. The materials received were tested through a broad range of test procedures outlined by the American Society for Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO), the Strategic Highway Research Program (SHRP), and Law Engineering. Each test in the program was chosen to illustrate the engineering properties of each material to determine their suitability for structural embankment fill in highway construction.

In all, thirteen sources of fly ash, nine sources of bottom ash, two sources of boiler slag and three sources of scrubber gypsum (FGD - flue gas desulfurization) were received for testing. In addition, a Spent Bed Material and Char material were received from the single unit atmospheric fluidized bed boiler at Shawnee. Each source material was provided to us in six 5-gallon plastic buckets, labeled A through F.

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Soils Classification System (USCS) symbol are provided based on the Particle-Size Analysis and Atterberg Limits results. Similarly, an AASHTO classification is provided based on guidelines set forth in *The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes, AASHTO M145.*

Volumetric Testing

Several tests were performed to provide the general volumetric properties of each material. The tests outlined below were performed on one composite sample from each of the twenty-seven fly ash, bottom ash, boiler slag and scrubber gypsum sources.

Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3) (600 kN-m/m^3), ASTM D 698. This method defines the moisture content versus dry density relationship of the material using the standard specified level of energy. The method is commonly referred to as the Standard Proctor.

Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3) (2,700 kN-m/m^3), ASTM D 1557. This method defines the moisture content versus dry density relationship of the material using the standard specified level of energy. The method is commonly referred to as the Modified Proctor.

Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table. ASTM D 4253 and *Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density, ASTM D 4254.* Because the Standard and Modified Proctors do not necessarily define a good relationship between dry density and moisture content (typically because of the free draining nature of granular materials), the minimum and maximum index densities were determined for the nine bottom ash samples.

Test Method for One-Dimensional Consolidation Properties of Soils, ASTM D 2435. Samples of the fly ash, boiler slag and scrubber gypsum were remolded in nominal 2.5-inch diameter by 1.0-inch high rings to approximately 95 percent of the maximum dry density at the optimum moisture content as determined by the Standard Proctor. Nominal load increments of 0.5, 1.0, 2.0, 4.0, 8.0 and 16.0 ksf were applied. Moist porous stones were used; however, samples were not inundated for the test.

Hydraulic Conductivity and Static Strength Testing

Test Method for Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, ASTM D 5084. The fly ash, boiler slag and scrubber gypsum materials were remolded to approximately 95 percent of the maximum dry density at the optimum moisture content as determined by the Standard Proctor and tested for hydraulic conductivity. An effective confining pressure of 14 psi was used as the standard for all tests. The samples were remolded to a nominal 2.88-inch diameter by 6.0-in high specimen.

Test Method for Permeability of Granular Soils (Constant Head), ASTM D 2434. The bottom ash materials were remolded to approximately 95 percent of the maximum dry density as determined

Electro-Chemical Testing

Determining the Minimum Laboratory Soil Resistivity, AASHTO T 288. A supersaturated slurry was prepared for each of the fly ash, bottom ash, boiler slag and gypsum/spent bed/char materials (fraction passing the #10 sieve) and the minimum resistivity value was measured.

Determining pH of Soil for Use in Corrosion Testing, AASHTO T 289. Each of the fly ash, bottom ash, boiler slag and gypsum/spent bed/char materials (fraction passing the #10 sieve) was prepared and the pH value was measured.
Determining Water Soluble Sulfate Ion Content in Soil, AASHTO T 290. Each of the fly ash, bottom ash, boiler slag and gypsum/spent bed/char materials (fraction passing the #10 sieve) was prepared and the water soluble sulfate ion content was measured using the Turbidimetric Method (Method B).

Determining Water Soluble Chloride Ion Content in Soil, AASHTO T 291. Each of the fly ash, bottom ash, boiler slag and gypsum/spent bed/char materials (fraction passing the #10 sieve) was prepared and the water soluble chloride ion content was measured using the pH/mV Meter Method (Method B).

PECULIARITIES AND TEST RESULTS

Based on our years of experience with the testing of geotechnical materials and our experience derived from this test program, we have highlighted some instances in which these materials behaved differently than others, either visually or by test results that varied significantly from results calculated for similar materials.

- Both the spent bed material (Shawnee) and the char (Shawnee) were observed to react upon treatment with water. This phenomenon created complications with all the geotechnical tests (classification, volumetric, and strength test). Only the electro-chemical tests were performed on these materials. Because of the highly reactive nature of the spent bed material, the resistivity test was unable to be performed.

- The scrubber gypsum materials were observed to react upon treatment with water following the air dry preparation of these materials. The samples were air-dried overnight in a temperature controlled room set at 140 °F. This phenomenon created complications with the successful completion of the classification tests, although we were able to perform a specific gravity test on a composite sample of each source. We note that the scrubber gypsum materials exhibit relatively more strength than the other materials tested in this program when tested under dynamic conditions at low applied strains (Resilient Modulus). This may indicate that a weak chemical bond is created between particles.

- Beside the noticeable color difference of the Cumberland Dry Fly Ash (tan/brown as opposed to gray for all other fly ashes in this program) that was sampled from Units 1 and 2 on April 17, 18 and 19, 1995, several of the observations and test results are worth noting:

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Technical Procedures
for
Tennessee Valley Authortiy

TITLE: DETERMINING THE ANGLE OF REPOSE OF NON-COHESIVE GRANULAR SAMPLES

These procedures meet the Quality Assurance Program requirements for this project. LAW's Quality Assurance Program Description and all of its invoked documents govern the preparation, approval, and use of these procedures.

Copy Number ____

PREPARED BY:

Richard L. Boudreau, P.E. — 9/11/95 Date

APPROVALS:

James W. Niehoff, P.E. — 9/19/95 Date
Chief Engineer

______________________ ____________ Date

______________________ ____________ Date

3.1.6 Calculate the angle of repose, using the average of the 2 measurements taken, using the following equations:

$$\phi_1 = \text{Tan}^{-1} [(V_1 - V_0)/H_1]$$

$$\phi_2 = \text{Tan}^{-1} [(V_2 - V_1)/(H_2 - H_1)]$$

$$\phi_{avg} = (\phi_1 + \phi_2)/2$$

where: $H_{1,2}$ = Horizontal distance from mound peak along horizontal plane, inches

$V_{0,1,2}$ = Vertical distance from horizontal offset along horizontal plane to the surface of the mound, inches

4.0 REPORTING

4.1 The following information shall be reported:

- Sample I.D.
- Visual description
- Average angle of repose value

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Classification (Index Property) Summary
Law Engineering Project No. 5810860101

Source	Code	Material	Bucket Code	Date Collected	Moisture Content, %	Grain Size - ASTM D422 %Ret. on No. 4	%Pass No. 200	%Pass 0.005mm	Atterberg Limits ASTM D4318 LL	PL	PI	Specific Gravity	USCS Classification	AASHTO Classification
Allen	ALF	Boiler Slag - Fine Reed Rejects	A-B	5/11/95	0.06	0.0	18.2	0.8	NL	NP	N/A	2.75	SM	A-2-4(0.0)
			C-D		0.12	0.0	14.6	0.8	NL	NP	N/A	2.79	SM	A-2-4(0.0)
			E-F		0.10	0.0	16.0	0.8	NL	NP	N/A	2.81	SM	A-2-4(0.0)
Bull Run	BRF	Dry Fly Ash	A-B	4/4/95	0.02	0.0	91.2	16.6	NL	NP	N/A	2.36	ML	A-4(0.0)
			C-D	4/5/95	0.05	0.0	91.2	19.5	NL	NP	N/A	2.28	ML	A-4(0.0)
			E-F	4/6/95	0.03	0.0	90.7	17.5	NL	NP	N/A	2.37	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	3/29/95	6.99	23.0	4.0	----	NL	NP	N/A	2.31	SW	A-1-b
			C-D		6.07	21.3	6.9	----	NL	NP	N/A	2.29	SW-SM	A-1-b
			E-F		6.74	17.9	5.9	----	NL	NP	N/A	2.35	SW-SM	A-1-b
Colbert	COF	Dry Fly Ash - Units 1&2	A	5/25/95										
		- Units 3&4	B	5/25/95	0.01	0.0	81.6	14.9	NL	NP	N/A	2.02	ML	A-4(0.0)
		- Units 1&2	C	5/26/95										
		- Units 3&4	D	5/26/95	0.01	0.0	69.9	11.5	NL	NP	N/A	2.00	ML	A-4(0.0)
		- Units 1&2	E	5/30/95										
		- Units 3&4	F	5/30/95	0.12	0.0	83.6	3.9	NL	NP	N/A	1.95	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	5/25/95	8.02	7.2	13.6	----	NL	NP	N/A	2.15	SM	A-1-b
			C-D		6.86	15.9	10.8	----	NL	NP	N/A	2.08	SP-SM	A-1-b
			E-F		7.92	12.8	10.5	----	NL	NP	N/A	2.10	SP-SM	A-1-b
Cumberland	CUF	Dry Fly Ash - Units 1&2	A-B	4/17/95	0.31	0.0	95.1	30.0	NL	NP	N/A	2.57	ML	A-4(0.0)
		- Units 1&2	C-D	4/18/95		0.0	92.0	20.7	NL	NP	N/A	2.64	ML	A-4(0.0)
		- Units 1&2	E-F	4/19/95	0.01	0.0	93.2	29.8	NL	NP	N/A	2.65	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	4/6/95	14.32	30.9	1.1	----	NL	NP	N/A	2.59	SW	A-1-a
			C-D		13.66	46.2	2.2	----	NL	NP	N/A	2.66	SW	A-1-a
			E-F		5.08	32.2	2.8	----	NL	NP	N/A	2.63	SW	A-1-a
		Scrubber Gypsum	A-B	4/6/95	30.44	----	----	----	NL	NP	N/A	----	----	----
			C-D		30.39	----	----	----	NL	NP	N/A	3.41	----	----
			E-F		29.41	----	----	----	NL	NP	N/A	----	----	----
Gallatin	GAF	Dry Fly Ash - Unit 2 Hoppers	A-B	6/9/95	0.03	0.0	94.2	12.0	NL	NP	N/A	2.37	ML	A-4(0.0)
			C-D		0.01	0.0	95.2	13.8	NL	NP	N/A	2.40	ML	A-4(0.0)
			E-F		0.01	0.0	95.5	14.8	NL	NP	N/A	2.39	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	6/9/95	19.11	18.2	5.9	----	NL	NP	N/A	2.56	SP-SM	A-1-b
			C-D		7.32	27.0	4.0	----	NL	NP	N/A	2.57	SW	A-1-b
			E-F		10.20	18.8	5.6	----	NL	NP	N/A	2.52	SW-SM	A-1-b
John Sevier	JSF	Dry Fly Ash - Unit 4, Hoppers 11&12	A	5/25/95										
		- Unit 3, Hoppers 11&12	B		0.06	0.0	94.2	17.4	NL	NP	N/A	2.27	ML	A-4(0.0)
		- Unit 4, Hoppers 9, 10&13	C	5/25/95										
		- Unit 3, Hoppers 9&10	D		0.01	0.0	96.1	22.1	NL	NP	N/A	2.35	ML	A-4(0.0)
		- Unit 4, Hopper 15.	E	5/25/95										
		- Unit 3, Hopper 16			0.20	0.0	94.1	28.0	NL	NP	N/A	2.43	ML	A-4(0.0)
		- Unit 4, Hopper 15	F											
		Bottom Ash - From Pond	A-B	4/12/95	26.68	22.8	4.3	----	NL	NP	N/A	2.25	SP	A-1-a
			C-D		27.22	22.2	3.3	----	NL	NP	N/A	2.24	SW	A-1-a
			E-F		30.70	27.8	3.7	----	NL	NP	N/A	2.22	SW	A-1-a

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Classification (Index Property) Summary
Law Engineering Project No. 5810860101

Source	Code	Material	Bucket Code	Date Collected	Moisture Content, %	Grain Size - ASTM D422 %Ret. on No. 4	Grain Size - ASTM D422 %Pass No. 200	Grain Size - ASTM D422 %Pass 0.005mm	Atterberg Limits ASTM D4318 LL	Atterberg Limits ASTM D4318 PL	Atterberg Limits ASTM D4318 PI	Specific Gravity	USCS Classification	AASHTO Classification
Johnsonville	JOF	Ponded Fly Ash (New Dredge Cell)	A-B	6/7/95	28.82	3.2	47.1	2.4	NL	NP	N/A	2.36	SM	A-4(0.0)
			C-D		39.10	0.0	54.4	4.2	NL	NP	N/A	2.56	ML	A-4(0.0)
			E-F		31.07	1.8	59.2	3.5	NL	NP	N/A	2.31	ML	A-4(0.0)
		Ponded Fly Ash (Old Dredge Cell)	A-B	6/7/95	13.61	3.6	33.6	0.0	NL	NP	N/A	2.41	SM	A-2-4(0.0)
			C-D		10.98	8.7	42.2	4.1	NL	NP	N/A	2.43	SM	A-2-4(0.0)
			E-F		15.11	2.5	41.4	2.1	NL	NP	N/A	2.23	SM	A-4(0.0)
		Ponded Fly Ash (Active Ash Pond)	A-B	6/7/95	28.09	0.0	95.0	15.6	NL	NP	N/A	2.48	ML	A-4(0.0)
			C-D		31.07	0.0	94.8	14.8	NL	NP	N/A	2.48	ML	A-4(0.0)
			E-F		32.70	0.0	93.9	16.8	NL	NP	N/A	2.50	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	6/7/95	13.28	15.6	26.3	----	NL	NP	N/A	2.39	SM	A-1-b
			C-D		11.92	23.0	16.8	----	NL	NP	N/A	2.39	SM	A-1-b
			E-F		11.51	29.8	18.1	----	NL	NP	N/A	2.39	SM	A-1-b
Kingston	KIF	Ponded Fly Ash (Cell I)	A-B	5/3/95	28.28	0.0	86.4	13.6	NL	NP	N/A	2.28	ML	A-4(0.0)
			C-D		33.95	0.0	97.1	13.2	NL	NP	N/A	2.31	ML	A-4(0.0)
			E-F		30.95	0.0	94.0	13.1	NL	NP	N/A	2.30	ML	A-4(0.0)
		Ponded Fly Ash (Cell III)	A-B	5/3/95	36.09	0.0	96.5	22.6	NL	NP	N/A	2.31	ML	A-4(0.0)
			C-D			0.0	98.3	25.0	NL	NP	N/A	2.29	ML	A-4(0.0)
			E-F		36.19	0.0	96.1	18.4	NL	NP	N/A	2.34	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	5/3/95	9.62	21.9	9.7	----	NL	NP	N/A	2.37	SW-SM	A-1-b
			C-D		10.91	19.3	10.7	----	NL	NP	N/A	2.34	SP-SM	A-1-b
			E-F		17.15	18.4	11.3	----	NL	NP	N/A	2.33	SP-SM	A-1-b
Paradise	PAF	Ponded Fly Ash (East Cell)	A-B	5/17/95	----	0.0	99.4	20.9	NL	NP	N/A	2.82	ML	A-4(0.0)
			C-D		----	0.0	98.1	11.4	NL	NP	N/A	2.77	ML	A-4(0.0)
			E-F		----	0.0	98.5	18.7	NL	NP	N/A	2.93	ML	A-4(0.0)
		Boiler Slag (Reed Rejects)	A-B	5/18/95	----	0.0	5.8	0.0	NL	NP	N/A	2.78	SP-SM	A-1-b
			C-D		----	0.0	12.5	0.0	NL	NP	N/A	2.84	SM	A-2-4(0.0)
			E		----	1.0	10.2	0.0	NL	NP	N/A	2.73	SW-SM	A-1-b
		Scrubber Gypsum	A-B	5/17/95	----	----	----	----	NL	NP	N/A	----	----	----
			C-D		----	----	----	----	NL	NP	N/A	3.00	----	----
			E		----	----	----	----	NL	NP	N/A	----	----	----
Shawnee	SHF	Dry Fly Ash	A-B	4/6/95	0.14	0.0	91.6	7.6	NL	NP	N/A	2.14	ML	A-4(0.0)
			C-D	4/7/95	0.13	0.0	91.2	6.4	NL	NP	N/A	2.09	ML	A-4(0.0)
			E-F	4/10/95	0.16	0.0	90.1	7.5	NL	NP	N/A	2.11	ML	A-4(0.0)
		Bottom Ash - From Pond	A-B	4/5/95	23.64	20.0	11.2	----	NL	NP	N/A	2.14	SP-SM	A-1-b
			C-D		23.83	14.7	9.1	----	NL	NP	N/A	2.14	SP-SM	A-1-b
			E-F		21.11	18.3	9.3	----	NL	NP	N/A	2.09	SP-SM	A-1-b
		Spent Bed Material (SBM)	A-B	4/6/95	0.00	----	----	----	NL	NP	N/A	2.93	----	----
			C-D	4/7/95	0.00	----	----	----	NL	NP	N/A	2.86	----	----
			E-F	4/10/95	0.00	----	----	----	NL	NP	N/A	2.92	----	----
		Char	A-B	4/6/95	0.00	----	----	----	NL	NP	N/A	3.00	----	----
			C-D	4/7/95	0.00	----	----	----	NL	NP	N/A	2.99	----	----
			E-F	4/10/95	0.00	----	----	----	NL	NP	N/A	3.00	----	----
Widows Creek	WCF	Ponded Fly Ash (Ash Pond)	A-B	4/28/95	42.20	0.0	84.5	6.7	NL	NP	N/A	2.38	ML	A-4(0.0)
			C-D		75.19	1.5	84.6	8.2	NL	NP	N/A	2.40	ML	A-4(0.0)
			E-F		63.46	0.0	92.9	3.6	NL	NP	N/A	2.22	ML	A-4(0.0)
		Scrubber Gypsum	A-B	4/28/95	----	----	----	----	NL	NP	N/A	----	----	----
			C-D		----	----	----	----	NL	NP	N/A	3.01	----	----
			E-F		----	----	----	----	NL	NP	N/A	----	----	----
		Bottom Ash - From Pond	A-B	4/28/95	4.25	33.7	4.8	----	NL	NP	N/A	2.74	SW	A-1-a
			C-D		2.36	29.9	4.1	----	NL	NP	N/A	2.60	SW	A-1-a
			E-F		4.03	40.9	4.5	----	NL	NP	N/A	2.67	SW	A-1-a

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Volumetric Testing Summary
Law Engineering Project No. 5810860101

Source	Code	Material	Standard Proctor		Modified Proctor		Relative Density, Dry Method (pcf)	
			Max. Dry Dens. (pcf)	Opt. Moisture (%)	Max. Dry Dens. (pcf)	Opt. Moisture (%)	Minimum	Maximum
Allen	ALF	Boiler Slag (Fine Reed Rejects)	95.3	21.5	102.6	23.2	----	----
Bull Run	BRF	Dry Fly Ash	91.6	17.4	95.7	15.1	----	----
		Bottom Ash - From Pond	91.9	22.6	98.7	18.5	73.9	92.1
Colbert	COF	Dry Fly Ash (Units 1-4)	56.7	45.4	62.9	40.3	----	----
		Bottom Ash - From Pond	64.2	27.4	73.2	17.2	55.7	71.2
Cumberland	CUF	Dry Fly Ash (Units 1-2)	111.4	13.2	116.3	11.5	----	----
		Bottom Ash - From Pond	90.1	15.4	103.3	15.7	67.0	87.1
		Scrubber Gypsum	77.6	40.6	85.9	29.7	----	----
Gallatin	GAF	Dry Fly Ash (Unit 2 Hoppers)	86.6	21.4	88.9	18.8	----	----
		Bottom Ash - From Pond	92.0	25.5	102.5	20.9	71.3	90.7
John Sevier	JSF	Dry Fly Ash (Units 3-4)	83.7	18.6	86.7	17.8	----	----
		Bottom Ash - From Pond	78.9	30.3	96.2	21.9	55.7	73.9
Johnsonville	JOF	Ponded Fly Ash (New Dredge Cell)	75.8	31.4	92.5	20.6	----	----
		Ponded Fly Ash (Old Dredge Cell)	89.5	20.5	96.0	16.1	----	----
		Ponded Fly Ash (Active Ash Pond)	86.6	22.8	91.7	18.0	----	----
		Bottom Ash - From Pond	99.2	18.0	104.1	12.0	80.2	99.2
Kingston	KIF	Ponded Fly Ash (Cell I)	81.0	25.2	84.7	24.1	----	----
		Ponded Fly Ash (Cell III)	81.0	23.5	84.4	23.7	----	----
		Bottom Ash - From Pond	89.0	24.1	97.6	21.0	71.0	88.4
Paradise	PAF	Ponded Fly Ash (East Cell)	110.0	16.5	114.4	13.7	----	----
		Boiler Slag (Reed Rejects)	112.5	18.2	116.0	18.7	----	----
		Scrubber Gypsum	85.7	31.7	87.4	30.8	----	----
Shawnee	SHF	Dry Fly Ash	72.4	28.3	77.2	24.4	----	----
		Bottom Ash - From Pond	71.7	30.5	81.4	26.1	57.4	74.0
		Spent Bed Material (SBM)	----	----	----	----	----	----
		Char	----	----	----	----	----	----
Widows Creek	WCF	Ponded Fly Ash (Ash Pond)	67.0	39.8	73.5	27.8	----	----
		Scrubber Gypsum	92.0	23.1	99.9	19.4	----	----
		Bottom Ash - From Pond	106.2	17.6	120.8	15.8	83.0	103.3

lab\soil\tva\prgrm.xls (Proctor)

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Consolidation/Hydraulic Conductivity/Chemical Testing Summary
Law Engineering Project No. 5810860101

Source	Code	Material	Consolidation Compression Index, C_c	Hydraulic Conductivity (cm/sec)	Resistivity (Ohm-cm)	pH	Water Soluble Sulfate (mg/kg)	Water Soluble Chloride (mg/kg)
Allen	ALF	Boiler Slag (Fine Reed Rejects)	0.04	9.0E-4	30000	7.5	43	<10
Bull Run	BRF	Dry Fly Ash	0.04	4.0E-5	690	8.4	4630	<10
		Bottom Ash - From Pond	----	1.8E-2	7300	7.2	370	<10
Colbert	COF	Dry Fly Ash (Units 1-4)	0.08	2.8E-4	850	9.4	1660	<10
		Bottom Ash - From Pond	----	1.6E-2	4500	5.4	215	<10
Cumberland	CUF	Dry Fly Ash (Units 1-2)	0.01	2.2E-5	2600	11.6	5020	<10
		Bottom Ash - From Pond	----	6.8E-2	1200	2.7	4790	<10
		Scrubber Gypsum	0.12	1.2E-3	1100	7.8	4830	<10
Gallatin	GAF	Dry Fly Ash (Unit 2 Hoppers)	0.05	7.7E-5	420	10.6	5800	<10
		Bottom Ash - From Pond	----	2.9E-2	1600	2.8	1660	<10
John Sevier	JSF	Dry Fly Ash (Units 3-4)	0.05	5.5E-5	440	4.1	4910	<10
		Bottom Ash - From Pond	----	2.6E-2	5200	6.8	285	<10
Johnsonville	JOF	Ponded Fly Ash (New Dredge Cell)	0.06	5.0E-4	2800	8.1	83	<10
		Ponded Fly Ash (Old Dredge Cell)	0.10	5.8E-4	2600	6.8	1520	20
		Ponded Fly Ash (Active Ash Pond)	0.11	3.5E-5	690	8.4	2960	60
		Bottom Ash - From Pond	----	4.7E-3	740	6.0	2200	<10
Kingston	KIF	Ponded Fly Ash (Cell I)	0.05	8.3E-5	7700	7.6	200	<10
		Ponded Fly Ash (Cell III)	0.05	3.4E-5	6400	6.8	140	<10
		Bottom Ash - From Pond	----	9.1E-3	1900	4.0	490	<10
Paradise	PAF	Ponded Fly Ash (East Cell)	0.04	1.0E-5	2600	8.1	340	<10
		Boiler Slag (Reed Rejects)	----	1.3E-3	9700	4.3	220	<10
		Scrubber Gypsum	0.13	1.5E-4	1100	7.7	4630	10
Shawnee	SHF	Dry Fly Ash	0.04	9.2E-5	1000	11.5	2270	<10
		Bottom Ash - From Pond	----	8.9E-3	3000	8.1	4200	10
		Spent Bed Material (SBM)	----	----	----	12.0	4190	150
		Char	----	----	190	12.0	4130	980
Widows Creek	WCF	Ponded Fly Ash (Ash Pond)	0.12	1.8E-4	1400	9.2	1060	<10
		Scrubber Gypsum	0.07	3.9E-4	1200	6.7	3050	<10
		Bottom Ash - From Pond	----	3.4E-2	3100	8.0	4070	130

Note: Consolidation and Hydraulic Conductivity test specimen were remolded to approximately 95 percent of the Standard Proctor maximum dry density

lab soil tva prgm.xls (Consol)

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Strength Testing Summary
Law Engineering Project No. 5810860101

Source	Code	Material	Triaxial CU with pore pressure				Direct Shear		Angle of Repose
			Effective Stress		Total Stress		Cohesion, c (ksf)	Internal friction, ϕ	
			Cohesion, c' (ksf)	Internal friction, ϕ'	Cohesion, c (ksf)	Internal friction, ϕ			
Allen	ALF	Boiler Slag (Fine Reed Rejects)	0.00	37.3	1.15	39.2	2.32	25.2	----
Bull Run	BRF	Dry Fly Ash	0.31	27.7	1.12	21.2	1.36	27.4	----
		Bottom Ash - From Pond	----	----	----	----	----	----	32.4
Colbert	COF	Dry Fly Ash (Units 1-4)	0.34	27.6	0.69	19.9	1.31	28.6	----
		Bottom Ash - From Pond	----	----	----	----	----	----	30.9
Cumberland	CUF	Dry Fly Ash (Units 1-2)	0.00	53.5	1.70	50.5	2.53	33.4	----
		Bottom Ash - From Pond	----	----	----	----	----	----	30.8
		Scrubber Gypsum	0.00	38.1	3.33	33.4	1.32	41.4	----
Gallatin	GAF	Dry Fly Ash (Unit 2 Hoppers)	0.00	31.7	0.57	26.2	1.37	34.5	----
		Bottom Ash - From Pond	----	----	----	----	----	----	31.8
John Sevier	JSF	Dry Fly Ash (Units 3-4)	0.22	22.4	0.26	17.7	1.11	33.6	----
		Bottom Ash - From Pond	----	----	----	----	----	----	27.4
Johnsonville	JOF	Ponded Fly Ash (New Dredge Cell)	0.23	32.4	1.26	25.8	1.29	32.4	----
		Ponded Fly Ash (Old Dredge Cell)	0.12	30.5	0.66	15.2	2.14	39.3	----
		Ponded Fly Ash (Active Ash Pond)	0.00	22.6	0.01	15.8	1.41	36.6	----
		Bottom Ash - From Pond	----	----	----	----	----	----	30.8
Kingston	KIF	Ponded Fly Ash (Cell I)	0.14	26.1	0.36	19.6	0.82	39.1	----
		Ponded Fly Ash (Cell III)	0.03	24.4	0.00	17.8	1.47	37.6	----
		Bottom Ash - From Pond	----	----	----	----	----	----	31.3
Paradise	PAF	Ponded Fly Ash (East Cell)	0.37	21.2	0.55	15.6	2.27	20.2	----
		Boiler Slag (Reed Rejects)	0.06	40.6	2.00	40.3	----	----	----
		Scrubber Gypsum	0.00	39.7	3.07	35.5	0.97	45.7	----
Shawnee	SHF	Dry Fly Ash	1.24	22.4	1.79	14.7	1.10	39.8	----
		Bottom Ash - From Pond	----	----	----	----	----	----	31.6
		Spent Bed Material (SBM)	----	----	----	----	----	----	----
		Char	----	----	----	----	----	----	----
Widows Creek	WCF	Ponded Fly Ash (Ash Pond)	1.85	25.5	1.94	21.5	1.70	31.2	----
		Scrubber Gypsum	0.00	37.8	3.01	33.1	0.55	28.9	----
		Bottom Ash - From Pond	----	----	----	----	----	----	29.0

Note: Triaxial CU and Direct Shear test specimen were remolded to approximately 95 percent of the Standard Proctor maximum dry density at or near optimum moisture content

lab soil tva prgm.xls (Static)

TVA - Fly Ash, Bottom Ash and Scrubber Sludge Study
Strength Testing Summary
Law Engineering Project No. 5810860101

Source	Code	Material	CBR	Resilient Modulus (Standard Effort)				Resilient Modulus (Modified Effort)			
			%	K1	K2	K5	M_R at S_c=4psi, S_s=4psi	K1	K2	K5	M_R at S_c=4psi, S_s=4psi
Allen	ALF	Boiler Slag (Fine Reed Rejects)	37	2,662	0.09516	0.53980	6,419	2,468	0.14322	0.51069	6,110
Bull Run	BRF	Dry Fly Ash	2	3,225	-0.17750	0.54531	5,370	3,283	-0.01625	0.38843	5,500
		Bottom Ash - From Pond	35	1,857	0.10936	0.78070	6,378	1,977	0.13522	0.76648	6,901
Colbert	COF	Dry Fly Ash (Units 1-4)	9	1,353	-0.00868	0.56321	2,918	1,639	0.01011	0.53301	3,480
		Bottom Ash - From Pond	24	2,368	0.11934	0.58242	6,264	2,455	0.09488	0.59309	6,372
Cumberland	CUF	Dry Fly Ash (Units 1-2)	24	7,531	-0.03317	0.34550	11,612	10,959	0.14896	0.24877	19,021
		Bottom Ash - From Pond	15	2,194	0.09530	0.67882	6,417	1,994	0.13866	0.76150	6,945
		Scrubber Gypsum	20	9,623	0.09590	0.25471	15,646	11,738	0.08396	0.20475	17,515
Gallatin	GAF	Dry Fly Ash (Unit 2 Hoppers)	2	2,713	-0.09930	0.47991	4,598	3,602	-0.12389	0.45133	5,671
		Bottom Ash - From Pond	30	1,972	0.20995	0.65540	6,545	2,427	0.20416	0.61364	7,541
John Sevier	JSF	Dry Fly Ash (Units 3-4)	1	2,965	-0.08694	0.43636	4,813	4,033	-0.09489	0.39276	6,095
		Bottom Ash - From Pond	40	2,156	0.08085	0.76340	6,949	2,108	0.09702	0.69867	6,352
Johnsonville	JOF	Ponded Fly Ash (New Dredge Cell)	12	1,487	0.03358	0.63725	3,769	2,541	-0.01211	0.48836	4,917
		Ponded Fly Ash (Old Dredge Cell)	28	1,495	0.03707	0.78260	4,657	2,255	0.09559	0.65332	6,368
		Ponded Fly Ash (Active Ash Pond)	1	2,146	-0.18159	0.60215	3,844	3,980	-0.14235	0.42844	5,917
		Bottom Ash - From Pond	50	2,373	0.16927	0.51994	6,169	2,389	0.13323	0.56010	6,247
Kingston	KIF	Ponded Fly Ash (Cell I)	2	1,803	0.07728	0.41203	3,553	2,374	-0.04388	0.47386	4,309
		Ponded Fly Ash (Cell III)	1	2,592	-0.10787	0.48134	4,350	3,254	-0.09252	0.43051	5,199
		Bottom Ash - From Pond	60	1,427	0.13665	0.75876	4,938	1,822	0.19126	0.64487	5,807
Paradise	PAF	Ponded Fly Ash (East Cell)	4	5,929	-0.09595	0.40269	9,071	5,551	-0.06155	0.44309	9,421
		Boiler Slag (Reed Rejects)	55	1,661	0.06737	0.79102	5,460	1,715	0.08023	0.76411	5,529
		Scrubber Gypsum	14	9,420	0.10296	0.23790	15,110	10,977	0.08137	0.20492	16,325
Shawnee	SHF	Dry Fly Ash	9	2,390	-0.04340	0.45385	4,222	2,774	-0.03472	0.41978	4,731
		Bottom Ash - From Pond	25	1,928	0.11134	0.73640	6,244	1,558	0.08323	0.76224	5,030
		Spent Bed Material (SBM)	----	----	----	----	----	----	----	----	----
		Char	----	----	----	----	----	----	----	----	----
Widows Creek	WCF	Ponded Fly Ash (Ash Pond)	3	1,026	-0.02608	0.63430	2,384 •	3,283	-0.01625	0.38843	5,500
		Scrubber Gypsum	15	7,937	0.08949	0.23891	12,513	8,454	0.05337	0.26140	13,079
		Bottom Ash - From Pond	30	2,258	0.19103	0.66319	7,379	2,260	0.28011	0.26147	4,788

Note: CBR and Resilient Modulus test specimen were remolded to approximately 95 percent of the Standard Proctor (and Modified Proctor for Res. Mod.) maximum dry density at or near optimum moisture content

lab soil tva prgm.xls (Dynamic)