Memorandum from the Office of the Inspector General

June 27, 2011

Robert M. Deacy, Sr., LP 5D-C

FINAL REPORT – INSPECTION 2009-12910-04 – PEER REVIEW OF THE STABILITY ANALYSIS OF THE GYPSUM STACK AT THE WIDOWS CREEK FOSSIL PLANT

Attached is the subject final report for your review and action. Your written comments, which addressed your management decision and/or actions taken, have been included in the report. No further action is needed.

The Office of the Inspector General (OIG) contracted with Marshall Miller & Associates, Inc., to conduct this review. All work pertaining to this review was conducted by Marshall Miller. The OIG relied on Marshall Miller's processes and procedures for quality control in the attached report. Information contained in this report may be subject to public disclosure. Please advise us of any sensitive information in this report that you recommend be withheld.

If you have any questions, please contact Deana D. Scoggins, Senior Auditor, at (423) 785-4822 or Greg R. Stinson, Director, Inspections, at (865) 633-7367. We appreciate the courtesy and cooperation received from your staff during this review.

Robert E Martin

Robert E. Martin
Assistant Inspector General
(Audits and Inspections)
ET 3C-K

DDS:FAJ
Attachment
cc: See page 2

cc (Attachment):

Robert J. Fisher, LP 3K-C
Michael B. Fussell, WT 9B-K
Kimberly S. Greene, WT 7B-K
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Wendy Williams, WT 9B-K
OIG File No. 2009-12910-04

Mr. John Montgomery, Stantec

Peer Review of Stantec Consulting Services, Inc.
Report of Phase 2 Geotechnical Exploration, Gypsum Stack
Dated February 5, 2010

Tennessee Valley Authority Widows Creek Fossil Plant (WCF)
Stevenson, Jackson County, Alabama

Prepared for:

TVA Office of the Inspector General
Knoxville, Tennessee

Prepared by:

Project No.: TVA106-11

Effective Date:
September 8, 2010

Date of Issuance:
June 21, 2011

Marshall Miller & Associates, Inc.
ENERGY/ENVIRONMENTAL/ENGINEERING/CARBON MANAGEMENT

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Item 1: TITLE PAGE

Title of Report

Peer Review of Stantec Consulting Services, Inc.
Report of Phase 2 Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant
Dated February 5, 2010
Tennessee Valley Authority Widows Creek Fossil Plant
Stevenson, Jackson County, Alabama

Project Location

The project site is located in Stevenson, Jackson County, Alabama, at the confluence of Widows Creek and the Tennessee River.

Effective Date of Report

September 8, 2010

Qualified Persons

William S. Almes, P.E.
Formerly:
TVA OIG Contract Manager
Senior Engineer & Director of Geotechnical Services
Marshall Miller & Associates, Inc.

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Peter Lawson.
Executive Vice President
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Christopher J. Lewis, P.E.
Formerly:
Principal Engineer
D'Appolonia, Engineering Division of Ground Technology, Inc.

Aaron J. Antell, P.E.
Project Engineer
D'Appolonia, Engineering Division of Ground Technology, Inc.

Item 2: EXECUTIVE SUMMARY

The Tennessee Valley Authority Office of the Inspector General retained Marshall Miller & Associates, Inc. (Marshall Miller) to conduct a peer review of the report entitled: *Report of Phase 2 Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant* (Gypsum Stack Report) prepared by Stantec Consulting Services, Inc. (Stantec), of Lexington, Kentucky. The Widows Creek Fossil (WCF) Plant is located on the Guntersville Reservoir at the confluence of the Tennessee River and Widows Creek in Stevenson, Alabama.

In summary:

1. Marshall Miller believes that Stantec's evaluations of the WCF gypsum stack provide a reasonable assessment of the margin of safety associated with the evaluated conditions, which indicates that the facility is not in danger of imminent failure.

2. However, Marshall Miller did find that additional analyses and corresponding documentation are needed in order to assess the overall factor of safety of the stack in the midterm and long term, especially as the stack's crest elevation approaches the maximum design height. Marshall Miller observed that the model used by Stantec is 20 feet lower than the final height of the stack. Height is a fundamental factor for the stability of slopes and has a direct influence on the factor of safety. In other words, the stack that Stantec analyzed is 20 feet shorter than the proposed final height of the stack and, therefore, is more stable. It does not reflect the final conditions of the pile.

Specifically, Marshall Miller found Stantec did not:

- Perform adequate testing to support reliance on historical data and shear strength characterization of these materials.

- Calculate and document the exit gradients[1] and factors of safety against piping[2] for the 5-year build-out configurations.[3]

- Perform sufficient investigation of the clay foundation soils.

Exploration and Testing of Foundation Soils

Marshall Miller reviewed the scope, procedures, and results of the subsurface exploration and laboratory testing programs performed by Stantec at the WCF gypsum stack. Based on this review, it is Marshall Miller's professional opinion that Stantec applied appropriate and complementary suites of tests to characterize the engineering properties of the sedimented and cast gypsum-fly ash materials. However, it is also Marshall Miller's professional opinion that Stantec did not perform enough exploration and testing of the foundation soils to support its reliance on historical data and its shear strength characterization of these materials. The foundation soils have a controlling influence on the slope stability, but Stantec's Gypsum Stack Report does not supply sufficient data to characterize the foundation soils. Accordingly, Marshall Miller recommends that Stantec perform supplemental exploration, sampling, and testing programs to better determine the extent and consistency of the clay foundation soils, more thoroughly characterize the foundation soils, augment the available data, and support future evaluations. The characterization of the foundation soils would allow a more accurate assessment of the overall stability of the stack, which could be directly influenced by the properties of those soils.

Seepage Analysis Exit Gradients and Factors of Safety

Marshall Miller also reviewed Stantec's seepage analyses of the WCF gypsum stack, including the material properties and boundary conditions. In Marshall Miller's professional opinion, Stantec performed seepage analyses of the gypsum stack using generally accepted practices, including calibrating the seepage model using measured/observed conditions.

1 Is the hydraulic gradient (a measure of energy loss when water flows through soil) near the surface where water exits a soil slope, embankment face, or similar surface.
2 A measure of the level of safety where piping exists.
3 The planned layout based on 5 years of normal operations.

However, it appears that Stantec omitted the calculation of exit gradients and factors of safety against piping for the 5-year build-out configurations. Accordingly, Marshall Miller recommends that Stantec calculate the exit gradients and factors of safety against piping for the 5-year build-out configurations and document the results and their assessment thereof in an amendment to the WCF Gypsum Stack Report in order to provide an accurate representation of the seepage conditions within the final configuration of the stack and the factors of safety against piping associated with those conditions.

Clay Foundation Soil Data

Marshall Miller reviewed the results of Stantec's gypsum stack slope stability analyses, including development of material shear strength properties. It is Marshall Miller's professional opinion that Stantec performed stability analyses for static, long-term load conditions using appropriate methodologies. However, Marshall Miller noted that data on the clay foundation soils is lacking and has recommended additional investigation of the clay foundation. Stantec should revisit the seepage and slope stability analyses if necessitated by the findings of this additional investigation. Also, Marshall Miller believes that Stantec can improve its methodology to more rigorously characterize material properties in some instances. In order to avoid possible overstatement of the in-situ shear strength of the gypsum-fly ash material, Marshall Miller recommends that Stantec interpret shear strengths based on a definition of failure correlating with pore-pressure parameter A-bar equal to zero in instances when negative pore pressure (dilation) develops.

Periodic Reviews of 5-Year Transition to Dry Stacking/Landfilling

Marshall Miller observed that the maximum design height for the gypsum stack is approximately 20 feet higher than the crest elevation of the stack shown in Stantec's stability analysis results for the 5-year build-out. Provided the facility is converted to a dry landfill within the projected 5 years, Stantec's focus on the 5-year build-out configuration is appropriate. Marshall Miller recommends that the configuration of the evolving gypsum stack be reviewed annually, or more frequently, to ensure that the facility configuration and transition to dry stacking/landfilling are conforming with Stantec's projections.

Management's Response to Draft Report

To address this report, TVA management had Stantec review and respond to the findings of this report. TVA management and its contractor provided additional information on the findings and recommendations in this report. For complete responses, please see appendices A – TVA Transmittal Memo and B – Stantec's Response.

Marshall Miller Assessment of Management's Comments to Draft Report

Marshall Miller concluded that the additional information provided adequately addressed the concerns and recommendations identified in the report. For a complete response, see appendix C – Marshall Miller Response.

Item 3: TABLE OF CONTENTS

APPENDICES

Item 4: INTRODUCTION

The Tennessee Valley Authority (TVA) Office of the Inspector General (OIG) retained Marshall Miller & Associates, Inc. (Marshall Miller), to conduct a peer review of the report entitled: *Report of Phase 2 Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant* (Gypsum Stack Report) prepared by Stantec Consulting Services, Inc. (Stantec), of Lexington, Kentucky. TVA retained Stantec to address geotechnical issues identified during the Phase 1 facility assessment and corresponding Phase 1 report. During its engagement, Marshall Miller reviewed the Gypsum Stack Report dated February 5, 2010, and has documented its results herein.

This report presents the following:

- Marshall Miller Project Team.
- Description of Marshall Miller's scope of service.
- Background information for the Widows Creek Fossil Plant.
- Findings and recommendations from Marshall Miller's review of Stantec's geotechnical exploration, laboratory testing, seepage analyses, and slope stability analyses.

Item 5: MARSHALL MILLER PROJECT TEAM

Marshall Miller, an employee-owned and Engineering News-Record Magazine top 500 company, began offering geologic services to the mining industry in 1975. Marshall Miller provides a range of services to the mining, utility, financial, governmental, and legal industries. Marshall Miller employs nearly 200 engineers, geologists, scientists, and other professionals who work from regional offices in ten states.

Marshall Miller retained D'Appolonia, Engineering Division of Ground Technology, Inc., of Monroeville, Pennsylvania, for its expertise with tailings impoundments and dams, problem ground conditions, and forensic investigations.

The Marshall Miller Project Team comprises the following professionals:

- Mr. Peter Lawson – Executive Vice President & Principal-in-Charge.
- Mr. William S. Almes, P.E. – Director of Geotechnical Services & Contract Manager for the TVA OIG.
- Mr. Edmundo J. Laporte, P.E. – Senior Engineer.
- Mr. William M. Lupi, P.E. – Project Engineer.
- Mr. Richard G. Almes, P.E. – Principal Geotechnical Engineer.
- Mr. Christopher J. Lewis, P. E. – Principal Geotechnical Engineer.[4]
- Mr. Aaron J. Antell, P.E. – Project Engineer.[4]

[4] Christopher J. Lewis, P.E., and Aaron J. Antell, P.E., are Geotechnical Subconsultants of Marshall Miller and as of the effective date of this report were employed by D'Appolonia, Engineering Division of Ground Technology, Inc., Monroeville, Pennsylvania.

Item 6: SCOPE OF SERVICE

The OIG engaged Marshall Miller to provide a technical peer review of the geotechnical exploration, laboratory testing, and engineering analyses performed by Stantec for the gypsum stack at the Widows Creek Fossil Plant. Marshall Miller did not perform a parallel study (field exploration, laboratory testing, and engineering analyses) to the Stantec study of the existing gypsum stack conditions. Marshall Miller relied on the geotechnical exploration and test data provided in the Gypsum Stack Report to formulate the findings and recommendations in this report.

Marshall Miller peer reviewed Stantec's Gypsum Stack Report dated February 5, 2010, and Appendices A through L received in electronic format (pdf files) on March 3, 2010. Marshall Miller is unaware of newer versions of these documents. Marshall Miller based its professional opinions on the above-referenced documents.

In providing the professional services to compile this report, Marshall Miller used generally accepted engineering principles and practices to develop findings and recommendations. Marshall Miller reserves the right to amend and supplement this report based on additional information. If OIG, TVA, TVA's consultants, or others discover additional information pertinent to the engineering performance of the gypsum stack at the Widows Creek Fossil Plant, Marshall Miller requests the opportunity to review the information for relevance to Marshall Miller's findings and recommendations herein.

Item 7: BACKGROUND

The Widows Creek Fossil (WCF) Plant is located on the Guntersville Reservoir at the confluence of the Tennessee River and Widows Creek in Stevenson, Alabama. The WCF plant has eight coal-fired, turbine-generator units. Generators seven and eight are equipped with flue gas desulfurization units. The flue gas desulfurization units use limestone spray and forced oxidation to convert sulfur dioxide particles in the exhaust to gypsum (calcium sulfate). Additionally, generator units seven and eight generate fly ash as a waste product from burning coal. The gypsum and fly ash are mixed, then wet sluiced in pipes to the gypsum-fly ash disposal facility (gypsum stack).

The gypsum stack is situated along the eastern side of Widows Creek, northeast of the WCF Plant. The facility initially operated by sluicing the gypsum-fly ash material to disposal ponds and decanting water to a clarification pond. In 1994, the gypsum stack was expanded and started using the wet stacking method. In its current configuration, the facility is comprised of four disposal ponds and one stilling pond. The wet stacking operation includes expanding disposal volume vertically by building perimeter dikes on top of hydraulically placed gypsum-fly ash material. The sluiced gypsum-fly ash arrives at the facility near the southwest corner of the gypsum stack and is then directed into the southern or northern rim ditch. The rim ditches flow to the rim-ditch outfall located at the northern corner of the gypsum stack.

On January 9, 2009, a release occurred at the site in which gypsum-fly ash material was discharged from Pond 2B into the adjacent stilling pond. The volume of material (approximately 10,000 gallons of fly ash and gypsum waste and process water) overwhelmed the stilling pond, causing it to breach and overflow into Widows Creek. According to TVA personnel, the liquid waste materials impounded at the top of the gypsum pond drained freely into the adjacent stilling pond after an old cap dislodged from a decommissioned spillway pipe, which was formerly used to drain water from the gypsum pond into the settling pond.

TVA's efforts continued throughout 2009 to evaluate and stabilize portions of the gypsum stack (and other waste disposal areas of the plant) to prevent future failures. From June to August 2009, TVA authorized the implementation of Stantec's "Work Plan No. 5" at the gypsum stack. This construction phase consisted of slope re-grading and spillway pipe reconstruction within the area between the gypsum stack and stilling pond. In early November 2009, Stantec presented a final report to TVA and was subsequently issued a request to cease operations at the site since URS Corporation (URS) was engaged by TVA to take over the engineering work at the site going forward. TVA told Stantec the transition period could last approximately six weeks.

In December 2009, TVA personnel (unsupported by any outside professional engineering firm) completed additional construction work near the crest of Pond 2B, installing a segment of buried pipe between the pipe inlet and a junction box. The excavation for the pipe was approximately 17-feet deep with sloped sidewalls, resulting in a large trapezoidal-shaped pipe trench. Backfilling was completed by TVA and, evidently, standard compaction control methods were not employed. On January 4, 2010, following the completion of construction, TVA allowed sluiced ash/gypsum material to flow into Pond 2B.

On January 5, 2010, just one day after the TVA re-introduced sluiced ash/gypsum material onto the surface of the gypsum stack, a second release occurred at the WCF gypsum stack. A TVA equipment operator noticed that the sluiced waste material was permeating through the newly backfilled trench area and spilling onto the exterior slope and bench areas while collecting into the stilling pond. According to a review of documentation, it was evident that the filling of the pond caused saturation of the backfill material in the trench which led to soil "piping" and a localized failure of the backfilled containment dike above the pipe segment. Fortunately, the TVA equipment operator reacted quickly and used the heavy equipment to temporarily fill in the eroded area with on-site material so that the breach could be minimized.

Following the January 9, 2009, breach, TVA retained the services of Stantec to provide ongoing engineering support. Their involvement has consisted of a comprehensive field investigation, engineering analyses (slope stability), and full-time construction quality assurance/control of necessary site improvements. Stantec will continue to be involved with work associated with Pond 2B, while URS will focus their efforts on the Closure Plan for the entire site.

TVA has classified the gypsum stack as a "high hazard" potential structure according to federal guidelines for hazard classification of dams. Based on the high hazard[5] rating and the uncontrolled discharge on January 9, 2009, TVA initiated the conversion from wet stacking to dry stacking disposal at the WCF gypsum stack.

[5] A high hazard potential rating indicates that a failure will probably cause loss of human life. The rating is not an indication of the structural integrity of the unit or the possibility that a failure will occur in the future; it merely allows dam safety and other officials to determine where significant damage or loss of life may occur if there is a structural failure of the unit. This is based upon FEMA Federal Guidelines for Dam Safety – April 2004.

Item 8: GEOTECHNICAL EXPLORATION AND LABORATORY TESTING REVIEW

Marshall Miller reviewed the scope, procedures, and results of the subsurface exploration and laboratory testing performed by Stantec at the gypsum stack. Marshall Miller based its review on descriptions of the exploration and testing in the Gypsum Stack Report and relevant appended documents, including geotechnical drawings, boring logs, and results of laboratory testing. In general, it is Marshall Miller's opinion that the subsurface exploration and laboratory testing programs applied appropriate and complementary suites of tests to characterize the engineering properties of the sedimented and cast gypsum-fly ash materials. However, in Marshall Miller's opinion, Stantec's scope of subsurface exploration and laboratory testing did not provide enough information to characterize the clay foundation soils, considering that the gypsum stack is a high hazard structure and the clay foundation soils are a primary controlling factor in the overall stability.

8.1. FINDINGS

The shear strength and extent of the clay foundation soils primarily control the stability of the gypsum stack, along with the seepage conditions. The classifications of the foundation soils produced by Stantec indicate that the soils are predominately highly plastic/fat clay. In Marshall Miller's opinion, the exploration and laboratory testing has the following deficiencies:

- Based on Table 3 of the Gypsum Stack Report, Stantec terminated 10 of the 24 auger sample borings before refusal. Marshall Miller understands it may be impractical to advance holes used for piezometer installation to bedrock; however, when practical, borings should have been advanced to auger refusal (i.e., the depth at which further penetration is impractical employing the safe operating torque and available down pressure of the drilling rig) to increase exploratory information through the foundation soils. In some instances, borings were seemingly advanced for collection of undisturbed soil samples, but terminated upon encountering the clay foundation soils. Although historical documents include borings that penetrated the foundation soils and encountered bedrock, it is Marshall Miller's opinion that Stantec did not determine the extent and consistency of the foundation clays for verification purposes and broader delineation of the soils, wherever practical, during its subsurface exploration activities.

- Stantec collected 2 undisturbed samples of the clay foundation soil compared to approximately 40 undisturbed samples of the gypsum-fly ash materials. Although historical borings provide classification testing for the clay foundation soils, there is little shear strength testing on foundation soil compared to the gypsum-fly ash materials.

- The boring logs do not indicate results of field measurements using a pocket penetrometer[6] or torvane[7] device in clay foundation soils. While Marshall Miller acknowledges these devices are not ideal for determination of shear strength, they provide an indication of the consistency of cohesive soils. In its report, Stantec does not indicate how it estimated the consistency of cohesive soils, but indicates standard penetration tests (SPTs) are typically used to estimate the consistency of soil. Field devices like the pocket penetrometer are more appropriate for determining the consistency of cohesive soils than SPT results.

- Stantec performed vane shear testing on gypsum-fly ash materials in borings V-9 and V-10, but did not extend this in-situ testing into the clay foundation soils to help characterize undrained behavior.

- Stantec only performed one consolidated, undrained triaxial test series on undisturbed samples and natural moisture content testing on split-spoon samples of the foundation soil. Also, classification and consolidation test data on the foundation soils are lacking. Laboratory classification testing, including grain-size analyses and Atterberg limits tests are used to verify the field classification of soils and supplement shear

[6] A device used to estimate the unconfined compressive strength and consistency of cohesive/clayey soils.

[7] A miniature device used for the rapid estimation of undrained shear strength of cohesive/clayey soil samples in either the field or laboratory.

strength testing in characterizing soil behavior. Consolidation testing provides an indication of soil stress history and compressibility characteristics.

8.2. RECOMMENDATIONS

In Marshall Miller's opinion, Stantec performed insufficient sampling and laboratory testing to characterize the behavior of the clay foundation soils with a level of confidence consistent with the scope and goals of its evaluation. Therefore, Marshall Miller recommends that Stantec perform a supplemental scope of investigation and testing of the clay foundation soils.

- Based on the findings above, Marshall Miller recommends that Stantec perform supplemental subsurface exploration, sampling, and testing programs to better determine the extent and consistency of the clay foundation soils, more thoroughly characterize the foundation soils, augment the available data, and support future evaluations. The supplemental subsurface exploration can be focused along sections of the gypsum stack where Stantec obtained lower slope stability factors of safety for deep-seated failure surfaces passing through the clay foundation soils and where more highly plastic and/or sensitive clays exist and could have a significant bearing on the predicted margin of safety.

- Based on the currently available subsurface information, Stantec should plan to acquire additional undisturbed samples of the softer, more plastic, and more sensitive clay foundation soils for laboratory testing.

- Stantec should obtain and report the results of field measurements using a pocket penetrometer or torvane device on recovered samples of the clay foundation soils.

- In conjunction with the supplemental subsurface exploration, Marshall Miller recommends that Stantec perform field vane shear testing in the softer clay foundation soils to help characterize undrained shear strength (peak and residual) and behavior. Soil samples should be collected from each field vane shear test horizon for laboratory index testing (moisture content, grain size distribution, and Atterberg limits).

- Marshall Miller also recommends that Stantec subject the additional undisturbed samples of the clay foundation soils to laboratory index (moisture content, density, grain size distribution, and Atterberg limits), shear strength (e.g., isotropically consolidated undrained triaxial compression tests), and compressibility/consolidation testing.

Item 9: SEEPAGE ANALYSES REVIEW

Marshall Miller reviewed the scope, procedures, and results of Stantec's seepage analyses of the gypsum stack at WCF, including the material properties and boundary conditions. Marshall Miller based its review on the documentation included by Stantec in its report.

In general, it is Marshall Miller's opinion that Stantec applied appropriate methods, performed seepage analyses of the gypsum stack using generally accepted practices, and arrived at reasonable predictions and conclusions.

9.1. FINDINGS

For the seepage analyses, Stantec calibrated its model by changing permeability properties so that the modeled piezometric conditions approximated the observed field conditions. Marshall Miller agrees with the approach of calibrating the model to observed conditions.

Based on review of the Gypsum Stack Report and related appendices, it appears that Stantec omitted the calculation of exit gradients and factors of safety against piping for the 5-year build-out configurations. This information is important to assessments of the facility stability for the projected 5-year build-out configurations.

9.2. RECOMMENDATIONS

Marshall Miller recommends that Stantec calculate the exit gradients and factors of safety against piping for the 5-year build-out configurations, and document the results and their assessment thereof in an amendment to the WCF Gypsum Stack Report.

Item 10: SLOPE STABILITY ANALYSES REVIEW

Marshall Miller reviewed the scope, procedures, and results of Stantec's slope stability analyses of the gypsum stack at WCF, including development of material shear strength properties. Marshall Miller based its review on the documentation included by Stantec in its report.

In general, it is Marshall Miller's opinion that Stantec performed stability analyses for static, long-term load conditions using appropriate methodologies. However, as expressed in this report under Item 8, Geotechnical Exploration and Laboratory Testing Review, the amount of exploration and test data available to characterize the clay foundation soils is limited. This is a source of concern, especially considering the fact that the gypsum stack is a high hazard structure and the clay foundation soils are a primary controlling factor in the overall stability.

10.1. FINDINGS

Marshall Miller noted the following findings during the peer review:

- As outlined under Item 8 of this report, the investigation of the clay foundation soils was deficient, and the amount of data available to characterize the foundation is limited, especially relative to the scope of investigation of the gypsum-fly ash materials.

- Stantec performed isotropically consolidated undrained triaxial compression tests on sedimented gypsum-fly ash and cast gypsum-fly ash materials. Stantec assumed that failure occurred at the point of maximum effective principal stress ratio. Based on laboratory test results in Appendix F, the maximum effective principal stress ratio occurs at significant negative pore pressures for some test samples. The definition of failure at a stress state when significant negative pore pressure exists in low plasticity to non-plastic silt-like materials presents the following issues:

    - Significant negative pore pressure development suggests the gypsum-fly ash materials exhibit dilative (expansive) behavior when sheared undrained. Volume is constant during undrained loading of a saturated soil. Negative pore pressures can cause undrained shear strength to exceed drained shear strength and lead to interpretation of an overstated in-situ undrained shear strength. It is customary to neglect undrained strength above the drained strength in this situation.

- At negative pore pressures (generally less than negative one ton per square foot (tsf)), cavitation can occur in the pore water; however, it depends on the amount of dissolved air present in the pore water. If cavitation occurs, air is released from solution within the pore water, and the test sample may no longer be saturated. Cavitation generally limits the amount that the undrained strength might exceed the drained strength.

- For practical purposes, the dilative material behavior and selected failure criteria do not significantly affect the characterization of the effective shear strength but will affect the characterization of undrained shear strength.

- The maximum design height for the gypsum stack is approximately 20 feet higher than the crest elevation of the stack shown in Stantec's stability analysis results for the 5-year build-out. Provided the facility is converted to a dry landfill within the projected 5 years, Stantec's focus on the 5-year build-out configuration is appropriate.

10.2. RECOMMENDATIONS

Based on the findings described above, Marshall Miller has developed the following list of recommendations for consideration:

- As outlined under Item 8.2 of this report, Marshall Miller recommends that Stantec perform supplemental subsurface exploration, sampling, and testing programs to better determine the extent and consistency of the clay foundation soils, more thoroughly characterize the foundation soils, augment the available data, and support future evaluations. Stantec should revisit the seepage and slope stability analyses if necessitated by the findings of this additional investigation of the clay foundation.

- Marshall Miller recommends that Stantec use the pore pressure parameter, A-bar (ratio of change in pore pressure due to deviator stress increase to difference between changes in principal stresses), equal to zero as a failure criterion for selecting undrained and drained shear strength parameters from triaxial test results in instances when significant negative pore pressure (dilation) develops.

- Marshall Miller recommends that the configuration of the evolving gypsum stack be reviewed annually, or more frequently, to ensure that the facility configuration and transition to dry stacking/landfilling are conforming with Stantec's projections.

April 5, 2011

Mr. Robert E. Martin, ET 3C-K

TVA COMMENTS TO OIG DRAFT INSPECTION 2009-12910-04 - PEER REVIEW OF THE STABILITY ANALYSIS OF THE GYPSUM STACK AT THE WIDOWS CREEK FOSSIL PLANT

Attached please find Stantec's letter to John Kammeyer dated April 4, 2011, which represents TVA comments in response to your draft inspection regarding the stability analysis of the gypsum stack at Widows Creek Fossil Plant.

We appreciate the opportunity to provide comments on this draft report. Please direct any questions to John Kammeyer at 423-280-0407.

Robert M. Deacy, Sr.
Senior Vice President and Executive
Kingston Ash Recovery Project

DJC
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OIG File No. 2009-12910-04

Mr. John Montgomery, Stantec

Stantec

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April 4, 2011

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Mr. John Kammeyer
Vice President
Tennessee Valley Authority
1101 Market Street, LP 5G
Chattanooga, Tennessee 37402

Re: 1st Response to Comments
Marshall Miller Review – March 3, 2011
Stantec February 5, 2011 Report of Phase 2 Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant

Dear Mr. Kammeyer:

As requested, Stantec has completed a review of Marshall Miller and Associates (Marshall Miller) report: *Draft Peer Review of Stantec Consulting Services Inc. Report of Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant* dated March 3, 2011. Marshall Miller's findings/recommendations and Stantec's corresponding responses are listed below.

Item 8: Geotechnical Exploration and Laboratory Testing Review

Item 8.1 and 8.2 – first bullets – MM Findings and Recommendation: *Based on Table 3 of the Gypsum Stack Report, Stantec terminated 10 of 24 auger sample borings before refusal. Marshall Miller understands it may be impractical to advance holes used for piezometer installation to bedrock; however, when practical, borings should have been advanced to auger refusal (i.e., the depth at which further penetration is impractical employing the safe operating torque and available down pressure of the drilling rig) to increase exploratory information through the foundation soils. In some instances, borings were seemingly advanced for collection of undisturbed soil samples, but terminated upon encountering the clay foundation soils. Although historical documents include borings that penetrated the foundation soils and encountered bedrock, it is Marshall Miller's opinion that Stantec did not determine the extent and consistency of the foundation clays for verification purposes and broader delineation of the soils, wherever practical, during its subsurface exploration activities. Based on the findings above, Marshall Miller recommends that Stantec perform supplemental subsurface exploration, sampling, and testing programs to better determine the extent and consistency of the clay foundation soils, more thoroughly characterize the foundation soils, augment the available data, and support future evaluations. The supplemental subsurface exploration can be focused along sections of the gypsum stack* *where Stantec obtained lower slope stability factors of safety for deep-seated failure surfaces passing through the clay foundation soils and where more highly plastic and/or sensitive clays exist and could have a significant bearing on the predicted margin of safety.*

Stantec Response: Concur. Supplemental subsurface exploration efforts were implemented at the direction of the TVA to further characterize the foundations soils underlying the gypsum stack for future evaluations. Stantec carried out the additional field exploration work in accordance with a drilling and laboratory testing plan outlined by TVA's designated plant consultant (URS). The deliverables to TVA included boring layout, boring logs, and laboratory test results.

Item 8.1 and 8.2 – second bullets - MM Findings and Recommendation: *Stantec collected 2 undisturbed samples of the clay foundation soil compared to approximately 40 undisturbed samples of the gypsum-fly ash materials. Although historical borings provide classification testing for the clay foundation soils, there is little shear strength testing on foundation soil compared to the gypsum-fly ash materials. Based on the currently available subsurface information, Stantec should plan to acquire additional undisturbed samples of the softer, more plastic, and more sensitive clay foundation soils for laboratory testing.*

Stantec Response: Concur. Supplemental undisturbed samples of the foundation soils were taken and laboratory tested at the direction of the TVA to further characterize the foundations soils underlying the gypsum stack.

Item 8.1 and 8.2 – third bullets - MM Findings and Recommendation: *The boring logs do not indicate results of the field measurements using a pocket penetrometer or torvane device in clay foundation soils. While Marshall Miller acknowledges these devices are not ideal for determination of shear strength, they provide an indication of the consistency of cohesive soils. In its report, Stantec does not indicate how it estimated the consistency of cohesive soils, but indicates standard penetration tests (SPT's) are typically used to estimate the consistency of soil. Field devices like the pocket penetrometer are more appropriate for determining the consistency of soils than SPT results. Stantec should obtain and report the results of field measurements using a pocket penetrometer or torvane device on recovered samples of the clay foundation soils.*

Stantec Response: Stantec did not use pocket penetrometer and torvane devices. Stantec agrees that use of pocket penetrometer and torvane devices are an option to measure consistency of cohesive soils. It is also Stantec's opinion that SPT N-value data is an acceptable method for general interpretation of strength consistency of cohesive soils.

Item 8.1 and 8.2 – fourth bullets - MM Findings and Recommendation: *Stantec performed vane shear testing on gypsum-fly ash materials in borings V-9 and V-10, but did not extend this in-situ testing into the clay foundation soils to help characterize undrained behavior. In conjunction with the supplemental subsurface exploration, Marshall Miller recommends that Stantec perform field vane shear testing in the softer clay foundation soils to help characterize undrained shear strength (peak and residual) and behavior. Soil* *samples should be collected from each field vane shear test horizon for laboratory index testing (moisture content, grain size distribution, and Atterberg limits).*

Stantec Response: Stantec agrees that sampling and laboratory index testing on every vane shear test horizon provides a more rigorous characterization of undrained material properties. Given the character of the foundation soils encountered, we believe the initial study efforts along with subsequent exploration programs have provided sufficient data to evaluate the gypsum stack.

Item 8.1 and 8.2 – fifth bullets - MM Findings and Recommendation: *Stantec only performed one consolidated, undrained triaxial test series on undisturbed samples and natural moisture content testing on split-spoon samples of the foundation soil. Also, classification and consolidation test data on the foundation soils are lacking. Laboratory classification testing, including grain-size analyses and Atterberg limits tests are used to verify the field classification of soils and supplement shear strength testing in characterizing soil behavior. Consolidation testing provides an indication of soil stress history and compressibility characteristics. Marshall Miller also recommends that Stantec subject the additional undisturbed samples of the clay foundation soils to laboratory index (moisture content, density, grain size distribution, and Atterberg limits), shear strength (e.g., isotropically consolidated undrained triaxial compression tests), and compressibility/consolidation testing.*

Stantec Response: Concur. Supplemental undisturbed samples of the foundation soils were taken and laboratory tested at the direction of the TVA to further characterize the foundations soils underlying the gypsum stack for future evaluations.

Item 9: Seepage Analyses Review

Item 9.1 and 9.2 - MM Findings and Recommendation: *For the seepage analyses, Stantec calibrated its model by changing permeability properties so that modeled conditions approximated the observed field conditions. Marshall Miller agrees with the approach of calibrating the model to observed conditions. Based on review of the Gypsum Stack Report and related appendices, it appears that Stantec omitted the calculation of exit gradients and factors of safety against piping for the 5-year build-out configurations. This information is important to assessments of the facility stability for the projected 5-year build-out configurations. Marshall Miller recommends that Stantec calculate the exit gradients and factors of safety against piping for the 5-year build out configurations, and document the results and their assessment in an amendment to the WCF Gypsum Stack Report.*

Stantec Response: We agree with the reviewer that the calibrated seepage models approximated the observed field conditions. Based the seepage evaluation for as found conditions, TVA proceeded with the construction a graded filter designed to increase the factor of safety against piping. The 5-year build out scheme provided by the TVA at the time of the subject study is no longer applicable. We agree the ultimate build out configuration should be further evaluated in the detailed design of closure as plans are finalized.

Item 10: Slope Stability Analyses Review

Item 10.1 and 10.2 – first bullets – MM Findings and Recommendation: *As outlined under Item 8 of this report, the investigation of the clay foundation soils was deficient, and the amount of data available to characterize the foundation is limited, especially relative to the scope of investigation of the gypsum-fly ash materials. As outlined under Item 8.2 of this report, Marshall Miller recommends that Stantec perform supplemental subsurface exploration, sampling, and testing programs to better determine the extent of the clay foundation soils, more thoroughly characterize the foundation soils, augment the available data, and support future evaluations. Stantec should revisit the seepage and slope stability analyses if necessitated by the findings of this additional investigation of the clay foundation.*

Stantec Response: Concur. Supplemental subsurface exploration efforts were implemented at the direction of the TVA to further characterize the foundations soils underlying the gypsum stack for future evaluations.

Item 10.1 and 10.2 – second bullets - MM Findings and Recommendation: *Stantec performed isotropically consolidated undrained triaxial compression tests on sedimented gypsum-fly ash and cast gypsum-fly ash materials. Stantec assumed that failure occurred at the point of maximum principal stress ratio. Based on laboratory test results in Appendix F, the maximum effective principal stress ratio occurs at significant negative pore pressures for some test samples. The definition of failure at a stress state when significant negative pore pressure exists in low plasticity silt-like materials presents the following issues:*

- *Significant negative pore pressure development suggests the gypsum-fly ash materials exhibit dilative (expansive) behavior when sheared undrained. Volume is constant during undrained loading of a saturated soil. Negative pore pressures can cause undrained shear strength to exceed drained shear strength and lead to interpretation of overstated shear strength. It is customary to neglect undrained strength above the drained strength in this situation.*

- *At negative pore pressure (generally less than negative one ton per square foot (tsf)), cavitation can occur in the pore water; however, it depends on the amount of dissolved air present in the pore water. If cavitation occurs, air is released from solution within the pore water, and the test sample may no longer be saturated. Cavitation generally limits the amount that the undrained strength might exceed the drained strength.*

- *For practical purposes, the dilative material behavior and selected failure criteria do not significantly affect the characterization of the effective shear strength but will affect the characterization of the undrained shear strength.*

Marshall Miller recommends that Stantec use the pore pressure parameter, A-bar (ratio of change in pore pressure due to deviator stress increase to difference between changes in principal stress), equal to zero as a failure criterion for selecting undrained shear strength parameters from triaxial test results in instances when negative pore pressure (dilation) develops.

Stantec Response: Stantec agrees that negative pore pressures in the subject tests can cause undrained shear strength to exceed drained shear strength, which can result in overstating the shear strength. Stantec also agrees that the dilative material behavior and Stantec's selected failure criteria will not significantly affect the characterization of the effective shear strength, which is the type of shear strength used for all analyses in this report.

Stantec did not insert laboratory shear strength test results directly into the analyses, but rather selected values following the methodology outlined in the US Army Corps of Engineers Engineer Manual EM 1110-2-1902, where failure stresses are expressed in terms of "p'-q" values, and envelops that fit conservatively through the data. Stantec also reviewed other available data to further evaluate the selection of the different parameters. One of the references used for this purpose is the Ardaman and Associates Report "Engineering Evaluation and Design Recommendations for Renovation of the Widows Creek Gypsum-Fly Ash Storage Facility" dated May 9, 2005. The analyses described in this report used similar failure criteria (maximum effective principal stress ratio) and selected larger internal angles of friction of 42 and 44 degrees, for cast and sedimented gypsum-fly ash, respectively. The Ardaman report comments that generation of negative pore pressures during shear, normally referred to as 'dilation", is a characteristic normally observed with gypsum samples that do not contain fly ash, and that the development of negative pore pressures during shear is desirable since the negative pore pressures will increase effective stresses and material strength during shear.

Item 10.1 and 10.2 – third bullets - MM Findings and Recommendation: *The maximum design height for the gypsum stack is approximately 20 feet higher than the crest elevation of the stack shown in Stantec's stability analysis results for the 5-year build out. Provided the facility is converted to a dry landfill within the projected 5 years, Stantec's focus on the 5-year build-out configuration is appropriate. Marshall Miller recommends that the configuration of the evolving gypsum stack be reviewed annually, or more frequently, to ensure that the facility configuration and transition to dry stacking/landfilling are conforming within Stantec's projections.*

Stantec Response: Stantec agrees with the reviewer that the projected 5-year build out evaluation was appropriate at the time of study. However, the 5-year build out scheme provided by the TVA at the time of the subject study is no longer applicable. We agree the ultimate build out configuration should be further evaluated in the detailed design phase of closure as plans are finalized.

Tennessee Valley Authority
April 4, 2011
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We appreciate the opportunity to provide these responses. If you have any questions or need additional information, please call.

Sincerely,

STANTEC CONSULTING SERVICES INC.

Hugo R. Aparicio, PE
Principal

Hugo Aparicio
for Robert D. Fuller, PE
Senior Associate

cc: Michael S. Turnbow
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June 15, 2011

Mr. Greg R Stinson
Director, Inspections
Tennessee Valley Authority
Office of the Inspector General
1101 Market Street EB 2G-C
Chattanooga, TN 37402-2801

Re: Response to Comments to OIG Draft Inspection 2009-12910-04

Facility:	Widows Creek Fossil Plant
Report Title:	*Report of Geotechnical Exploration and Slope Stability, Gypsum Stack, Widows Creek Fossil Plant*
Firm:	Stantec Consulting Services Inc. (Stantec)
Date:	January 28, 2010

Dear Mr. Stinson:

Marshall Miller & Associates, Inc. (*Marshall Miller*) was contracted by the **Tennessee Valley Authority Office of the Inspector General (*TVA OIG*)** to provide response and rebuttal to comments prepared by **Stantec Consulting Services Inc. (*Stantec*)** dated March 24, 2011. These comments were prepared for TVA in response to Marshall Miller's Technical Peer Review of the January 28, 2010, draft report prepared by Stantec entitled *Report of Geotechnical Exploration and Slope Stability Gypsum Stack, Widows Creek Fossil Plant.*

Mr. Hugo R. Aparicio, PE, and Mr. Robert D. Fuller, PE, of Stantec reviewed Marshall Miller's peer review and provided response in a letter report dated April 4, 2011. Marshall Miller's responses are provided below.

Stantec's Response to Items 8.1 and 8.2 – First and Second Bullets
Stantec's response is acknowledged and accepted.

Stantec's Response to Items 8.1 and 8.2 – Third and Fourth Bullets
Stantec's responses are acknowledged, and accepted.

Stantec's Response to Items 8.1 and 8.2 – Fifth Bullets
Stantec's response is acknowledged and accepts the testing of the underlying foundation soils for future evaluations.

Stantec's Response to Items 9.1 and 9.2
Stantec's response is acknowledged and accepted.

Stantec's Response to Items 10.1 and 10.2 – First and Second Bullets
Stantec's response is acknowledged and accepted.

Stantec's Response to Items 10.1 and 10.2 – Third Bullet
Stantec's response is acknowledged and accepted.

Thank you for the opportunity to submit a response to comments. Should you have any questions or need additional clarification, please contact Peter Lawson at (304) 255-8937

Sincerely,

MARSHALL MILLER & ASSOCIATES, INC.

John E. Feddock

John E. Feddock, P.E.
Senior Vice President

Peter Lawson

Peter Lawson
Executive Vice President
Principal-in-Charge

Attachments

cc: Mr. Robert E. Martin, Assistant Inspector General (Audits & Inspections)
Ms. Julie Lovingood, Auditor