COPY

Minor Permit Modification
for Solid Waste Permit Number 073-00045 (C-746-U Landfill),
Agency Interest Number 3059,
Activity ID Number APE20100007

February 2012

Steven L. Beshear
Governor

RECEIVED
APR 03 2012
BY: .....

Leonard K. Peters
Secretary

ENERGY AND ENVIRONMENT CABINET
Division of Waste Management
200 Fair Oaks, 2nd Floor
FRANKFORT, KY 40601
TELEPHONE: 502-564-6716
FACSIMILE: 502-564-3492
waste.ky.gov

March 30, 2012

Mr. William E. Murphie, Manager
United States Department of Energy
Portsmouth Paducah Project Office
1017 Majestic Place, Suite 200
Lexington, Kentucky 40513

Certified Mail Number: 7011 2970 0003 7286 0683

Mr. Kerry Stone, Landfill Manager
LATA Environmental Services of Kentucky, LLC
101 Liberty Drive, Suite 8
Kevil, Kentucky 42053

Certified Mail Number: 7011 2970 0003 7286 0690

RE: Approval of Minor Permit Modification
United States Department of Energy - Paducah Gaseous Diffusion Plant
Agency Interest No. 3059
Activity ID No. APE20100007
Solid Waste Permit # 073-00014, 073-00015 and 073-00045
McCracken County

Dear Mr. Murphie and Mr. Stone:

The Kentucky Division of Waste Management (DWM), Solid Waste Branch has completed review of your application for a minor modification for the C-746-U Contained Landfill initially received on July 26, 2010, and revised on April 12, 2011 and March 8, 2012. The subject application concerns the removal of the permit condition requiring a complete seismic hazard reevaluation of the C-746-U Contained Landfill. DWM hereby approves this application. Please find enclosed a copy of the approved application and a revised permit for your facility.

Be advised, if you consider yourself aggrieved by the issuance of this permit, you have a right pursuant to KRS 224.10-420(2) and 401 KAR 47:130 Section 2(3), to file with the cabinet a petition demanding a hearing. This right to demand a hearing shall be limited to a period of thirty

(30) days after receipt of this permit. Should you have any questions, please contact Lindsey Briggs, P.E. at (502) 564-6716, extension 4665.

Sincerely,

R. D. Gruzesky

Ronald D. Gruzesky, P.E.
Manager, Solid Waste Branch

Enclosures
RDG/rth

Kentucky Energy and Environment Cabinet
Department for Environmental Protection
Division of Waste Management

PERMIT

Facility: **U.S. Department of Energy - Paducah Gaseous Diffusion Plant**
5600 Hobbs Rd
Paducah, KY 42001-1410

Permittee (Owner): **U.S. Department of Energy**
PO Box 1410
Paducah, KY 42002-1410

Permittee (Operator): **LATA Environmental Services of Kentucky, LLC**
101 Liberty Drive, Suite 8
Kevil, KY 42053

Agency Interest: **Dept of Energy-Paducah Gaseous Diffusion Plant**
5600 Hobbs Rd
Paducah, KY 42001-1410

The Division has issued the permit under the provisions of KRS Chapter 224 and regulations promulgated pursuant thereto. This permitted activity or activities are subject to all conditions and operating limitations contained herein. Issuance of this permit does not relieve the permittee from the responsibility of obtaining any other permits, licenses or approvals required by this Division or other state and local agencies.

No deviation from the plans and specifications submitted with your application or any condition specified herein is allowed, unless authorized in writing from the Division. Violation of the terms and conditions specified herein may render this permit null and void. All rights of inspection by representatives of the Division are reserved. Conformance with all applicable Waste Management Regulations is the responsibility of the permittee.

Agency Interest ID #: **3059**

Solid Waste Permit #: **SW07300015, SW07300014, SW07300045**

County: **McCracken**

Permitted Activities:

Subject Item	Activity	Type	Status
ACTV004	Residential Landfill/07300014	Closure Activities Only	Post-closure
ACTV005	Inert Landfill/07300015	Closure Activities Only	Post-closure
ACTV006	Contained Landfill/07300045	Construction/Operation	Active

PERMIT

Acreage Summary:

Waste Disposal Area (in Acres):

Activity	Disposal Area
Contained Landfill	22.10
Inert Landfill	10.50
Residential Landfill	3.90
Total Disposal Area	36.50
Total Permitted Area	100.00

Cost Estimate Summary:

Coverage Type	Cost Estimate	Effective	Comments
N/A			

Financial Assurance Summary:

The owner or operator shall maintain the following financial assurance approved by the Division in compliance with KRS Chapter 224.40-650, KRS Chapter 224.50-862, 401 KAR 45:250, and 401 KAR 48:310:

Instrument Type	Instrument Number	Amount	Date Received	Comments
N/A				

First Operational Permit Effective Date: 11/04/1996 -- Contained Landfill

Permit Effective Date: 11/05/2006

Permit Expiration Date: 11/04/2016

Permit issued: 03/30/2012

R. D. Gruzesky

Ronald D. Gruzesky, P.E.
Manager, Solid Waste Branch

PERMIT

Permit Conditions:

Subject Items

ACTV0004 - Residential Landfill

Variances, Alternate Specifications and Special Conditions:

1. C-746-S Landfill: This permit is for the post-closure care, groundwater monitoring, groundwater assessment, and- if necessary- groundwater corrective action of the C-746-S Residential Landfill. [401 KAR 47:120 Section 2, 401 KAR 48:300 Section 8]

2. C-746-S Landfill: The permittee shall complete closure and post-closure activities at this landfill in accordance with the approved plans and applications. The landfill cap and surface water control structures shall be maintained as necessary to: 1) maintain positive drainage; 2) prevent the growth of weeds, trees, and woody plants on the landfill cap; 3) protect the integrity of the low permeability layer; and 4) ensure compliance with the environmental performance standards of 401 KAR 47:030 and the requirements of KRS 224 and the administrative regulations issued pursuant thereto. [401 KAR 47:120 Section 2]

3. The permittee shall test the C-746-S Landfill leachate annually for the parameters listed in 401 KAR 48:300 Section 11(3), minus 2-Chlorovinyl Ethyl Ether, Dichlorodifluoromethane, Ethyl Alcohol, and Ethyl Methacrylate, plus the following: Aluminum, Boron, Bromide, Calcium, Cyanide, Eh, Fluoride, Gross Alpha, Gross Beta, Iodide, Magnesium, Manganese, Molybdenum, Dissolved Oxygen, PCBs, Potassium, Radium-226, Rhodium, Strontium-90, Sulfate, Tantalum, Technetium-99, Thorium-230, Tritium, and Uranium (total). Samples shall not be filtered. The leachate shall be thoroughly agitated in the tank(s) prior to sampling in order to ensure representative samples. [401 KAR 47:120 Section 2]

Approved Applications - The owner or operator shall comply with applicable statutes and regulations and the following approved applications:

1. 04/09/81 - Application
2. 07/03/89 - Application
3. 11/05/90 - Application
4. 04/12/93 - APE19930003 - Closure Plan
5. 02/21/95 - APE19900002 - Closure Plan
6. 08/09/95 - APE19890001 - Closure Plan
7. 03/04/96 - APE19990001 - Closure Plan
8. 03/04/96 - APE19930004 - Closure Plan
9. 03/04/96 - APE19910003 - LR1 PR1 - Permit Renewal
10. 03/04/96 - APE19910001 - Closure Plan
11. 03/06/96 - APE19900003 - Closure Plan
12. 04/25/01 - APE19980002 - LR1 PR2 - Permit Renewal
13. 02/01/01 - APE20000002 - Plan for Abandonment and Replacement of Monitoring Wells
14. 03/14/02 - APE20010002 - LI1MOGW1 - Groundwater Monitoring Plan
15. 02/16/06 - APE20030005 - Permit Renewal
16. 03/16/06 - APE20060003 - Minor Modification - TEMPO permit revision
17. 03/20/06 - APE20060003 - Minor Modification - Updated TEMPO permit revision

18. 04/24/06 - APE20060005 - Minor Modification - Add Paducah Remediation Services, LLC (operator)
19. 05/24/07 - APE20060007 - Permit Renewal
20. 06/12/07 - APE20060007 - Revised Permit Issued to replace 5/24/07 permit issued
21. 07/11/07 - APE20060007 - Revised Permit Issued to replace 06/12/07 permit issued
22. 11/20/08 - APE20080002 - Groundwater and Surface Water Monitoring Plan Modification
23. 07/28/10 - APE20100005 - Permit Modification to Remove PRS from Permit and Add LATA to Permit
24. 08/02/10 - APE20100005 - Revised Permit Issued to replace 07/28/10 permit issued
25. 01/25/12 - APE20110004 - Groundwater Monitoring Modification - Remove Iodine-131 parameter

ACTV0005 - Inert Landfill

Variances, Alternate Specifications and Special Conditions:

1. C-746-T Landfill: This permit is for the post-closure care, groundwater monitoring, groundwater assessment, and- if necessary- groundwater corrective action of the C-746-T Inert Landfill. [401 KAR 47:120 Section 2, 401 KAR 48:300 Section 8]

2. C-746-T Landfill: The permittee shall complete closure and post-closure activities at this landfill in accordance with the approved plans and applications. The landfill cap and surface water control structures shall be maintained as necessary to: 1) maintain positive drainage; 2) prevent the growth of weeds, trees, and woody plants on the landfill cap; 3) protect the integrity of the low permeability layer; and 4) ensure compliance with the environmental performance standards of 401 KAR 47:030 and the requirements of KRS 224 and the administrative regulations issued pursuant thereto. [401 KAR 47:120 Section 2]

Approved Applications - The owner or operator shall comply with applicable statutes and regulations and the following approved applications:

1. 01/25/85 - Application
2. 02/05/85 - Application
3. 04/25/01 - APE19980001 - LI1PR2 - Permit Renewal
4. 02/01/01 - APE20000003 - Plan for Abandonment and Replacement of Monitoring Wells
5. 03/14/02 - APE20010003 - LI1MOGW1 - Groundwater Monitoring Plan
6. 02/16/06 - APE20020005 - Permit Renewal
7. 03/16/06 - APE20060003 - Minor Modification - TEMPO permit revision
8. 03/20/06 - APE20060003 - Minor Modification - Updated TEMPO permit revision
9. 04/24/06 - APE20060005 - Minor Modification - Add Paducah Remediation Services, LLC (operator)
10. 05/24/07 - APE20060007 - Permit Renewal
11. 06/12/07 - APE20060007 - Revised Permit Issued to replace 5/24/07 permit issued
12. 07/11/07 - APE20060007 - Revised Permit Issued to replace 06/12/07 permit issued
13. 11/20/08 - APE20080002 - Groundwater and Surface Water Monitoring Plan Modification
14. 07/28/10 - APE20100005 - Permit Modification to Remove PRS from Permit and Add LATA to Permit
15. 08/02/10 - APE20100005 - Revised Permit Issued to replace 07/28/10 permit issued
16. 01/25/12 - APE20110004 - Groundwater Monitoring Modification - Remove Iodine-131 parameter

ACTV0006 - Contained Landfill

Standard Requirements:

1. General: The owner or operator of a solid waste site or facility shall comply with KRS Chapter 224 and 401 KAR Chapters 30, 40, 47 and 48 for the construction and operation of solid waste facilities. [KRS 224.40-305]

2. Permit Renewal: The owner or operator of a solid waste facility shall submit a permit application for renewal at least 180 days prior to permit expiration unless permission for a later date has been granted in writing by the cabinet. [401 KAR 47:160 Section 5(2)]

3. General: For construction and operation of the contained landfill, the owner or operator shall comply with KRS Chapter 224.40-310, 401 KAR 48:090, and the approved permit applications. [KRS 224.43-310]

4. Working Face: The owner or operator shall not place an initial lift containing any object that may damage the bottom liner. [401 KAR 48:090 Section 9(3)]

5. Recordkeeping: The owner or operator shall submit a report quarterly, by the 15th of January, April, July, and October, containing the monthly volume of waste received from each source. [401 KAR 47:190 Section 8(1)(b)]

6. Recordkeeping: The owner or operator shall submit a report quarterly, by the 15th of January, April, July, and October, containing the description of compliance with cover requirements. [401 KAR 47:190 Section 8(1)(c)]

7. Recordkeeping: The owner or operator shall submit a report quarterly, by the 15th of January, April, July, and October, describing the quantity and concentration of leachate removed from the site, where disposed, and the method of disposal. The concentration shall be determined using appropriate parameters from Section 10(3) of 401 KAR 48:300 for contained landfills. [401 KAR 47:190 Section 8(1)(e)]

8. Recordkeeping: The owner or operator shall conduct an annual survey to determine the remaining landfill volume which may be used for waste disposal. The quantity of waste disposed per day shall be determined by dividing the total waste received in one (1) year by 365 calendar days. This survey shall bear the seal and signature of the registered professional land surveyor or professional engineer who performed the survey. The owner or operator shall submit the annual survey to the cabinet by July 1 of each year. The annual survey shall contain the following information: Cross-sections on 100 foot intervals showing current waste placement and proposed final contours and remaining capacity in cubic yards. [401 KAR 47:190 Section 8(2)]

Variances, Alternate Specifications and Special Conditions:

1. Monitoring: The permittee shall test the C-746-U Landfill leachate annually for the parameters listed in 401 KAR 48:300 Section 11(3), minus 2-Chlorovinyl Ethyl Ether, Dichlorodifluoromethane, Ethyl Alcohol, and Ethyl Methacrylate, plus the following: Aluminum, Boron, Bromide, Calcium, Cyanide, Eh, Fluoride, Gross Alpha, Gross Beta, Iodide, Magnesium, Manganese, Molybdenum, Dissolved Oxygen, PCBs, Potassium, Radium-226, Rhodium, Strontium-90, Sulfate, Tantalum, Technetium-99, Thorium-230, Tritium, and Uranium (total). Samples shall not be filtered. The leachate shall be thoroughly agitated in the tank(s) prior to sampling in order to ensure representative samples. [401 KAR 47:120 Section 2]

2. Operation: The leachate collection system shall include tanks capable of storing at least fifteen (15) days volume of leachate. A quarterly log of the volume, method, and place of disposal of the leachate shall be maintained, and shall be made available for review by Cabinet representatives upon request. [401 KAR 48:080 Section 6(4)(f)]

3. Recordkeeping: Groundwater, surface water, and methane samples shall be taken quarterly and the results submitted to the Cabinet according to the following schedule:
First Quarter samples: Results due May 30
Second Quarter samples: Results due August 30
Third Quarter samples: Results due November 30
Fourth Quarter samples: Results due February 28.
[401 KAR 48:300 Section 11(3)]

4. Monitoring: The permittee shall comply with all requirements of 401 KAR 48:300 and the Surface Water Monitoring Plan. Except as otherwise provided by statute, the requirements of 401 KAR 48:300 Section 8, Subsections 8, 9, 11, 12, 13, and 14 shall not apply to statistical exceedences of radionuclides, Uranium, and Technetium-99. However, in the event that a statistically significant increase of these contaminants occurs, the permittee shall perform a complete Groundwater Contamination Assessment as required by 401 KAR 48:300 Section 8. [401 KAR 48:300 Section 8, 401 KAR 47:120 Section 2]

5. Operation: The leachate recirculation shall occur only at the working face. A leachate transfer tank shall be used to discharge leachate into a hole excavated into the waste. No more than 1,600 gallons per day shall be recirculated. The discharge shall be restricted to sunny days. Recirculation shall not occur during periods of high winds, freezing temperatures, following rainfall events, or at night. No leachate shall be applied to waste that is less than ten (10) feet thick. Leachate recirculation shall be performed in accordance with the approved application, APE20110003. [401 KAR 47:120 Section 2]

6. Operation: In accordance with approved plan APE20040005, the landfill leachate treatment facility shall only accept leachate from the C-746-U and C-746-S landfills at the Paducah Gaseous Diffusion Plant. [401 KAR 47:120 Section 2]

7. General: The maximum extent of operation that may be open at any time during the active life of the landfill is 22.10 acres. [401 KAR 48:070 Section 15(2)(b)]

8. Wastestreams: The C-746-U Contained Landfill may accept for disposal only: 1) non-hazardous solid waste generated by, or on behalf of the United States Department of Energy (USDOE), on the USDOE-owned Paducah Gaseous Diffusion Plant (PGDP); 2) non-hazardous solid waste generated offsite from the DOE-owned PGDP as a result of environmental restoration/management activities (e.g., corrective action, removal action, remedial action, investigations, and/or monitoring) conducted by, or on behalf of, USDOE, associated with releases or potential releases from the PGDP; and 3) any non-hazardous residuals generated from the treatment or analysis of PGDP waste. The C-746-U Landfill may accept for disposal all non-hazardous solid waste including residential, commercial, institutional, industrial, and municipal waste, shredded tires, and non-hazardous spill cleanup residue. The technical requirements for contained landfills are found in 401 KAR 48:050 and 401 KAR 48:070 through 401 KAR 48:090. [401 KAR 47:080 Section 2(1), 401 KAR 47:120 Section 2]

9. Recordkeeping: The owner or operator shall submit a report quarterly, by the 15th of January, April, July, and October, detailing the source, disposal location and quantity of any spill residues, and records as to the source and quantity of all other wastes disposed of at the contained landfill. [401 KAR 47:190 Section 8(5)]

Approved Applications - The owner or operator shall comply with applicable statutes and regulations and the following approved applications:

1. 02/28/95 - APE19930001- LC1 NW 1 - Construction Permit
2. 01/19/96 - APE19950001 - LC1 MOMN1 - Minor Modification
3. 11/04/96 - APE19930001 - Construction/Operating Permit
4. 01/03/97 - Unnumbered Minor Modification
5. 02/01/01 - LC1 MOGW1 - APE20000002 - Well Corrosion Study Work Plan
6. 02/01/01 - LC1 MOGW2 - APE20000003 - Plan for Abandonment & Replacement of Monitoring Wells
7. 02/01/01 - LC1 MOMN2 - APE20000001 - Minor Modification
8. 01/04/02 - LC1 MOGW3 - Groundwater Monitoring Plan
9. 10/08/02 - Conditional Reopening of the Landfill
10. 10/03/03 - LC1 MOMN 3 and parts of LC1 MOMJ1 - Minor Modification and Part of Major Modification - Waste Acceptance Criteria
11. 07/14/04 - APE20010001- LC1MOMJ1 - Major Modification - Waste Acceptance Criteria
12. 02/16/06 - APE20040005 - Minor Modification - Leachate Treatment Facility
13. 03/13/06 - APE20060002 - Minor Modification - Waste Acceptance Criteria
14. 03/16/06 - APE20060003 - Minor Modification - TEMPO permit revision
15. 03/20/06 - APE20060003 - Minor Modification - Updated TEMPO permit revision
16. 04/24/06 - APE20060005 - Minor Modification - Add Paducah Remediation Services, LLC (operator)
17. 05/24/07 - APE20060007 - Permit Renewal
18. 06/12/07 - APE20060007 - Revised Permit Issued to replace 5/24/07 permit issued
19. 07/11/07 - APE20060007 - Revised Permit Issued to replace 06/12/07 permit issued
20. 02/12/08 - APE20060011 - Leachate Storage Capacity Minor Modification
21. 02/13/08 - AIN20070003 - Groundwater Contamination Assessment Plan
22. 11/20/08 - APE20080003 - Minor Modification - Revised HELP Model and Leachate Tank Design
23. 11/20/08 - APE20080002 - Groundwater and Surface Water Monitoring Plan Modification
24. 03/08/10 - APE20100001 - Construction Progress Report - Leachate Tank Installation - Approval pursuant to drawing numbers C7DC7460UA002 and S7DC7460UA001
25. 07/28/10 - APE20100005 - Permit Modification to Remove PRS from Permit and Add LATA to Permit
26. 08/02/10 - APE20100005 - Revised Permit Issued to replace 07/28/10 permit issued
27. 04/21/11 - APE20100003 - Minor Modification - Operational and Recordkeeping Changes
28. 01/25/12 - APE20110001 - Minor Modification - Working Face Procedures
29. 01/25/12 - APE20110003 - Minor Modification - Leachate Recirculation
30. 01/25/12 - APE20110004 - Groundwater Monitoring Modification - Remove Iodine-131 parameter
31. 03/30/12 - APE20100007 - Minor Modification - Revised Technical Application, Attachments 1, 5, 16, 22, and 26

ACTV0002 - Financial Assurance

The following is a history of the financial assurance for this facility:

Cost Estimates and Financial Assurance holdings are not applicable for this site.

Monitoring Conditions

GSTR0001 - Groundwater Monitoring - SW: 073-00045 C-746-U LF Groundwater Monitoring Group

Group Members: STRC0003 - Well MW-357; STRC0004 - Well MW-358; STRC0005 - Well MW-359; STRC0006 - Well MW-360; STRC0007 - Well MW-361; STRC0008 - Well MW-362; STRC0009 - Well MW-363; STRC0010 - Well MW-364; STRC0011 - Well MW-365; STRC0012 - Well MW-366; STRC0014 - Well MW-367; STRC0015 - Well MW-368; STRC0016 - Well MW-371; STRC0017 - Well MW-372; STRC0018 - Well MW-375; STRC0019 - Well MW-376; STRC0020 - Well MW-377; STRC0021 - Well MW-369; STRC0022 - Well MW-370; STRC0023 - Well MW-373; STRC0024 - Well MW-374

Standard Requirements:

1. The owner or operator shall satisfy the requirements of 401 KAR 48:300 for all wastes (or constituents thereof) contained in waste management units at the facility regardless of the time waste was placed in such unit. [401 KAR 48:300 Section 1]

2. The owner or operator shall monitor groundwater on the approved schedule at each approved groundwater monitoring location in accordance with 401 KAR 48:300, the permit, and the approved plans. A table summarizing the parameters to be monitored, their respective limits and monitoring frequency is included herein. [401 KAR 48:300, 401 KAR 47:120 Section 1]

3. The owner or operator shall conduct statistical analysis of the groundwater data in accordance with 401 KAR 48:300 Section 9 and the approved applications. The statistical test chosen shall be conducted separately for each parameter in each well for each monitoring event. The results shall be maintained as part of the facility record throughout the operating and post-closure life of the facility. [401 KAR 48:300 Section 9, 401 KAR 47:120 Section 1]

4. Metal criteria shall be total metals to be measured in an unfiltered sample. [401 KAR 47:030 Section 6(1)]

5. Groundwater monitoring wells shall be constructed and maintained in accordance with 401 KAR 48:300 Section 6, the permit, and the approved plans. [401 KAR 48:300 Section 6, 401 KAR 47:120 Section 1]

6. No monitoring well construction, maintenance, or abandonment may be conducted without prior approval by the Division of Waste Management. [401 KAR 47:120 Section 1, 401 KAR 47:120 Section 2]

7. Only a Kentucky Certified Monitoring Well Driller may construct or abandon monitoring wells. [401 KAR 6:320, 401 KAR 48:300 Section 7(3)]

8. If the analysis of groundwater sample results indicates contamination (i.e., a statistical or MCL exceedence) as specified in 401 KAR 48:300 Section 8(1), the owner or operator shall notify the cabinet within (forty-eight) 48 hours of receiving the results and shall arrange to split samples no later than ten (10) days from the receipt of the results. [401 KAR 48:300 Section 7]

9. The owner or operator shall be required to prepare and submit a groundwater contamination assessment plan if laboratory analyses of one (1) or more monitoring wells at the site shows the presence of one (1) or more parameters above the maximum contaminant level (MCL) as specified in 401 KAR 47:030 or a statistically significant increase over background levels for parameters that have no MCL. [401 KAR 48:300 Section 8, 401 KAR 47:120 Section 1]

10. The owner or operator shall provide alternate water supplies to all affected parties within twenty-four (24) hours of notification of the cabinet that sample results indicate contamination of a drinking water supply if it has been determined that the site or facility is the probable source of the contamination. [401 KAR 48:300 Section 8]

11. If required by the cabinet, groundwater contamination assessment and corrective action shall be performed in full compliance with all provisions of 401 KAR 48:300 Section 8. [401 KAR 48:300 Section 8]

12. The owner or operator shall provide the division a minimum of five (5) working days advance notice for all groundwater monitoring well construction and abandonment activities. [401 KAR 40:020 Section 2(4)]

Variances, Alternate Specifications and Special Conditions:

1. At each approved groundwater monitoring location, the permittee shall monitor quarterly for the parameters listed in 401 KAR 48:300 Section 11(3), minus 2-Chlorovinyl Ethyl Ether, Dichlorodifluoromethane, Ethyl Alcohol, and Ethyl Methacrylate, plus the following: Aluminum, Boron, Bromide, Calcium, Cyanide, Eh, Fluoride, Gross Alpha, Gross Beta, Iodide, Magnesium, Manganese, Molybdenum, Dissolved Oxygen, Potassium, Radium, Rhodium, Strontium-90, Sulfate, Tantalum, Technetium-99, Thorium-230, Tritium, Uranium (total) and Polychlorinated Biphenyls. Metals samples shall not be filtered. [401 KAR 47:120 Section 2, 401 KAR 48:300 Section 11(3)]

GSTR0003 - Groundwater Monitoring - SW: 073-00014 and 073-00015 C-746-S and C-746-T Landfill Combined Groundwater Monitoring Group

Group Members: STRC0017 - Well MW-372; STRC0021 - Well MW-369; STRC0022 - Well MW-370; STRC0023 - Well MW-373; STRC0060 - Well MW-220; STRC0061 - Well MW-221; STRC0062 - Well MW-222; STRC0063 - Well MW-223; STRC0064 - Well MW-224; STRC0073 - Well MW-384; STRC0074 - Well MW-385; STRC0075 - Well MW-386; STRC0076 - Well MW-387; STRC0077 - Well MW-388; STRC0078 - Well MW-389; STRC0079 - Well MW-390; STRC0080 - Well MW-391; STRC0081 - Well MW-392; STRC0082 - Well MW-393; STRC0083 - Well MW-394; STRC0084 - Well MW-395; STRC0085 - Well MW-396; STRC0086 - Well MW-397

Standard Requirements:

1. The owner or operator shall satisfy the requirements of 401 KAR 48:300 for all wastes (or constituents thereof) contained in waste management units at the facility regardless of the time waste was placed in such unit. [401 KAR 48:300 Section 1]

2. The owner or operator shall monitor groundwater on the approved schedule at each approved groundwater monitoring location in accordance with 401 KAR 48:300, the permit, and the approved plans. A table summarizing the parameters to be monitored, their respective limits and monitoring frequency is included herein. [401 KAR 48:300, 401 KAR 47:120 Section 1]

3. The owner or operator shall conduct statistical analysis of the groundwater data in accordance with 401 KAR 48:300 Section 9 and the approved applications. The statistical test chosen shall be conducted separately for each parameter in each well for each monitoring event. The results shall be maintained as part of the facility record throughout the operating and post-closure life of the facility. [401 KAR 48:300 Section 9, 401 KAR 47:120 Section 1]

4. Metal criteria shall be total metals to be measured in an unfiltered sample. [401 KAR 47:030 Section 6(1)]

5. Groundwater monitoring wells shall be constructed and maintained in accordance with 401 KAR 48:300 Section 6, the permit, and the approved plans. [401 KAR 48:300 Section 6, 401 KAR 47:120 Section 1]

6. No monitoring well construction, maintenance, or abandonment may be conducted without prior approval by the Division of Waste Management. [401 KAR 47:120 Section 1, 401 KAR 47:120 Section 2]

7. Only a Kentucky Certified Monitoring Well Driller may construct or abandon monitoring wells. [401 KAR 6:320, 401 KAR 48:300 Section 7(3)]

8. If the analysis of groundwater sample results indicates contamination (i.e., a statistical or MCL exceedence) as specified in 401 KAR 48:300 Section 8(1), the owner or operator shall notify the cabinet within (forty-eight) 48 hours of receiving the results and shall arrange to split samples no later than ten (10) days from the receipt of the results. [401 KAR 48:300 Section 7]

9. The owner or operator shall be required to prepare and submit a groundwater contamination assessment plan if laboratory analyses of one (1) or more monitoring wells at the site shows the presence of one (1) or more parameters above the maximum contaminant level (MCL) as specified in 401 KAR 47:030 or a statistically significant increase over background levels for parameters that have no MCL. [401 KAR 48:300 Section 8, 401 KAR 47:120 Section 1]

10. The owner or operator shall provide alternate water supplies to all affected parties within twenty-four (24) hours of notification of the cabinet that sample results indicate contamination of a drinking water supply if it has been determined that the site or facility is the probable source of the contamination. [401 KAR 48:300 Section 8]

11. If required by the cabinet, groundwater contamination assessment and corrective action shall be performed in full compliance with all provisions of 401 KAR 48:300 Section 8. [401 KAR 48:300 Section 8]

12. The owner or operator shall provide the division a minimum of five (5) working days advance notice for all groundwater monitoring well construction and abandonment activities. [401 KAR 40:020 Section 2(4)]

Variances, Alternate Specifications and Special Conditions:

1. At each approved groundwater monitoring location, the permittee shall monitor annually for Polychlorinated biphenyls (PCBs). [401 KAR 48:300 Section 11(3)]

2. With respect to the C-746-S and C-746-T Landfills, the permittee shall comply with all of the requirements of 401 KAR 48:300 except 401 KAR 48:300 Section 8. The groundwater assessment and corrective action requirements of 401 KAR 48:300 Section 8 shall not apply to the C-746-S Residential Landfill and the C-746-T Inert Landfill. The permittee shall perform groundwater assessment and corrective action for these landfills in accordance with the provisions of 401 KAR 34:060, Section 12. [401 KAR 47:120 Section 2]

3. At each approved groundwater monitoring location, the permittee shall monitor quarterly for the parameters listed in 401 KAR 48:300 Section 11(3), minus 2-Chlorovinyl Ethyl Ether, Dichlorodifluoromethane, Ethyl Alcohol, and Ethyl Methacrylate, plus the following: Aluminum, Boron, Bromide, Calcium, Cyanide, Eh, Fluoride, Gross Alpha, Gross Beta, Iodide, Magnesium, Manganese, Molybdenum, Dissolved Oxygen, Potassium, Radium, Rhodium, Strontium-90, Sulfate, Tantalum, Technetium-99, Thorium-230, Tritium, and Uranium (total). Metals samples shall not be filtered. [401 KAR 47:120 Section 2, 401 KAR 48:300 Section 11(3)]

GSTR0004 - Groundwater Monitoring - SW: 073-00014 and 073-00015 C-746-S and C-746-T Landfill Combined Groundwater Monitoring Group / Water Levels Only

Group Members: STRC0065 - Well MW-225; STRC0071 - Well MW-353

Variances, Alternate Specifications and Special Conditions:

1. The permittee shall monitor these wells for static water levels only on a quarterly basis. [401 KAR 48:300 Section 11, 401 KAR 47:120 Section 2]

GMNP0001 - Surface Water Monitoring - SW: 073-00045 C-746-U LF Surface Water Monitoring Group

Group Members: MNPT0002 - Upstream Point L154; MNPT0003 - Instream Point L150; MNPT0012 - Downstream Point L351

Standard Requirements:

1. The owner or operator shall monitor surface water in accordance with 401 KAR 48:300 Section 2 and the approved surface water monitoring plan. A table summarizing the parameters to be monitored and the monitoring frequency is included herein. [401 KAR 48:300 Section 2]

Variances, Alternate Specifications and Special Conditions:

1. Subject to applicable law, surface water corrective action shall be completed by the owner or operator as necessary to comply with 401 KAR 47:030 Section 4. [401 KAR 47:030 Section 4]

GMNP0003 - Surface Water Monitoring - SW: 073-00014 and 073-00015 C-746-S and C-746-T Combined Surface Water Monitoring Group

Group Members: MNPT0002 - Upstream Point L154; MNPT0009 - Upstream Point L135; MNPT0010 - Instream Point L136

Standard Requirements:

1. The owner or operator shall monitor surface water in accordance with 401 KAR 48:300 Section 2 and the approved surface water monitoring plan. A table summarizing the parameters to be monitored and the monitoring frequency is included herein. [401 KAR 48:300 Section 2]

Variances, Alternate Specifications and Special Conditions:

1. Subject to applicable law, surface water corrective action shall be completed by the owner or operator as necessary to comply with 401 KAR 47:030 Section 4. [401 KAR 47:030 Section 4]

GMNP0002 - Methane Monitoring - SW: Methane Monitoring Group

Group Members: ACTV0004 - Residential Landfill; ACTV0006 - Contained Landfill

Standard Requirements:

1. Property Line Explosive Gas Monitoring: The owner or operator of a contained landfill shall quarterly monitor for explosive gas at locations along the facility property boundary as shown in the permit. [401 KAR 48:090 Section 4(2)(b)]

2. Quarterly Facility Structure Explosive Gas Monitoring: The owner or operator of a contained landfill shall monitor quarterly for explosive gas underneath or in the low area of each on-site building. [401 KAR 48:090 Section 4(2)(a)]

3. Continuous Facility Structure Explosive Gas Monitoring: The owner or operator shall install, operate, and maintain a gas detector with an alarm set at twenty-five (25) percent of the lower explosive limit in each on-site building. [401 KAR 48:090 Section 4(4)]

4. Passive Gas Vent Explosive Gas Monitoring: The owner or operator of a contained landfill shall quarterly monitor for explosive gas at each passive gas vent installed under the final closure cap. [401 KAR 48:090 Section 4(2)(c)]

5. Problem Area Explosive Gas Monitoring: The owner or operator of a contained landfill shall quarterly monitor for explosive gas at any potential gas problem areas, as revealed by dead vegetation or other indicators. [401 KAR 48:090 Section 4(2)(d)]

6. Other Explosive Gas Monitoring: The owner or operator of a contained landfill shall monitor quarterly for explosive gas at any other points required by the Cabinet in the permit. [401 KAR 48:090 Section 4(2)(e)]

7. Exceedences: If methane gas levels exceeding twenty-five (25) percent of the lower explosive limits (LEL) for methane in facility structures (excluding gas control or recovery system components) or the lower explosive limit for methane at the facility property boundary are detected, the owner or operator shall, within fourteen days, submit to the Cabinet for approval a remediation plan for the methane gas releases. The plan shall describe the extent of the problem and the proposed remedy. The plan shall be implemented upon approval by the Cabinet. [401 KAR 48:090 Section 4(5)(c)]

8. Exceedences: If methane gas levels exceeding twenty-five (25) percent of the lower explosive limits (LEL) for methane in facility structures (excluding gas control or recovery system components) or the lower explosive limit for methane at the facility property boundary are detected, the owner or operator shall immediately notify the Cabinet of the methane gas levels detected and the immediate steps taken to protect human health. [401 KAR 48:090 Section 4(5)(b)]

9. Exceedences: If methane gas levels exceeding twenty-five (25) percent of the lower explosive limits (LEL) for methane in facility structures (excluding gas control or recovery system components) or the lower explosive limit for methane at the facility property boundary are detected, the owner or operator shall take all necessary steps to ensure immediate protection of human health. [401 KAR 48:090 Section 4(5)(a)]

10. Recordkeeping: The owner or operator shall record the date, time, location, percent lower explosive limit and other pertinent information regarding explosive gas monitoring on a recordkeeping form approved by the cabinet. [401 KAR 48:090 Section 4(3)]

Groundwater Monitoring Limits:

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0001	00630-20-6	1,1,1,2-Tetrachloroethane	quarterly			mg/L	Yes	
GSTR0001	00071-55-6	1,1,1-Trichloroethane	quarterly		0.2	mg/L		
GSTR0001	00079-34-5	1,1,2,2-Tetrachloroethane	quarterly			mg/L	Yes	
GSTR0001	00079-00-5	1,1,2-Trichloroethane	quarterly			mg/L	Yes	
GSTR0001	00075-34-3	1,1-Dichloroethane	quarterly			mg/L	Yes	
GSTR0001	00075-35-4	1,1-Dichloroethylene	quarterly		0.007	mg/L		
GSTR0001	00096-18-4	1,2,3-Trichloropropane	quarterly			mg/L	Yes	
GSTR0001	00096-12-8	1,2-Dibromo-3-Chloropropane	quarterly			mg/L	Yes	
GSTR0001	00106-93-4	1,2-Dibromoethane	quarterly			mg/L	Yes	
GSTR0001	00095-50-1	1,2-Dichlorobenzene	quarterly			mg/L	Yes	
GSTR0001	00107-06-2	1,2-Dichloroethane	quarterly		0.005	mg/L		
GSTR0001	00078-87-5	1,2-Dichloropropane	quarterly			mg/L	Yes	
GSTR0001	00106-46-7	1,4-Dichlorobenzene	quarterly		0.075	mg/L		
GSTR0001	00591-78-6	2-Hexanone	quarterly			mg/L	Yes	
GSTR0001	00067-64-1	Acetone	quarterly			mg/L	Yes	
GSTR0001	00107-02-8	Acrolein	quarterly			mg/L	Yes	
GSTR0001	00107-13-1	Acrylonitrile	quarterly			mg/L	Yes	
GSTR0001	07429-90-5	Aluminum	quarterly			mg/L	Yes	
GSTR0001	07440-36-0	Antimony, Total (as Sb)	quarterly			mg/L	Yes	
GSTR0001	07440-38-2	Arsenic, Total (as As)	quarterly		0.05	mg/L		
GSTR0001	07440-39-3	Barium, Total (as Ba)	quarterly		2.0	mg/L		
GSTR0001	00071-43-2	Benzene	quarterly		0.005	mg/L		
GSTR0001	07440-41-7	Beryllium, Total	quarterly			mg/L	Yes	
GSTR0001	07440-42-8	Boron	quarterly			mg/L	Yes	
GSTR0001	24959-67-9	Bromide	quarterly			mg/L	Yes	
GSTR0001	00075-27-4	Bromodichloromethane	quarterly			mg/L	Yes	
GSTR0001	07440-43-9	Cadmium, Total (as Cd)	quarterly		0.005	mg/L		
GSTR0001	07440-70-2	Calcium	quarterly			mg/L	Yes	
GSTR0001	00075-15-0	Carbon Disulfide	quarterly			mg/L	Yes	
GSTR0001	00056-23-5	Carbon Tetrachloride	quarterly		0.005	mg/L		
GSTR0001		Carbon, Total Organic	quarterly			mg/L	Yes	
GSTR0001		Chemical Oxygen Demand (COD)	quarterly			mg/L	Yes	
GSTR0001	16887-00-6	Chloride	quarterly			mg/L	Yes	
GSTR0001	00108-90-7	Chlorobenzene	quarterly			mg/L	Yes	

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Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0001	00074-97-5	Chlorobromomethane	quarterly			mg/L	Yes	
GSTR0001	00075-00-3	Chloroethane	quarterly			mg/L	Yes	
GSTR0001	00067-66-3	Chloroform	quarterly			mg/L	Yes	
GSTR0001	07440-47-3	Chromium, Total (as Cr)	quarterly		0.1	mg/L		
GSTR0001	10061-01-5	Cis 1,3-Dichloropropylene	quarterly			mg/L	Yes	
GSTR0001	00156-59-2	Cis-1,2-Dichloroethylene	quarterly			mg/L	Yes	
GSTR0001	07440-48-4	Cobalt, Total	quarterly			mg/L	Yes	
GSTR0001	07440-50-8	Copper, Total (as Cu)	quarterly			mg/L	Yes	
GSTR0001	00057-12-5	Cyanide, Total (as Cn)	quarterly			mg/L	Yes	
GSTR0001	00124-48-1	Dibromochloromethane	quarterly			mg/L	Yes	
GSTR0001	00075-09-2	Dichloromethane	quarterly			mg/L	Yes	
GSTR0001		Eh	quarterly			mV	Yes	
GSTR0001	00100-41-4	Ethyl Benzene	quarterly			mg/L	Yes	
GSTR0001	16984-48-8	Fluoride	quarterly		4.0	mg/L		
GSTR0001		Gross Alpha	quarterly		15	pCi/L		
GSTR0001		Gross Beta	quarterly		50	pCi/L		
GSTR0001		Halides, Total Organic	quarterly			mg/L	Yes	
GSTR0001		Iodide	quarterly			mg/L	Yes	
GSTR0001	00074-88-4	Iodomethane	quarterly			mg/L	Yes	
GSTR0001	07439-89-6	Iron, Total (as Fe)	quarterly			mg/L	Yes	
GSTR0001	07439-92-1	Lead, Total (as Pb)	quarterly		0.050	mg/L		
GSTR0001	07439-95-4	Magnesium, Total (as Mg)	quarterly			mg/L	Yes	
GSTR0001	07439-96-5	Manganese	quarterly			mg/L	Yes	
GSTR0001	07439-97-6	Mercury, Total (as Hg)	quarterly		0.002	mg/L		
GSTR0001	00074-83-9	Methyl Bromide	quarterly			mg/L	Yes	
GSTR0001	00074-87-3	Methyl Chloride	quarterly			mg/L	Yes	
GSTR0001	00078-93-3	Methyl Ethyl Ketone	quarterly			mg/L	Yes	
GSTR0001	00108-10-1	Methyl Isobutyl Ketone	quarterly			mg/L	Yes	
GSTR0001	00074-95-3	Methylene Bromide	quarterly			mg/L	Yes	
GSTR0001	07439-98-7	Molybdenum	quarterly			mg/L	Yes	
GSTR0001	07440-02-0	Nickel, Total (as Ni)	quarterly			mg/L	Yes	
GSTR0001		Nitrogen, Nitrate Total (as N)	quarterly		10	mg/L		
GSTR0001		Oxygen, Dissolved	quarterly			mg/L	Yes	

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0001	01336-36-3	Polychlorinated Biphenyls (PCBs)	quarterly			mg/L	Yes	
GSTR0001	07440-09-7	Potassium	quarterly			mg/L	Yes	
GSTR0001	13982-63-3	Radium-226	quarterly			pCi/L	Yes	
GSTR0001	13982-63-3	Radium-226	quarterly			pCi/L	Yes	
GSTR0001	07440-16-6	Rhodium	quarterly			mg/L	Yes	
GSTR0001	07782-49-2	Selenium, Total (as Se)	quarterly		0.05	mg/L		
GSTR0001	07440-22-4	Silver, Total (as Ag)	quarterly		0.05	mg/L		
GSTR0001	07440-23-5	Sodium	quarterly			mg/L	Yes	
GSTR0001		Solids, Total Dissolved	quarterly			mg/L	Yes	
GSTR0001		Specific Conductance	quarterly			umho/cm	Yes	
GSTR0001		Strontium-90	quarterly		8	pCi/L		
GSTR0001	00100-42-5	Styrene	quarterly			mg/L	Yes	
GSTR0001	14808-79-8	Sulfate	quarterly			mg/L	Yes	
GSTR0001		Tantalum, Total	quarterly			mg/L	Yes	
GSTR0001	14133-76-7	Technetium 99, Total	quarterly			pCi/L	Yes	
GSTR0001	00127-18-4	Tetrachloroethylene (PCE)	quarterly			mg/L	Yes	
GSTR0001	07440-05-3	Thallium, Total	quarterly			mg/L	Yes	
GSTR0001		Thorium-230	quarterly			pCi/L	Yes	
GSTR0001	00108-88-3	Toluene	quarterly			mg/L	Yes	
GSTR0001	00156-60-5	Trans-1,2-Dichloroethylene	quarterly			mg/L	Yes	
GSTR0001	10061-02-6	Trans-1,3-Dichloropropene	quarterly			mg/L	Yes	
GSTR0001	00110-57-6	Trans-1,4-Dichloro-2-Butene	quarterly			mg/L	Yes	
GSTR0001	00075-25-2	Tribromomethane	quarterly			mg/L	Yes	
GSTR0001	00079-01-6	Trichloroethylene	quarterly		0.005	mg/L		
GSTR0001	00075-69-4	Trichlorofluoromethane	quarterly			mg/L	Yes	
GSTR0001	10028-17-8	Tritium; Tritium, Total	quarterly		20,000	pCi/L	Yes	
GSTR0001	07440-61-1	Uranium, Total	quarterly		30	ug/L		
GSTR0001	07440-62-2	Vanadium, Total	quarterly			mg/L	Yes	
GSTR0001	00108-05-4	Vinyl Acetate	quarterly			mg/L	Yes	
GSTR0001	00075-01-4	Vinyl Chloride	quarterly		0.002	mg/L		
GSTR0001	01330-20-7	Xylenes (Total)	quarterly			mg/L	Yes	
GSTR0001	07440-66-6	Zinc, Total (as Zn)	quarterly			mg/L	Yes	

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Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0001		pH	quarterly			standard units	Yes	
GSTR0003	00630-20-6	1,1,1,2-Tetrachloroethane	quarterly			mg/L	Yes	
GSTR0003	00071-55-6	1,1,1-Trichloroethane	quarterly		0.2	mg/L		
GSTR0003	00079-34-5	1,1,2,2-Tetrachloroethane	quarterly			mg/L	Yes	
GSTR0003	00079-00-5	1,1,2-Trichloroethane	quarterly			mg/L	Yes	
GSTR0003	00075-34-3	1,1-Dichloroethane	quarterly			mg/L	Yes	
GSTR0003	00075-35-4	1,1-Dichloroethylene	quarterly		0.007	mg/L		
GSTR0003	00096-18-4	1,2,3-Trichloropropane	quarterly			mg/L	Yes	
GSTR0003	00096-12-8	1,2-Dibromo-3-Chloropropane	quarterly			mg/L	Yes	
GSTR0003	00106-93-4	1,2-Dibromoethane	quarterly			mg/L	Yes	
GSTR0003	00095-50-1	1,2-Dichlorobenzene	quarterly			mg/L	Yes	
GSTR0003	00107-06-2	1,2-Dichloroethane	quarterly		0.005	mg/L		
GSTR0003	00078-87-5	1,2-Dichloropropane	quarterly			mg/L	Yes	
GSTR0003	00106-46-7	1,4-Dichlorobenzene	quarterly		0.075	mg/L		
GSTR0003	00591-78-6	2-Hexanone	quarterly			mg/L	Yes	
GSTR0003	00067-64-1	Acetone	quarterly			mg/L	Yes	
GSTR0003	00107-02-8	Acrolein	quarterly			mg/L	Yes	
GSTR0003	00107-13-1	Acrylonitrile	quarterly			mg/L	Yes	
GSTR0003	07429-90-5	Aluminum	quarterly			mg/L	Yes	
GSTR0003	07440-36-0	Antimony, Total (as Sb)	quarterly			mg/L	Yes	
GSTR0003	07440-38-2	Arsenic, Total (as As)	quarterly		0.05	mg/L		
GSTR0003	07440-39-3	Barium, Total (as Ba)	quarterly		2.0	mg/L		
GSTR0003	00071-43-2	Benzene	quarterly		0.005	mg/L		
GSTR0003	07440-41-7	Beryllium, Total	quarterly			mg/L	Yes	
GSTR0003	07440-42-8	Boron	quarterly			mg/L	Yes	
GSTR0003	24959-67-9	Bromide	quarterly			mg/L	Yes	
GSTR0003	00075-27-4	Bromodichloromethane	quarterly			mg/L	Yes	
GSTR0003	07440-43-9	Cadmium, Total (as Cd)	quarterly		0.005	mg/L		
GSTR0003	07440-70-2	Calcium	quarterly			mg/L	Yes	
GSTR0003	00075-15-0	Carbon Disulfide	quarterly			mg/L	Yes	
GSTR0003	00056-23-5	Carbon Tetrachloride	quarterly		0.005	mg/L		

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Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0003		Carbon, Total Organic	quarterly			mg/L	Yes	
GSTR0003		Chemical Oxygen Demand (COD)	quarterly			mg/L	Yes	
GSTR0003	16887-00-6	Chloride	quarterly			mg/L	Yes	
GSTR0003	00108-90-7	Chlorobenzene	quarterly			mg/L	Yes	
GSTR0003	00074-97-5	Chlorobromomethane	quarterly			mg/L	Yes	
GSTR0003	00075-00-3	Chloroethane	quarterly			mg/L	Yes	
GSTR0003	00067-66-3	Chloroform	quarterly			mg/L	Yes	
GSTR0003	07440-47-3	Chromium, Total (as Cr)	quarterly		0.1	mg/L		
GSTR0003	10061-01-5	Cis 1,3-Dichloropropylene	quarterly			mg/L	Yes	
GSTR0003	00156-59-2	Cis-1,2-Dichloroethylene	quarterly			mg/L	Yes	
GSTR0003	07440-48-4	Cobalt, Total	quarterly			mg/L	Yes	
GSTR0003	07440-50-8	Copper, Total (as Cu)	quarterly			mg/L	Yes	
GSTR0003	00057-12-5	Cyanide, Total (as Cn)	quarterly			mg/L	Yes	
GSTR0003	00124-48-1	Dibromochloromethane	quarterly			mg/L	Yes	
GSTR0003	00075-09-2	Dichloromethane	quarterly			mg/L	Yes	
GSTR0003		Eh	quarterly			mV	Yes	
GSTR0003	00100-41-4	Ethyl Benzene	quarterly			mg/L	Yes	
GSTR0003	16984-48-8	Fluoride	quarterly		4.0	mg/L		
GSTR0003		Gross Alpha	quarterly		15	pCi/L		
GSTR0003		Gross Beta	quarterly		50	pCi/L		
GSTR0003		Halides, Total Organic	quarterly			mg/L	Yes	
GSTR0003		Iodide	quarterly			mg/L	Yes	
GSTR0003	00074-88-4	Iodomethane	quarterly			mg/L	Yes	
GSTR0003	07439-89-6	Iron, Total (as Fe)	quarterly			mg/L	Yes	
GSTR0003	07439-92-1	Lead, Total (as Pb)	quarterly		0.050	mg/L		
GSTR0003	07439-95-4	Magnesium, Total (as Mg)	quarterly			mg/L	Yes	
GSTR0003	07439-96-5	Manganese	quarterly			mg/L	Yes	
GSTR0003	07439-97-6	Mercury, Total (as Hg)	quarterly		0.002	mg/L		
GSTR0003	00074-83-9	Methyl Bromide	quarterly			mg/L	Yes	
GSTR0003	00074-87-3	Methyl Chloride	quarterly			mg/L	Yes	
GSTR0003	00078-93-3	Methyl Ethyl Ketone	quarterly			mg/L	Yes	
GSTR0003	00108-10-1	Methyl Isobutyl Ketone	quarterly			mg/L	Yes	

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Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0003	00074-95-3	Methylene Bromide	quarterly			mg/L	Yes	
GSTR0003	07439-98-7	Molybdenum	quarterly			mg/L	Yes	
GSTR0003	07440-02-0	Nickel, Total (as Ni)	quarterly			mg/L	Yes	
GSTR0003		Nitrogen, Nitrate Total (as N)	quarterly		10	mg/L		
GSTR0003		Oxygen, Dissolved	quarterly			mg/L	Yes	
GSTR0003	01336-36-3	Polychlorinated Biphenyls (PCBs)	annually			mg/L	Yes	
GSTR0003	07440-09-7	Potassium	quarterly			mg/L	Yes	
GSTR0003	13982-63-3	Radium-226	quarterly			pCi/L	Yes	
GSTR0003	07440-16-6	Rhodium	quarterly			mg/L	Yes	
GSTR0003	07782-49-2	Selenium, Total (as Se)	quarterly		0.05	mg/L		
GSTR0003	07440-22-4	Silver, Total (as Ag)	quarterly		0.05	mg/L		
GSTR0003	07440-23-5	Sodium	quarterly			mg/L	Yes	
GSTR0003		Solids, Total Dissolved	quarterly			mg/L	Yes	
GSTR0003		Specific Conductance	quarterly			umho/cm	Yes	
GSTR0003		Strontium-90	quarterly		8	pCi/L		
GSTR0003	00100-42-5	Styrene	quarterly			mg/L	Yes	
GSTR0003	14808-79-8	Sulfate	quarterly			mg/L	Yes	
GSTR0003		Tantalum, Total	quarterly			mg/L	Yes	
GSTR0003	14133-76-7	Technetium 99, Total	quarterly			pCi/L	Yes	
GSTR0003	00127-18-4	Tetrachloroethylene (PCE)	quarterly			mg/L	Yes	
GSTR0003	07440-05-3	Thallium, Total	quarterly			mg/L	Yes	
GSTR0003		Thorium-230	quarterly			pCi/L	Yes	
GSTR0003	00108-88-3	Toluene	quarterly			mg/L	Yes	
GSTR0003	00156-60-5	Trans-1,2-Dichloroethylene	quarterly			mg/L	Yes	
GSTR0003	10061-02-6	Trans-1,3-Dichloropropene	quarterly			mg/L	Yes	
GSTR0003	00110-57-6	Trans-1,4-Dichloro-2-Butene	quarterly			mg/L	Yes	
GSTR0003	00075-25-2	Tribromomethane	quarterly			mg/L	Yes	
GSTR0003	00079-01-6	Trichloroethylene	quarterly		0.005	mg/L		
GSTR0003	00075-69-4	Trichlorofluoromethane	quarterly			mg/L	Yes	
GSTR0003	10028-17-8	Tritium; Tritium, Total	quarterly		20,000	pCi/L	Yes	
GSTR0003	07440-61-1	Uranium, Total	quarterly		30	ug/L		
GSTR0003	07440-62-2	Vanadium, Total	quarterly			mg/L	Yes	

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GSTR0003	00108-05-4	Vinyl Acetate	quarterly			mg/L	Yes	
GSTR0003	00075-01-4	Vinyl Chloride	quarterly		0.002	mg/L		
GSTR0003	01330-20-7	Xylenes (Total)	quarterly			mg/L	Yes	
GSTR0003	07440-66-6	Zinc, Total (as Zn)	quarterly			mg/L	Yes	
GSTR0003		pH	quarterly			standard units	Yes	

Surface Water Monitoring Limits:

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GMNP0001		Carbon, Total Organic	quarterly					Yes
GMNP0001		Chemical Oxygen Demand (COD)	quarterly					Yes
GMNP0001	16887-00-6	Chloride	quarterly					Yes
GMNP0001		Gross Alpha	quarterly					Yes
GMNP0001		Gross Beta	quarterly					Yes
GMNP0001	07439-89-6	Iron, Total (as Fe)	quarterly					Yes
GMNP0001	07440-23-5	Sodium	quarterly					Yes
GMNP0001		Solids, Total Dissolved	quarterly					Yes
GMNP0001		Solids, Total Suspended (TSS)	quarterly					Yes
GMNP0001		Specific Conductance	quarterly					Yes
GMNP0001	14808-79-8	Sulfate	quarterly					Yes
GMNP0001		Total Solids	quarterly					Yes
GMNP0001	07440-61-1	Uranium, Total	quarterly					Yes
GMNP0001		pH	quarterly					Yes
GMNP0003		Carbon, Total Organic	quarterly					Yes
GMNP0003		Chemical Oxygen Demand (COD)	quarterly					Yes
GMNP0003	16887-00-6	Chloride	quarterly					Yes
GMNP0003		Gross Alpha	quarterly					Yes
GMNP0003		Gross Beta	quarterly					Yes

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GMNP0003	07439-89-6	Iron, Total (as Fe)	quarterly					Yes
GMNP0003	07440-23-5	Sodium	quarterly					Yes
GMNP0003		Solids, Total Dissolved	quarterly					Yes
GMNP0003		Solids, Total Suspended (TSS)	quarterly					Yes
GMNP0003		Specific Conductance	quarterly					Yes
GMNP0003	14808-79-8	Sulfate	quarterly					Yes
GMNP0003		Total Solids	quarterly					Yes
GMNP0003	07440-61-1	Uranium, Total	quarterly					Yes
GMNP0003		pH	quarterly					Yes

Methane Monitoring Limits:

Subject Item	CAS Number	Parameter	Frequency	Lower Limit	Upper Limit	Units	Statistical Limit	Report Only
GMNP0002		Continuous Facility Structure Explosive Gas Monitoring	continuously		25	% Lower Explosive Limit for Methane		
GMNP0002		Property Line Explosive Gas Monitoring	quarterly		100	% Lower Explosive Limit for Methane		
GMNP0002		Quarterly Facility Structure Explosive Gas Monitoring	quarterly		25	% Lower Explosive Limit for Methane		

Department of Energy
Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

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Mr. Ronald D. Gruzesky
Kentucky Department for Environmental Protection
Division of Waste Management, Solid Waste Branch
200 Fair Oaks Lane, 2nd Floor
Frankfort, Kentucky 40601

PPPO-02-1392217-12

Dear Mr. Gruzesky:

TRANSMITTAL OF A MINOR PERMIT MODIFICATION FOR SOLID WASTE PERMIT NUMBER 073-00045 (C-746-U LANDFILL), ANSWERING QUESTIONS ON SEISMIC CONDITIONS EXPECTED AND DESIGN CRITERIA NEEDED WITH PREDICTED SEISMIC CONDITIONS, PADUCAH GASEOUS DIFFUSION PLANT, AGENCY INTEREST NUMBER 3059, ACTIVITY ID NO. APE20100007

Enclosed is a request for a minor permit modification to the referenced solid waste permit. The modification requests removal of condition 5, Section ACTV0006, Variances, Alternate Specifications, and Special Conditions. The current permit reads as follows:

> No construction may begin on phases 6 thru 24 of the landfill until the seismic hazard reevaluation and fault study reports are approved by the Division. [401 *KAR* 47: 120 § 2, 401 *KAR* 48:050 § 5, 401 *KAR* 48:070 § 3]

In preparation for the opening of phases 6–23 of the C-746-U Landfill, LATA Environmental Services of Kentucky, LLC, is submitting with this request, *Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant*, by Dr. Neven Matasovic. Resubmitted (unchanged) for your convenience is the *Investigation of Holocene Faulting Proposed C-746-U Landfill Expansion, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* by The University of Kentucky Research Consortium for Energy and Environment that was submitted to the Kentucky Division of Waste Management (KDWM) July 21, 2010.

KDWM issued a Notice of Deficiency (NOD) on October 27, 2010. The NOD gave directions for conducting the seismic hazard reevaluation, required a study to determine if the present landfill design can withstand the type of displacement and degree of offset a maximum predicted seismic event would administer, and required a permit modification of the landfill technical application and design to meet developed seismic criteria. Several cooperative meetings, markups, draft documents, and comment resolutions have occurred since the NOD was issued.

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The seismic evaluation recommends replacement of the current design of a 40-mil smooth very low density polyethylene resin landfill liner cap with a 60-mil, textured on both sides, high density polyethylene resins geomembrane liner cap.

A comment response is attached to this letter that answers the most recent questions posed by the KDWM during their reviews of the seismic studies.

This permit modification requests removal of condition 5 of the landfill permit. It includes seismic reports and provides changes to 4 of the 51 drawings originally submitted as Technical Application Attachment 1. Technical Application Attachment 5, "Narrative of Design to Resist Seismic Events"; Technical Application Attachment 16, "Leachate Storage Tanks"; Technical Application Attachment 22, "Construction Quality Control Plan"; and Technical Application Attachment 26, "Closure Cap Specifications of the Technical Application," also have been modified. Technical Application Attachment 5 has been modified to include a description of the provided studies. Technical Application Attachment 16 was modified to include a new geosynthetic liner used in the cap as a part of the HELP model. The modification resulted in no change to leachate storage requirements. The only change in Technical Application Attachments 22 and 26 and drawings from Attachment 1 was to references to the type of geosynthetic liner used in the cap.

If you have any questions or require additional information, please contact Lisa Santoro at (270) 441-6804.

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Sincerely,

William E. Murphie
Manager
Portsmouth/Paducah Project Office

Enclosures:
1. Certification Sheet
2. Permit Modification Request
3. Comment Response Summary

e-copy w/enclosures:
david.ashburn@lataky.com, LATA/Kevil
gaye.brewer@ky.gov, KDEP/PAD
jeffrey.gibson@ky.gov, KDEP/Frankfort
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kerry.stone@lataky.com, LATA/Kevil
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todd.hendricks@ky.gov, KDEP/Frankfort
william.creech@lex.doe.gov, PPPO/LEX

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CERTIFICATION

Document Identification: **Technical Notice of Deficiency No. 1, Response to Application Deficiencies, Minor Permit Modification for Solid Waste Permit Number 073-00045 (C-746-U Landfill), Paducah Gaseous Diffusion Plant, Agency Interest Number 3059**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

LATA Environmental Services of Kentucky, LLC

Mark J. Duff, Paducah Project Manager — Date Signed: 2-23-12

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy (DOE)

William E. Murphie, Manager
Portsmouth/Paducah Project Office — Date Signed: 3/7/12

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Response to Kentucky Division of Waste Management
Comments Received May 30, 2011,
Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,
PAD-ENG-1003, Dated February 2011

These responses have been prepared by Geosyntec Consultants (Geosyntec) on behalf of LATA Environmental Services of Kentucky, LLC, (LATA Kentucky) to address comments from Kentucky Division of Waste Management (KDWM) on the report entitled, *Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, (subject report) that was prepared by Geosyntec. Note that the majority of the KDWM comments are related to Appendix A of the subject report that contains a report entitled "Seismic Hazard Evaluation Report," prepared by James A. Beavers Consultants (JEB) and their subcontractor, Dr. Chris Cramer. The latter report is referenced as "Beavers/Cramer" report by KDWM in their comments. For consistency with the format of this letter report and to acknowledge that the "Beavers/Cramer" report has been significantly rewritten as a part of this work, the "Beavers/Cramer" report is referenced as "JEB (2010; 2011)" herein.

General Comments:

Comment 1: The chronology table indicates that DOE submitted a seismic hazard reevaluation proposal on 6/30/10 that received no response from KDWM. Neither David Ashburn nor I can find correspondence dated 6/30/10 regarding seismic issues.

Response 1: The reference to the hazard reevaluation proposal dated 6/30/10 was inadvertently included in the summary table (page A-11) of JEB (2010), Seismic Hazard Evaluation Report. The JEB (2010) reference has been revised as a part of this work, with the reference to the hazard reevaluation proposal dated 6/30/10 deleted. The revised report is further referenced as JEB (2010; 2011).

Comment 2: The predicted top-of-soil ground motions vary considerably between the Beavers/Cramer analysis and the Geosyntec analysis, principally because the Beavers/Cramer analysis includes Monte Carlo sampling which may not account for nonlinear soil effects. The application should be revised so that the sections are more consistent.

Response 2: The seismic site response analysis has been revised (i.e., the results of the Monte Carlo simulation have been deleted from JEB (2010; 2011) and its appendices. We note that a nonlinear (i.e., equivalent-linear frequency domain) site response analysis with computer code SHAKE2000 was performed as a part of Geosyntec (2012) study. The stability evaluations in Geosyntec (2012), including landfill composite liner and cover system evaluations and soil liquefaction potential evaluation, were based upon these nonlinear evaluations.

Comment 3: Attachment 2: The S1E and S2E scenario earthquakes are acceptable both in location and magnitude as reasonable, geologically defensible, scenario earthquakes for the site.

However, the local earthquake, S3E, lacks sufficient geological justification. The local scenario earthquake <u>should not</u> be chosen on the presumed frequency of the event as Section 3.2 of the Beavers Report suggests. Rather, it should be chosen as the local earthquake that is reasonably likely to cause the greatest expected earthquake ground motions at the site based upon the weight of the geological evidence, including local seismicity.

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In general, KDWM agrees that an M_w 5.5 local earthquake is a geologically defensible local MCE for PGDP. However, KDWM feels that the distance to the S3E earthquake is excessive because of recent seismicity in the immediate PGDP area. (The USGS earthquake database lists numerous recent local earthquakes as close as approximately 2.6 kilometers from the center of the C-746-U Landfill. When the uncertainty of calculating earthquake locations is considered, the C-746-U Landfill is potentially within the epicentral area.)

Response 3: We agree with this comment and have addressed it both in terms of the acceleration/duration and the fault rupture propagation hazards. The peak ground acceleration (PGA) calculations for a M_w 5.5 event at a distance of 2.5 km are included as scenario S4E in Appendix F of Geosyntec (2012) (mean value; bedrock; median value of calculations using 5 NGA attenuation relationships (Abrahamson et al. 2008). The calculated PGA value of 0.22 g is significantly lower that the controlling S1E (M_w 7.6 New Madrid Seismic Zone event) PGA value of 0.36 g and is hence dismissed from further considerations.

The fault rupture propagation and impact evaluations documented in Geosyntec (2012) demonstrate that a M_w 5.5 event at a distance of 2.5 km can be accommodated by the C-476-U Landfill composite liner and cover systems.

Comment 4: Attachment 2, Section 3.4: In the second line of the narrative, "January 13, 1812" should read "January 23, 1812". However, if the intent of the sentence is to say that the January 23, 1812 earthquake was the closest of the three main shocks to PGDP, the general consensus of scientific opinion is that this is not the case. Of the three main shocks of the 1811-1812 earthquake sequence, the February 7, 1812 event was closest to PGDP.

Additionally, clarify the differences between the M_s and M_w values referenced in Section 3.4 and those listed on the USGS website.

Response 4: The intent was to refer to the earthquake with the largest magnitude of this series of seismic events. The largest magnitude reported was used to evaluate acceleration hazard at the PGDP site. The site-to-source distance was measured from the closest approach of the postulated New Madrid fault plane to the geometric center of the PGDP site. This correction has been made in the revised JEB (2010; 2011) report.

The M_s values listed on the United States Geological Survey (USGS) Web site have been added to this section. The largest magnitude listed for the three events is M_s of approximately 7.7, which is less than the M_s 7.8 used as a maximum in the report.

Comment 5: Attachment 2, Appendix B: Monte Carlo sampling is not a method currently used in site-effect analysis for engineering design. The narrative should provide 1) the time histories from the scenario earthquakes and 2) SHAKE 2000 analysis.

Response 5: We concur. Monte Carlo sampling is not a method currently used in site-effect analysis for engineering design. The JEB (2010; 2011) report and its appendix have been edited and the analysis based upon the Monte Carlo sampling has been deleted.

The analyses documented in Geosyntec (2012) are based upon 1) the time histories from the scenario earthquakes; and 2) *SHAKE*2000 equivalent-linear site response analysis. The stability evaluations documented in Geosyntec (2012), including stability evaluations of landfill composite liner and cover systems and soil liquefaction evaluations, were based upon the *SHAKE*2000 analyses.

Comment 6: Attachment 3: The Commonwealth of Kentucky's administrative regulations specifically 401 KAR Chapters 47 and 48 govern the construction and operation of contained landfills in Kentucky.

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Remove references to Subtitle D from the narrative and replace them with references to the corresponding Kentucky Administrative Regulations.

Response 6: References to Subtitle D are removed from Sections 1.2 and 2.2 of the Geosyntec (2012) narrative. The appropriate references to the corresponding Kentucky Administrative Regulations have been cited.

Comment 7: Attachment 3, Section 6.1.2: On the weight of the waste issue and MSW vs. DOE wastes, even if the OII landfill waste was used, CDD [Construction Demolition Debris] characteristics vary significantly. For horizontal acceleration, the weight of DOE's wastes could be obtained from the Annual Survey and Cross-Section reports. It is unclear what effect this will have on the Static Deformation Analyses, p. 18.

Response 7: We were aware of the anticipated composition of DOE wastes; therefore, we have selected the OII waste as the model waste. We note that the OII waste includes relatively high percentage of CDD wastes and is characterized with a relatively high unit weight (85 to 100 pcf) as opposed to commonly used 65 pcf for municipal solid waste and with fairly linear (upper bound) modulus reduction curves. We further note that the use of high unit weight is conservative (force = mass x acceleration; larger the mass → larger the force), and that fairly linear modulus reduction curves typically result in larger acceleration response.

Geosyntec reviewed the 2008-2011 Annual Survey Reports for the C-746-U Landfill at the Paducah Gaseous Diffusion Plant. Those reports contain information of unit weight of waste actually disposed of in the subject landfill. The unit weight value γ_{MSW} of 59 pcf was evaluated by TetraTech, Inc., based upon the 2008-2009 survey records (reported in "Annual Survey Summary Sheet for Solid Waste Landfills," March 2009; attachment to the Annual Survey Report for the site). This value of γ_{MSW} does not, however, include the effects of long-term settlement, decomposition, and degradation of waste – processes that will ultimately increase the value of unit weight of material disposed of in the C-746-U Landfill.

Unit weight is an important parameter for static and seismic stability analysis of solid waste landfills. The higher the assumed unit weight, the more conservative the analysis is because the driving force is proportional with weight of sliding mass.

For stability evaluations of the subject landfill, Geosyntec assigned 85 lb/ft^3 to waste materials that will be disposed of in the landfill. This weight of waste materials corresponds to the conditions at the end of landfill life, when most of settlement, degradation, and decomposition has occurred and is, as noted above and compared to the measured values, conservative.

Comment 8: Attachment 3, Section 6: The key issue for plastic liner sliding is the friction coefficient. See the wedge diagram on page 14. This looks like Bob Koerner's equation form "Designing with Geosynthetics", even though he doesn't hold a patent on static and dynamic diagrams. If it is a layer of soil over the wastes, then use soil. If it is CDD, then these characteristics should be used. The friction coefficient would probably be lower. It would probably be better to get a geotextile down, and then put a foot or two of sacrificial dirt on top of the waste before constructing the cap. But, this is up to DOE and the design engineer.

Response 8: The wedge diagram on page 14 is from Koerner and Soong [1998] (similar diagram is in Koerner's book "Designing with Geosynthetics," but with no provision for a pseudostatic force). The calculations are for the interface with the lowest friction coefficient in the profile. By inspection, we established the interface between high density polyethylene (HDPE) geomembrane and compacted

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protective soil layer (layer above HDPE) as the interface with the lowest friction coefficient is. This interface is referred to herein as the "critical interface."

The results of our stability evaluations indicated that the originally proposed composite landfill cover design (40-mil smooth very low density polyethylene geomembrane/cushion geotextile) cannot meet the stability criteria established for the C-476-U Landfill. Therefore, we recommended that a 40-mil smooth geomembrane be replaced with a 60-mil double-textured HDPE geomembrane. The stability criteria are met for a composite cover configuration with a 60-mil double-textured HDPE geomembrane, as explained in Geosyntec (2012).

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Minor Permit Modification
for Solid Waste Permit Number 073-00045
(C-746-U Landfill),
Agency Interest Number 3059,
Activity ID Number APE20100007

February 2012

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ENERGY AND ENVIRONMENT CABINET

DEPARTMENT FOR ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT
200 FAIR OAKS LANE, SECOND FLOOR
FRANKFORT, KY 40601
TELEPHONE NUMBER 502-564-6716

STATE OF KENTUCKY
J. KEITH THORN
18809
LICENSED PROFESSIONAL ENGINEER
02/23/12

Application for a Minor Modification To a Formal Solid Waste Permit Form DEP 7017 (6/10)

Statutes and regulations may be viewed online at the following website address: http://www.lrc.ky.gov/search.htm
Solid waste application forms are available at the following website address: http://www.waste.ky.gov

DWM OFFICIAL USE ONLY

AI#: 3059 Application #: APE20100007

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COMMONWEALTH OF KENTUCKY
DEPARTMENT FOR
ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT

R. D. Lynch
SIGNATURE

BRANCH MANAGER
SOLID WASTE BRANCH
TITLE

MAR 30 2012
DATE

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GENERAL INSTRUCTIONS

1. **APPLICABILITY – This form must be completed and submitted to the Cabinet by persons who propose to apply for a minor modification of a formal permit.**

2. **ASSISTANCE – Questions regarding this form may be directed in writing to the Division of Waste Management (DWM), Solid Waste Branch at the address listed above, or by calling 502-564-6716.**

3. **SUBMISSION – Please type or print legibly in permanent ink. Submit the original and two (2) copies of the completed form to the DWM at the address listed above. If an item is not applicable, write "N/A" in the space provided.**

4. **FEES - Applicants must submit the appropriate filing fee at the time of application submittal in accordance with 401 KAR 47:090, Section 2.**

5. **LAWS AND REGULATIONS – Applicants are expected to understand and comply with all laws and regulations applicable to the facility.**

To assist you in the submittal of a complete and accurate application, the Division has identified the most common errors found during the review process. These errors are listed below for your convenience.

1. **Failure to provide the appropriate fee. See 401 KAR 47:090, Section 2. (6)(a).**

2. **Failure to complete the application.**

3. **Failure to comply with public notice requirements. See KRS 224.40-310 and 401 KAR 47:140, Section 7 for more information.**

4. **Failure to comply with Financial Assurance requirements. If the existing financial assurance is insufficient to fully cover current closure and post-closure costs, updates will be required.**

5. **Failure to properly sign and notarize the application. An individual with signature authority for the applicant as defined by KRS 224.01-010(44) and 401 KAR 47:160 must sign and notarize the appropriate signature sections of the application.**

6. **Failure to provide appropriate, fully completed attachments. Maps, drawings, narratives or any attachments that lack sufficient detail or drawings that are not signed, dated and sealed by a professional engineer or geologist may cause delays in the review and approval of the application.**

Warning! Due to the potential for identity theft, do not provide social security numbers to the DWM as part of this application. If this information is required during the normal course of review of the application, a cabinet representative will contact the appropriate individual to acquire this information in a secure format.

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Application for a Minor Modification to a Formal Solid Waste Permit

General Information

1. Agency Interest #: 3059 **2.** Permit #: 073-00045

3. Fee submitted: **4.** Check or Money Order #: NA

5. Method of payment:
- ☐ Check
- ☐ Money Order
- ☐ Cash
- ☒ Exempt (Publicly Owned Facility)

Applicant Information

6. Permittee Name: U.S. Department of Energy (DOE)
(This refers to the corporation, LLC, business, person, government agency, etc., that owns or operates the facility.)

7. Permittee Mailing Address: P.O. Box 1410

8. City: Paducah **9.** State: KY **10.** Zip Code: 42002-1410

11. Contact Person: Reinhard Knerr **12.** Title: Paducah Site Lead

13. E-mail Address: reinhard.knerr@lex.doe.gov

14. Phone #: (270) 441-6800 ext.

15. Cell #: **16.** Fax #: (270) 441-6801

Facility Information

17. Facility Name: U.S. Department of Energy Paducah Gaseous Diffusion Plant

18. County: McCracken

19. Facility Location: 5600 Hobbs Road
(Provide the street or physical location. Do not use P. O. Box #'s, etc.)

20. City: Kevil **21.** Zip Code: 42053

22. Facility Contact: Mark J. Duff **23.** Title: Paducah Project Manager

24. E-mail Address: mark.duff@lataky.com

25. Phone #: 270-441-5030 ext. NA

26. Fax #: 270-441-5022 **27.** Cell #: 270-816-5434

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Preparer Information

(Complete items 28 – 37 if the following information concerning the person preparing this application is different from the contact persons named in items 11 and 22.)

28. Preparers Name: **29.** Company:

30. Mailing Address:

31. City: **32.** State: **33.** Zip Code:

34. E-mail Address:

35. Phone #: ext.

36. Cell #: **37.** Fax #:

Attachments and Descriptions

38. Type of modification you are seeking:

- ☐ A vertical expansion of less than two (2) years
- ☐ A Groundwater Assessment Plan
- ☐ A Groundwater Corrective Action Plan
- ☐ A modification to the Groundwater or Surface Water Monitoring Plan
- ☐ A modification to the sediment pond design
- ☐ A modification to the alternate daily cover
- ☐ A modification to the leachate collection system
- ☐ A modification to the Closure Plan
- ☐ A modification to change the name of the owner or facility
- ☐ A modification to change the closure or post closure cost estimate
- ☐ A modification to change the permit boundary other than waste boundary
- ☒ Other (describe): Submittal of seismic information and modifications of drawings altering cap construction.

39. Provide, as **Attachment 1,** a detailed description of the permitting action you are seeking.

40. Provide, as **Attachment 2,** appropriate drawings, calculations, maps, cross-sections, etc.

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CONTENTS OF THE MODIFICATION REQUEST

ATTACHMENT 1—FORM DEP 7017 OVERVIEW OF THE MINOR MODIFICATION PERMIT REQUEST AND NOTICE OF DEFICIENCY RESPONSE WITH CHANGES TO TECHNICAL APPLICATION ATTACHMENT 1, 5, 16, 22, AND 26

Part 1 Overview of the Minor Modification

Part 2 Revised Technical Application Attachment 1, *Plans*, Technical Application Drawings to the C-746-U Landfill (4)

Part 3
A. Revised Technical Application Attachment 5, *Narrative of Design to Resist Seismic Events*, Clean Copy
B. Revised Technical Application Attachment 5, *Narrative of Design to Resist Seismic Events*, Redline Copy

Part 4
A. Revised Technical Application Attachment 16, *Leachate Collection System*, Clean Copy
B. Revised Technical Application Attachment 16, *Leachate Collection System*, (Replacement Pages Only), Redline Copy

Part 5
A. Revised Technical Application Attachment 22, *Construction Quality Control Plan*, Replacement Page A-22-8, Clean Copy
B. Revised Technical Application Attachment 22, *Construction Quality Control Plan*, Replacement Page A-22-8, Redline Copy

Part 6
A. Revised Technical Application Attachment 26, *Closure Cap Specifications*, Clean Copy
B. Revised Technical Application Attachment 26, *Closure Cap Specifications*, Redline Copy

ATTACHMENT 2—FORM DEP 7017 APPROPRIATE DRAWINGS, CALCULATIONS, MAPS, CROSS-SECTIONS, ETC.

Part 1 *Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*

Part 2 *Investigation of Holocene Faulting Proposed C-746-U Landfill Expansion Paducah Gaseous Diffusion Plant, Paducah, Kentucky*

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ATTACHMENT 1 TO FORM DEP 7017

OVERVIEW OF THE MINOR MODIFICATION PERMIT REQUEST AND NOTICE OF DEFICIENCY RESPONSE WITH CHANGES TO TECHNICAL APPLICATION ATTACHMENTS 1, 5, 16, 22, AND 26

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ATTACHMENT 1

PART 1

OVERVIEW OF THE MINOR MODIFICATION PERMIT REQUEST

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MODIFICATIONS TO THE C-746-U LANDFILL PERMIT AND TECHNICAL APPLICATION

This document is a request for a minor permit modification to the C-746-U Landfill solid waste permit. The modification requests approval of the enclosed reports and removal of the condition 5, Section ACTV0006, Variances, Alternate Specifications, and Special Conditions. The current permit condition reads as follows:

> No construction may begin on phases 6 thru 24 of the landfill until the seismic hazard reevaluation and fault study reports are approved by the Division. [401 *KAR* 47:120 § 2, 401 *KAR* 48:050 § 5, 401 *KAR* 48:070 § 3]

Your office issued a Notice of Deficiency (NOD) on October 27, 2010, associated with the submittal. The NOD gave directions for conducting the seismic hazard reevaluation, required a study to determine if the present landfill design can withstand the type of displacement and degree of offset a maximum predicted seismic event would administer, and required a permit modification of the landfill technical application and design to meet developed seismic criteria.

In preparation for the opening of Phases 6–23 of the C-746-U Landfill, the U.S. Department of Energy is submitting this request with an *Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant* by Dr. Neven Matasovic. Resubmitted unchanged for your convenience is the *Investigation of Holocene Faulting Proposed C-746-U Landfill Expansion, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, by The University of Kentucky Research Consortium for Energy and Environment that was submitted to your office July 21, 2010. After several iterations of these documents and through cooperative efforts with your office, finals of these documents are provided.

The permit modification request contains changes to 4 of the 51 drawings originally submitted as Technical Application Attachment 1. As a result of conducting the studies, Technical Application Attachment 5, *Narrative of Design to Resist Seismic Events*, was modified to include a description of the provided studies. Technical Application Attachment 16, *Leachate Collection System*, Technical Application Attachment 22, *Construction Quality Control Plan,* and Technical Application Attachment 26, *Closure Cap Specifications*, were modified to adjust the planned cap design because the seismic evaluation recommended replacement of the 40-mil smooth very low density polyethylene with a 60-mil, textured on both sides, high-density polyethylene geomembrane.

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ATTACHMENT 1

PART 2

REVISED TECHNICAL APPLICATION ATTACHMENT 1, *PLANS*, TECHNICAL APPLICATION DRAWINGS TO THE C-746-U LANDFILL (4)

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ATTACHMENT 1

TECHNICAL APPLICATION DRAWINGS

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DRAWING INDEX

SHEET NO.	DRAWING NO.	REV	TITLE
1 OF 51	C5E-59701-C10	B	ACCESS PLAN
2 OF 51	C5E-59701-C11	D	DRAWING INDEX AND CIVIL LEGEND
3 OF 51	C5E-59701-D10	B	SITE INFORMATION
4 OF 51	C5E-59701-E10	C	GENERAL LAYOUT/PHASE PLAN
5 OF 51	C5E-59701-F10	B	EXISTING TOPOGRAPHY PLAN - SHEET 1
6 OF 51	C5E-59701-F11	A	EXISTING TOPOGRAPHY PLAN - SHEET 2
7 OF 51	C5E-59701-F12	A	EXISTING TOPOGRAPHY PLAN - SHEET 3
8 OF 51	C5E-59701-F13	A	EXISTING TOPOGRAPHY PLAN - SHEET 4
9 OF 51	C5E-59701-F14	A	EXISTING TOPOGRAPHY PLAN - SHEET 5
10 OF 51	C5E-59701-F15	A	EXISTING TOPOGRAPHY PLAN - SHEET 6
11 OF 51	C5E-59701-F16	A	EXISTING TOPOGRAPHY PLAN - SHEET 7
12 OF 51	C5E-59701-F17	A	EXISTING TOPOGRAPHY PLAN - SHEET 8
13 OF 51	C5E-59701-G10	B	GENERAL SUBGRADE EXCAVATION PLAN
14 OF 51	C5E-59701-H10	B	SUBGRADE EXCAVATION PLAN - SHEET 1
15 OF 51	C5E-59701-H11	B	SUBGRADE EXCAVATION PLAN - SHEET 2
16 OF 51	C5E-59701-H12	B	SUBGRADE EXCAVATION PLAN - SHEET 3
17 OF 51	C5E-59701-H13	B	SUBGRADE EXCAVATION PLAN - SHEET 4
18 OF 51	C5E-59701-H14	B	SUBGRADE EXCAVATION PLAN - SHEET 5
19 OF 51	C5E-59701-H15	B	SUBGRADE EXCAVATION PLAN - SHEET 6
20 OF 51	C5E-59701-H16	B	SUBGRADE EXCAVATION PLAN - SHEET 7
21 OF 51	C5E-59701-I10	B	GENERAL DRAINAGE LAYER PLAN
22 OF 51	C5E-59701-J10	B	DRAINAGE LAYER PLAN - SHEET 1
23 OF 51	C5E-59701-J11	B	DRAINAGE LAYER PLAN - SHEET 2
24 OF 51	C5E-59701-J12	B	DRAINAGE LAYER PLAN - SHEET 3
25 OF 51	C5E-59701-J13	B	DRAINAGE LAYER PLAN - SHEET 4
26 OF 51	C5E-59701-J14	B	DRAINAGE LAYER PLAN - SHEET 5
27 OF 51	C5E-59701-J15	B	DRAINAGE LAYER PLAN - SHEET 6
28 OF 51	C5E-59701-J16	B	DRAINAGE LAYER PLAN - SHEET 7
29 OF 51	C5E-59701-K10	B	GENERAL FINAL GRADING PLAN
30 OF 51	C5E-59701-L10	B	FINAL GRADING PLAN - SHEET 1
31 OF 51	C5E-59701-L11	B	FINAL GRADING PLAN - SHEET 2
32 OF 51	C5E-59701-L12	B	FINAL GRADING PLAN - SHEET 3
33 OF 51	C5E-59701-L13	B	FINAL GRADING PLAN - SHEET 4
34 OF 51	C5E-59701-L14	B	FINAL GRADING PLAN - SHEET 5
35 OF 51	C5E-59701-L15	B	FINAL GRADING PLAN - SHEET 6
36 OF 51	C5E-59701-L16	B	FINAL GRADING PLAN - SHEET 7
37 OF 51	C5E-59701-P10	B	STORM DRAIN PROFILES
38 OF 51	C5E-59701-Q10	B	CROSS SECTIONS - SHEET 1
39 OF 51	C5E-59701-Q11	B	CROSS SECTIONS - SHEET 2
40 OF 51	C5E-59701-Q12	B	CROSS SECTIONS - SHEET 3
41 OF 51	C5E-59701-Q13	B	CROSS SECTIONS - SHEET 4
42 OF 51	C5E-59701-Q14	B	CROSS SECTIONS - SHEET 5
43 OF 51	C5E-59701-Q15	B	CROSS SECTIONS - SHEET 6
44 OF 51	C5E-59701-Q16	B	CROSS SECTIONS - SHEET 7
45 OF 51	C5E-59701-Q17	B	CROSS SECTIONS - SHEET 8
46 OF 51	C5E-59701-Q18	B	CROSS SECTIONS - SHEET 9
47 OF 51	C5E-59701-S10	C	CONSTRUCTION DETAILS - SHEET 1
48 OF 51	C5E-59701-S11	B	CONSTRUCTION DETAILS - SHEET 2
49 OF 51	C5E-59701-S12	B	CONSTRUCTION DETAILS - SHEET 3
50 OF 51	C5E-59701-S13	C	CONSTRUCTION DETAILS - SHEET 4
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APPROVED
MAR 30 2012

ABBREVIATIONS

CMP	CORRUGATED METAL PIPE
CONC	CONCRETE
EL	ELEVATION
F.B.	FLAT BOTTOM
H.P.	HIGH POINT
I.E.	INVERT ELEVATION
L.F.	LINEAR FOOT
L.P.	LOW POINT
MON	MONUMENT
MIN	MINIMUM
NO.	NUMBER

CIVIL LEGEND

EXISTING		NEW
350	CONTOURS	350
351.26	SPOT ELEVATION	351.26
	BUILDING	
X	BOUNDARY FENCE	X-X
	TREE LINE	
N 6500.00 W 3000.00	COORDINATES	N 6500.00 W 3000.00
N.A.	LIMITS OF WASTE	
N.A.	INTERIOR PHASE LIMITS	
N.A.	PERMIT BOUNDARY	
N.A.	FUTURE BORROW AREA	
	EASEMENT	N.A.
	GRAVEL ROAD	
	ASPHALT PAVEMENT	
N.A.	ROAD CENTERLINE	
	GUARD POST	
	CULVERT WITH WINGWALLS	N.A.
SD	STORM DRAIN	SD
N.A.	LEACHATE PIPE	LP
	CONCRETE MONUMENT	
N.A.	HYDRANT	
N.A.	GAS VENT	
N.A.	LEACHATE CLEANOUT ACCESS	
MW-271	MONITORING WELL	N.A.
	EPHEMERAL SWALE/DITCH	
	INTERMITTENT STREAM	N.A.
N.A.	SIGN	
N.A.	RIPRAP	
N.A.	CONCRETE	
	SOIL BORING LOCATION	N.A.
N.A.	METHANE GAS MONITORING PROBE	MG-3
	SURFACE WATER MONITORING POINT	SW-3
N.A.	GROUND SLOPE	S
N.A.	BASE LINE	
N.A.	TRANSIT LINE	
	PIEZOMETER	N.A.

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Division of Waste Management
Solid Waste Branch

THE ORIGINAL DRAWING AND SUBSEQUENT REVISIONS THEREOF, WITH APPROVAL NAMES, INITIALS, DATES AND WITH THE PE SEAL, IF APPLICABLE, ARE MAINTAINED IN THE FILES OF ERWM DOCUMENT CONTROL.

C5E-59701-C11

NUMBER OF SECTION OR DETAIL
DRAWING ON WHICH SECTION OR DETAIL IS TAKEN
DRAWING ON WHICH SECTION OR DETAIL IS SHOWN
SECTION AND DETAIL KEY

THIS DOCUMENT CONTROLLED BY
CHANGE CONTROL SYSTEM 2
ENGINEERING PROCEDURE EP-C-18

REV.	DATE	DESCRIPTION	DRAWN BY	PROJ ENGR	PROJ MGR	LEAD ENGR	CONF CTRL/ NUC. SFTY	FAC ENG	DATA MGR	Doc CONT
△	/ /									
△	/ /									
D	2/18/2011	TECHNICAL APPLICATION - ISSUED FOR KDWM REVIEW	NDH	JKT	JKT	JKT	SBM	CLA	RES	DLA

DRAWING REVISIONS

REV	CHANGE TYPE	CONTROL SYSTEM	CHANGE NUMBER	DESCRIPTION	BY	CHK	SECT	DEPT	DATE	PE	REG	DATE	MMES	DATE	RPE	RPE NO	DATE	CLASS	DATE	DA	DATE	ST	CV	EC	EE	EM	IE	M	PD	SI	ARC	VER
C				TECHNICAL APPLICATION - ISSUE FOR KDWM REVIEW	DRS	JLC	-	JLC	8/1/94													-	DRS	-	-	-	-	-	-	-	-	-
B				TECHNICAL APPLICATION - ISSUE FOR KDWM REVIEW	JCM	WLC	-	WLC	8/25/94	JKT	GSV	8/26/94	JWD/BE	8/26/94								-	DRS	-	-	-	-	-	-	-	-	-
A				TECHNICAL APPLICATION - ISSUE FOR CLIENT REVIEW	JMK	WLC	-	WLC	7/7/94	JKT	GSV	7/8/94	JWD/BE	7/8/94								-	DRS	-	-	-	-	-	-	-	-	-

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK

LPE

ORIGINAL PE STAMP ON FILE
J. KEITH THORN
15809
DATE 2/21/2011
PROFESSIONAL SEAL

DES	D R SMITH	8/25/94
DRW	J MCKINNEY	8/25/94
CHK	W L CROWDER	8/25/94
SECT	-	
DEPT	W L CROWDER	8/25/94
PE	J K THORN	8/26/94
PJ	K L HOLT	8/26/94
REG	G S VANDER BOEGH	8/26/94
A-E		
MMES	J W DOUTHITT/GW MONIT	8/26/94
	D R GUMINSKI/ENV COMP	8/26/94

DRAWING APPROVALS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

[redacted]

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
SOLID WASTE LANDFILL, PGDP

TITLE:
DRAWING INDEX AND CIVIL LEGEND

SHEET 2 OF 51

EDCS CAD FILENAME	BUILDING	PLANT	CLASS
C5E-59701-C11 REV D.DGN	AREA	PGDP	U

SCALE:	TYPE	DRAWING NUMBER	REV
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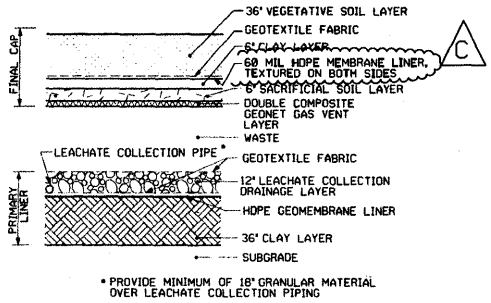
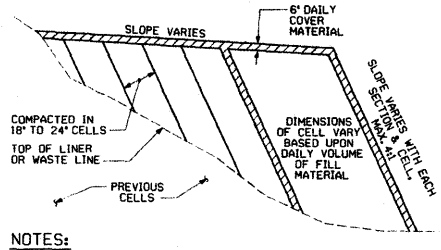


* PROVIDE MINIMUM OF 18" GRANULAR MATERIAL OVER LEACHATE COLLECTION PIPING

GENERAL LANDFILL CROSS-SECTION

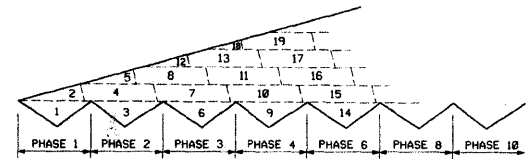


NOTES:

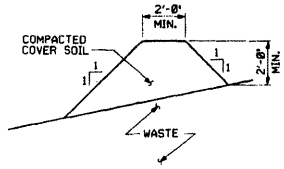
1. INTERIM COVER: IN AREAS WHERE NO DISTURBANCE ON THE DAILY COVER WILL BE MADE FOR A PERIOD OF THIRTY (30) DAYS, IT SHALL BE INCREASED TO A MINIMUM OF TWELVE (12) INCHES.
2. LONG TERM COVER: IN AREAS WHERE NO DISTURBANCE ON THE INTERIM COVER WILL BE MADE WITHIN FOUR (4) MONTHS BY SEPTEMBER OF EACH YEAR, IT SHALL BE INCREASED TO A MINIMUM OF THIRTY (30) INCHES.

TYPICAL LEVELING AND STANDARD CELL

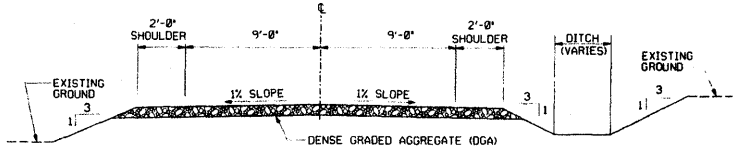
DETAIL 1
NOT TO SCALE
S10 S10



TYPICAL SECTION PHASE CONSTRUCTION SEQUENCE



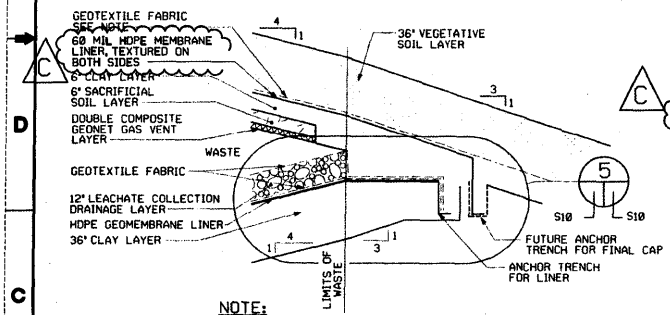
TEMPORARY RUNOFF BERM



PERIMETER ROAD

DETAIL 2
NOT TO SCALE
S10

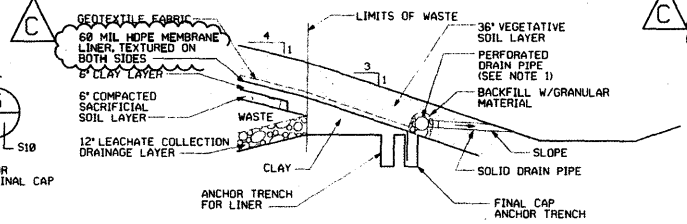
AS APPROVED MAR 30 2012



NOTE:
FOR FINAL CAP, WHERE SLOPES ARE LESS THAN 15% A DOUBLE COMPOSITE GEONET IS REQUIRED INSTEAD OF THE GEOTEXTILE.

TYPICAL LINER/CAP ARRANGEMENT

DETAIL 3
NOT TO SCALE
L10 L14
L11 L15
L12 L16
L13
S10

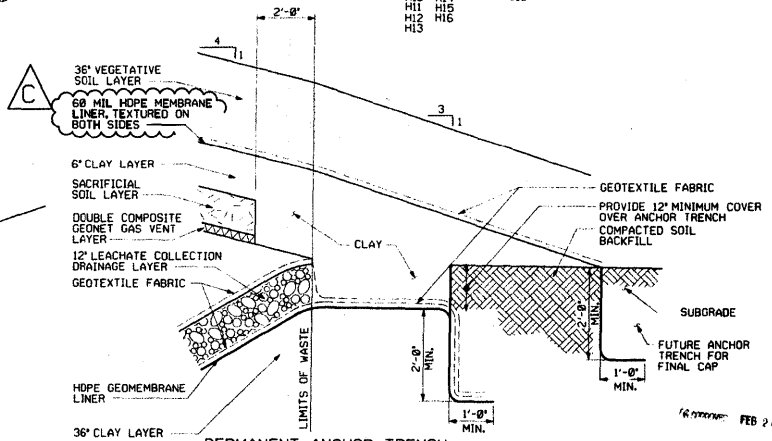


NOTES:

1. PERFORATED HDPE PIPE SHALL BE BACKFILLED WITH AGGREGATE AND WRAPPED W/GEOTEXTILE FABRIC.

EDGE DRAIN FOR CAP

DETAIL 4
NOT TO SCALE
S10 S10



PERMANENT ANCHOR TRENCH

DETAIL 5
NOT TO SCALE
S10 S10

FEB 26 1993

REV.	DATE	DESCRIPTION	DRAWN BY	CHECK BY	PROJ ENGR	LEAD ENGR	CONF CTRL/ HAZL DPTY	PAC MGR	ENTR MGR	DIV CHIEF
	/ /									
	/ /									
	/ /									
A	2/18/2011	TECHNICAL APPLICATION - ISSUED FOR KDWM REVIEW	HDH	JKT	JKT	JKT	SBM	CLA	RES	DLA

DRAWING REVISIONS

REV	DESCRIPTION	BY	CHK	SECT	DEPT	DATE	PE	REG	DATE	NMES	DATE	RPE	RPE NO	DATE	CLASS	DATE	QA	DATE
B	TECHNICAL APPLICATION - ISSUE FOR KDWM REVIEW	JCM	WLC	-	WLC	8/15/94												
A	TECHNICAL APPLICATION - ISSUE FOR CLIENT REVIEW	JMK	WLC	-	WLC	7/7/94												

REVISION OR ISSUE PURPOSE — REVISION APPROVALS

ST	CV	EC	EE	EM	IE	M	PD	RE	ARC	VER
-	CVD	-	-	-	-	-	-	-	-	-
-	DRS	-	-	-	-	-	-	-	-	-

SQUAD CHECK

NUMBER OF SECTION OR DETAIL — DRAWING ON WHICH SECTION OR DETAIL IS TAKEN — DRAWING ON WHICH SECTION OR DETAIL IS SHOWN

SECTION AND DETAIL KEY

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CHANGE CONTROL SYSTEM 2
ENGINEERING PROCEDURE EP-C-18

LPE
ORIGINAL PE STAMP ON FILE
J. KEITH THORN
18809
DATE 2/21/2011
PROFESSIONAL SEAL

DES		8/15/94
DRW	J.C. McKinney	8/15/94
CHK		8/15/94
SECT	—	
DEPT		8/15/94
PE		9/9/94
PJ		9/9/94
REG		9/9/94
A-E		
NMES		9/14/94

DRAWING APPROVALS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

[redacted]

Managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

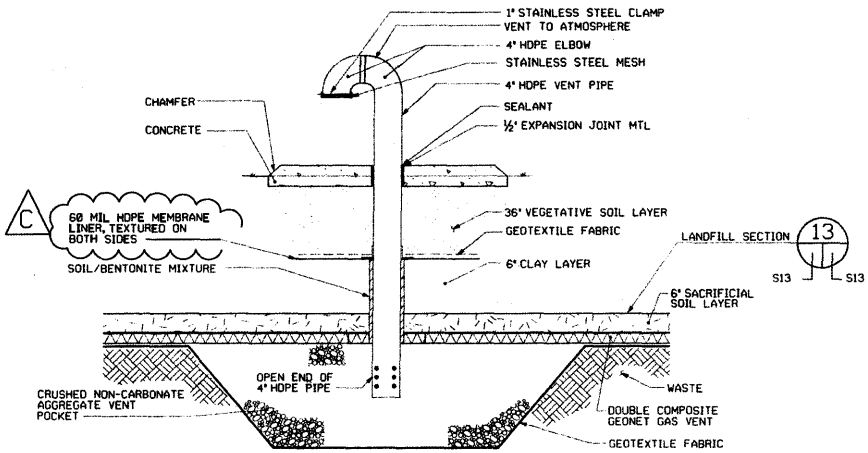
PROJECT NAME:
SOLID WASTE LANDFILL, PGDP

TITLE:
CONSTRUCTION DETAILS
SHEET 1

SHEET 47 OF 51

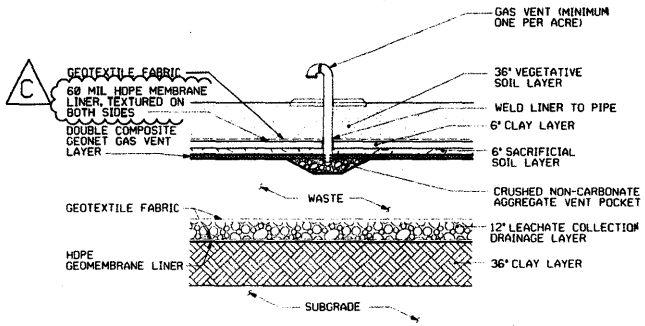
EDCS CAD FILENAME	BUILDING AREA	PLANT	CLASS
C5E-59701-S10 REV C.DGN		PGDP	U

SCALE	TYPE	DRAWING NUMBER	REV
NOT TO SCALE	S	C5E-59701-S10	C



TYPICAL GAS VENT SECTION

DETAIL 12
NOT TO SCALE
L10 L12 L14 L16 S13



LANDFILL SECTION

DETAIL 13
NOT TO SCALE
S13 S13

AS APPROVED

MAR 30 2012

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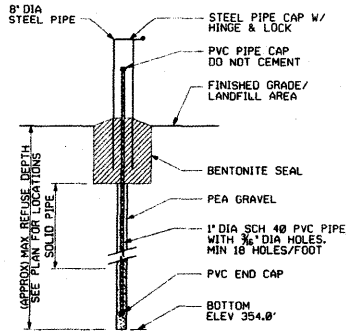
MAR 08 2012
Division of Waste Management
Solid Waste Branch



NOTES:

1. ALL PVC MATERIALS TO BE SCHEDULE 40.
2. PAINT EXPOSED STEEL CAP YELLOW.

METHANE GAS MONITORING PROBE

DETAIL 14
NOT TO SCALE
H10 H11 H16 S13

NUMBER OF SECTION OR DETAIL — DRAWING ON WHICH SECTION OR DETAIL IS TAKEN — DRAWING ON WHICH SECTION OR DETAIL IS SHOWN
SECTION AND DETAIL KEY

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CHANGE CONTROL SYSTEM 2
ENGINEERING PROCEDURE EP-C-18

REV.	DATE	DESCRIPTION	DRAWN BY	DIRECT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	SBH	CLA	RES	DLA
△	/ /										
△	/ /										
△	/ /										
△	2/18/2011	TECHNICAL APPLICATION - ISSUED FOR KDWM REVIEW	HDH	JKT	JKT	JKT	SBH	CLA	RES	DLA	

DRAWING REVISIONS

REV	PROJECT REV			DESCRIPTION	BY	CHK	SECT	DEPT	DATE	PE	REG	DATE	MMES	DATE	RPE	RPE NO	DATE	CLASS	DATE	QA	DATE	ST	CV	EC	EE	EM	IE	M	PD	SE	ARC	VER
B				TECHNICAL APPLICATION - ISSUE FOR KDWM REVIEW	JCM	WLC	-	WLC	11/21/08													-	CVL	-	-	-	-	-	-	-	-	-
A				TECHNICAL APPLICATION - ISSUE FOR CLIENT REVIEW	JMK	WLC	-	WLC	2/7/08													-	DRS	-	-	-	-	-	-	-	-	-

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SOUND CHECK

LPE

ORIGINAL PE STAMP ON FILE
J. KEITH THORN
88805
DATE 2/21/2011
PROFESSIONAL SEAL

DES	[illegible]	8/2/09
DRW	[illegible]	8/26/09
CHK	[illegible]	8/26/09
SECT	—	
DEPT	[illegible]	8/26/09
PE	[illegible]	8/26/09
PJ	[illegible]	8/26/09
REG	[illegible]	[illegible]
A-E		
MMES	[illegible]	8/26/09

DRAWING APPROVALS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

[redacted]

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: SOLID WASTE LANDFILL, PGDP

TITLE: CONSTRUCTION DETAILS SHEET 4

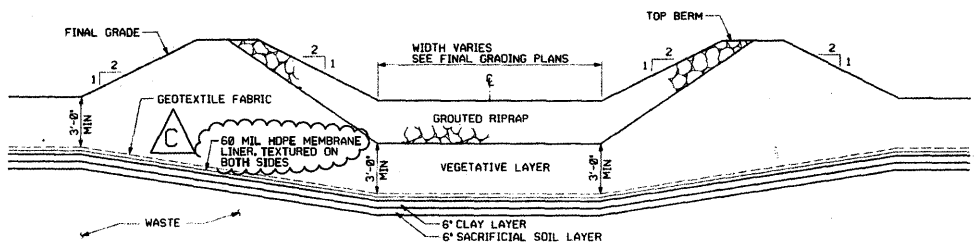
SHEET 50 OF 51

EDCS CAD FILENAME	BUILDING AREA	PLANT	CLASS
C5E-59701-S13 REV C.DGN		PGDP	U

SCALE	TYPE	DRAWING NUMBER	REV
NOT TO SCALE	S	C5E-59701-S13	C

NOTES:

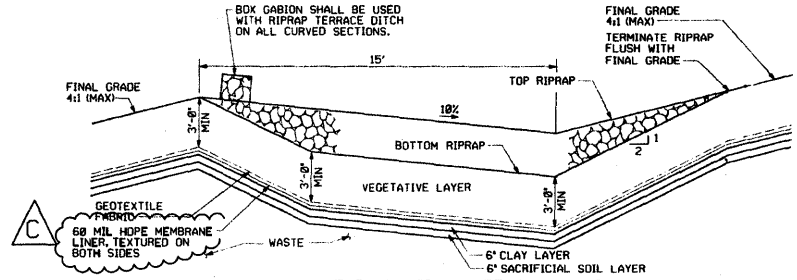
1. COMPOSITE GEONET GAS VENT LAYER SHOWN FOR CLARITY. SEE DETAILS.



TYPICAL CONVEYANCE DITCH

DETAIL 15
NOT TO SCALE

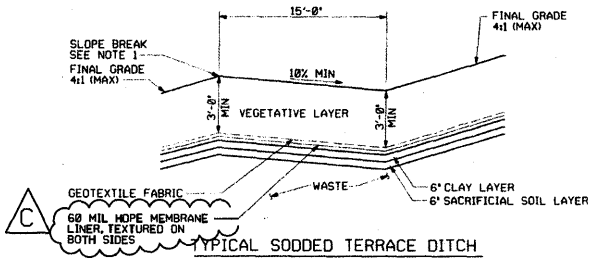
L10 L12 L14 L15 L16 S14



TYPICAL RIPRAP TERRACE DITCH

DETAIL 16
NOT TO SCALE

L10 L11 L12 L14 L16 S14



TYPICAL SODDED TERRACE DITCH

DETAIL 17
NOT TO SCALE

L10 L11 L12 L13 L14 L16 S14

AS APPROVED MAR 3 0 2012

NUMBER OF SECTION OR DETAIL — DRAWING ON WHICH SECTION OR DETAIL IS TAKEN — DRAWING ON WHICH SECTION OR DETAIL IS SHOWN

SECTION AND DETAIL KEY

THIS DOCUMENT CONTROLLED BY
CHANGE CONTROL SYSTEM 2
ENGINEERING PROCEDURE EP-C-18

REV.	DATE	DESCRIPTION	DRAWN BY	CHKD BY	SECT	LEAD ENGR	CHIEF CIVIL/ MECH. ENGR	PROJ MGR	ENGR MGR	DIV COMP
△	/ /									
△	/ /									
△	/ /									
A	2/18/2011	TECHNICAL APPLICATION - ISSUED FOR KDWM REVIEW	HDH	JKT	JKT	JKT	SBM	CLA	RES	DLA

DRAWING REVISIONS

REV	DESCRIPTION	BY	CHK	SECT	DEPT	DATE	PE	REQ	DATE	NMES	DATE	APE	APE NO	DATE	CLASS	DATE	QA	DATE	ST	CV	EC	EE	EM	IE	M	PD	SE	ARC	VER
B	TECHNICAL APPLICATION - ISSUE FOR KDWM REVIEW	JCA	JLL	-	JLL	8/10/94													-	CVL	-	-	-	-	-	-	-	-	-
A	TECHNICAL APPLICATION - ISSUE FOR CLIENT REVIEW	JHK	WLC	-	WLC	7/7/94													-	DRB	-	-	-	-	-	-	-	-	-

REVISION OR ISSUE PURPOSE — REVISION APPROVALS — SQUAD CHECK

LPE

ORIGINAL PE STAMP ON FILE

J. KEITH THORN
16803

DATE 2/20/2011

PROFESSIONAL SEAL

DES	CVL	8/26/94
DRW	JC McWaters	8/26/94
CHK		8/26/94
SECT	—	
DEPT		8/26/94
PE		8/26/94
PM		8/26/94
REQ		8/26/94
A-E		
NMES		3/4/09

DRAWING APPROVALS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

[redacted]

prepared for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: SOLID WASTE LANDFILL, PGDP

TITLE: CONSTRUCTION DETAILS SHEET 5

SHEET 51 OF 51

EDCS CAD FILENAME	BUILDING	PLANT	CLASS
C5E-59701-S14 REV C.DGN	AREA	PGDP	U

SCALE	TYPE	DRAWING NUMBER	REV
NOT TO SCALE	S	C5E-59701-S14	C

ATTACHMENT 1

PART 3A

REVISED TECHNICAL APPLICATION ATTACHMENT 5, *NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS*

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Solid Waste Branch

SOLID WASTE LANDFILL
TECHNICAL APPLICATION

ATTACHMENT 5—NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS

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ATTACHMENT 5

NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS

The C-746-U Landfill (site) is located within a seismic impact zone as defined by 40 *CFR* § 258.14. These federal regulations state that the horizontal acceleration to be used in the seismic analysis shall correspond to a bedrock acceleration that has a ninety (90) percent probability of not being exceeded in two hundred and fifty (250) years or the maximum expected horizontal accelerations based on a site-specific risk assessment. The seismic hazard maps that accompany these federal regulations indicate that the maximum horizontal acceleration in bedrock at the site (PHGA) is approximately 0.40g. This PHGA value is consistent with its counterpart established based upon a site-specific *Seismic Hazard Evaluation for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* by Risk Engineering Inc. (1993). This PHGA was a basis for thus far designed and constructed containment structures, liners, leachate collection system, and surface water control systems at the site.

The C-746-U Landfill itself has been designed to accommodate seismically induced lateral forces by considering slip surfaces that pass through waste mass and/or along landfill composite liner and cover systems. The critical slip surfaces (one for liner and one for cover) were established through static and pseudo-static limiting equilibrium evaluations by SLOPE/W. The corresponding stability evaluation report may be found in *Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Geosyntec report 2012). The sedimentation pond has been designed in like manner.

The slopes on the embankments for the landfill containment structures have been evaluated and are designed to provide resistance to seismic forces with a factor of safety as indicated in the calculations in Geosyntec report 2012.

The slopes for the sedimentation basins have been evaluated and are designed to provide resistance to seismic forces with a factor of safety as indicated in the calculations within this attachment.

The high-density polyethylene (HDPE) component of landfill composite base liner system has been specified as textured to provide increased frictional resistance to both statically induced and seismic forces.

The leachate collection system and piping supports have been designed to function when subjected to any deformations induced by settlement resulting from seismic events or other design forces.

The leachate collection material has been selected to provide an angle of internal friction greater than or equal to that evaluated in the design calculations in Geosyntec report 2012.

In response to a request by Kentucky Division of Waste Management (KDWM), a Deterministic Seismic Hazard Assessment (DSHA) was performed by James E. Beavers Consultants (JEBc) (2010). JEBc considered three representative earthquake scenarios for the area to establish the controlling seismic event for seismic design, but also a local seismic event for a fault rupture propagation study. The controlling event for seismic design other than fault rupture propagation study was established as a Moment Magnitude M_w 7.6 event on the New Madrid Fault with a PHGA of 0.36 g. The local seismic event for fault rupture propagation study was established as a M_w 6.0 event directly beneath the site. The seismic evaluations based upon the deterministically evaluated seismic hazard parameters were conducted by Geosyntec (2012). These evaluations consisted of the following:

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- Establish by reference the largest local scenario earthquake that reasonably could be expected beneath the site;

- Evaluate whether a displacement associated with local scenario earthquake can be propagated from the seismogenic depth to the surface assuming normal, dip-slip faulting;

- Demonstrate that displacement from the local scenario earthquake cannot propagate to the surface;

- Demonstrate that the present landfill design can withstand the type and magnitude of displacement that can be expected from the largest local scenario earthquake; and

- Provide recommended design modifications necessary to enable the landfill containment systems to withstand the predicted ground motions form the largest scenario earthquake.

The results of seismic evaluations by Geosyntec (2012) indicate that, with the exception of the C-746-U Landfill composite final cover system, the landfill, as presently designed, will perform in an acceptable manner during a deterministically determined design earthquake. The composite cover system, if modified, will perform in an acceptable manner as well. In particular, the results of seismic evaluations indicate that seismically induced deformations of the composite landfill base liner and cover systems will be small, that the potential for soil liquefaction at the C-746-U Landfill is low, and that even an extreme fault movement directly below the C-746-U Landfill will be absorbed by an approximately 400-ft thick layer of alluvium. The results of seismic evaluations further indicate that the impact of design earthquake motions and fault movement on ancillary facilities, including leachate and surface water collection systems, will be small, provided that the tanks are bolted properly into the foundations.

The originally specified 40-mil very low density polyethylene geomembrane of the composite landfill cover system will be replaced with a textured (both sides) 60-mil thick HDPE geomembrane.

The assumed composite landfill cover interface properties (i.e., properties assumed along the 60-mil thick double textured HDPE geomembrane/geotextile interface) (residual friction angle = 18 degrees; apparent adhesion = 100 psf) require confirmation during construction. This confirmation is accomplished by interface testing of representative material samples by an accredited soil-geosynthetic interface testing laboratory.

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ATTACHMENT 1

PART 3B

REVISED TECHNICAL APPLICATION ATTACHMENT 5, *NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS*

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ATTACHMENT 5

NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS

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SOLID WASTE LANDFILL
TECHNICAL APPLICATION

ATTACHMENT 5—NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS

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ATTACHMENT 5

NARRATIVE OF DESIGN TO RESIST SEISMIC EVENTS

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- Establish by reference the largest local scenario earthquake that reasonably could be expected beneath the site;
- Evaluate whether a displacement associated with local scenario earthquake can be propagated from the seismogenic depth to the surface assuming normal, dip-slip faulting;
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ATTACHMENT 1

PART 4A

REVISED TECHNICAL APPLICATION ATTACHMENT 16, *LEACHATE COLLECTION SYSTEM*

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ATTACHMENT 16

LEACHATE STORAGE TANKS
REPLACEMENT OF HELP MODEL

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ATTACHMENT 16

LEACHATE COLLECTION SYSTEM

The leachate collection system will consist of a 12-inch drainage layer or its equivalent, with a permeability of not less than 1×10^{-2} cm/sec. The system utilizes 8-inch diameter perforated pipe for the main collection lines. These lines shall slope a minimum of 1 percent toward the leachate collection system. The landfill liner will be graded with a "sawtooth" pattern, with one collection line running the length of the valley formed by the "sawtooth." The minimum bottom slope for the liner will be 10 percent; therefore, no lateral lines will be required. The spacing of the collection lines will allow leachate to sheet-flow a distance of less than 50 feet. The Hydrologic Evaluation of Landfill Performance (HELP) model calculations found in Appendix B of this submittal will verify that the configuration of the leachate collection system will not result in a hydraulic head in excess of 1 foot or the thickness of the drainage layer. The leachate will be gravity-piped to the appropriate storage tanks as described in this Attachment.

The initial HELP model calculations conducted in 1994 predicted that 32,500 gallons of storage would be required for storing 15 days of leachate at project peak production rates for Phases 1–23. In 2008, the estimated volume of leachate production for each phase was recalculated using the most current version of the HELP model. The output of the new HELP model runs for various operating conditions is included in Appendix B of this submittal.

Two 31,000-gallon leachate storage tanks were initially constructed for storing 15 days of leachate at projected peak production rates for Phases 1–23. The two leachate collection tanks are above grade steel tanks with secondary containment. The leachate collection and storage facilities are designed to allow for the installation of additional portable or permanent tank(s), as dictated by the anticipated need for the phases being served. If needed, additional collection tanks will be constructed from a material that is acceptable for storing leachate, such as steel, fiberglass, plastic, or glass-lined steel. As a result of a 2006 HELP model run, for Phases 4–5, additional tank capacity of 7,000 gallons now is on-site and will be installed. Installation of these tanks will result in approximately 69,000 gallons of leachate storage. The tanks are plastic, dual-wall, contained storage tanks to be housed inside the landfill's leachate treatment building. The 2008 HELP model predicts the 15-day storage capacity for opening Phases 4–5 will require approximately 19,000 gallons of additional storage capacity (88,000 gallons total capacity required). Approximately 40,000 gallons of additional leachate storage will be added to meet projected needs for Phases 4–5. This will result in approximately 109,000 gallons of leachate storage capacity and a 24 percent contingency for leachate storage.

Based on the 2008 HELP model, the maximum 15-day leachate storage volume needed to accommodate the projected maximum required leachate storage volume inclusive of all 23 phases is approximately 200,000 gallons. This volume is calculated to be generated when Phases 14/15 are active and Phases 1–13 are under long-term cover. See Attachment A of the HELP model (Appendix B) with projected leachate generation during each landfill phase throughout the life of the landfill. When construction is initiated to add liner and leachate collection to Phases 6–11, a leachate storage tank facility to accommodate future leachate tanks (up to 110,000 gallons) will be constructed. Conceptual design drawings in Appendix A—C7DC7460UA001, Rev. 2; C7DC7460UA003, Rev. 4; and C7DC7460UA002, Rev. 2—illustrate tanks sized to accept the approximately 200,000 gallons of leachate predicted in the 2008 HELP model for Phases 1–23. As the landfill expands from phase to phase, tanks will be added to the system to assure capacity is greater than HELP model projections. Attachment 16, Appendix B, HELP Model, *C-746-U*

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Landfill Leachate Generation-Tank Installations, presents the planned construction of additional leachate storage tanks in advance of projected leachate generation.

Additional tanks will be sized and specified to assure the tanks are constructed of materials that are compatible with the nature of the leachate, and that they will contain and have the durability and integrity to contain the stored liquid for the active life of the site including closure care. Dual contained tanks (tanks with inner and outer walls where the outer wall acts as secondary containment if a leak were to occur in the inner wall of the tank or tanks that have an outer physical barrier that provides secondary containment) will be inspected periodically for integrity. The specific construction and installation details will be contained in the Notice to Construct that will be provided to the Environmental and Public Protection Cabinet prior to construction of phases needing leachate storage capacity.

Leachate collected will be pumped from the tanks and disposed of by recirculating, treated in a permitted wastewater treatment facility, treated in the on-site leachate treatment facility, discharged to surface water in accordance with the Kentucky Pollutant Discharge Elimination System Permit, or managed through another approved treatment/disposal method. The recirculation option, if selected, will occur in a previously filled area where the final cap has not been constructed. Factors that would affect the type of disposal utilized are the weather at the time of collection and analysis of the leachate collected.

A log will be maintained by the landfill operator for the amount of leachate pumped from the tanks. An example of a log to be maintained is found in Appendix C of this Attachment. The volume of leachate shall be reported on the leachate log and shall represent quantities removed for disposal, treatment, or discharge, as described herein.

A visual inspection of the tanks and piping system will be conducted at least every two weeks to verify the integrity of the tanks. Maintenance to the tanks and piping system will be performed by the U.S. Department of Energy or its contractors on an as-needed basis.

At such time when the tanks will be removed from service, they will be decommissioned, cleaned, and transferred to a salvage/recycling facility, stored to prevent reuse, or disposed of in a landfill.

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APPENDIX A
TO REVISED ATTACHMENT 16

Engineering Plans and Drawings

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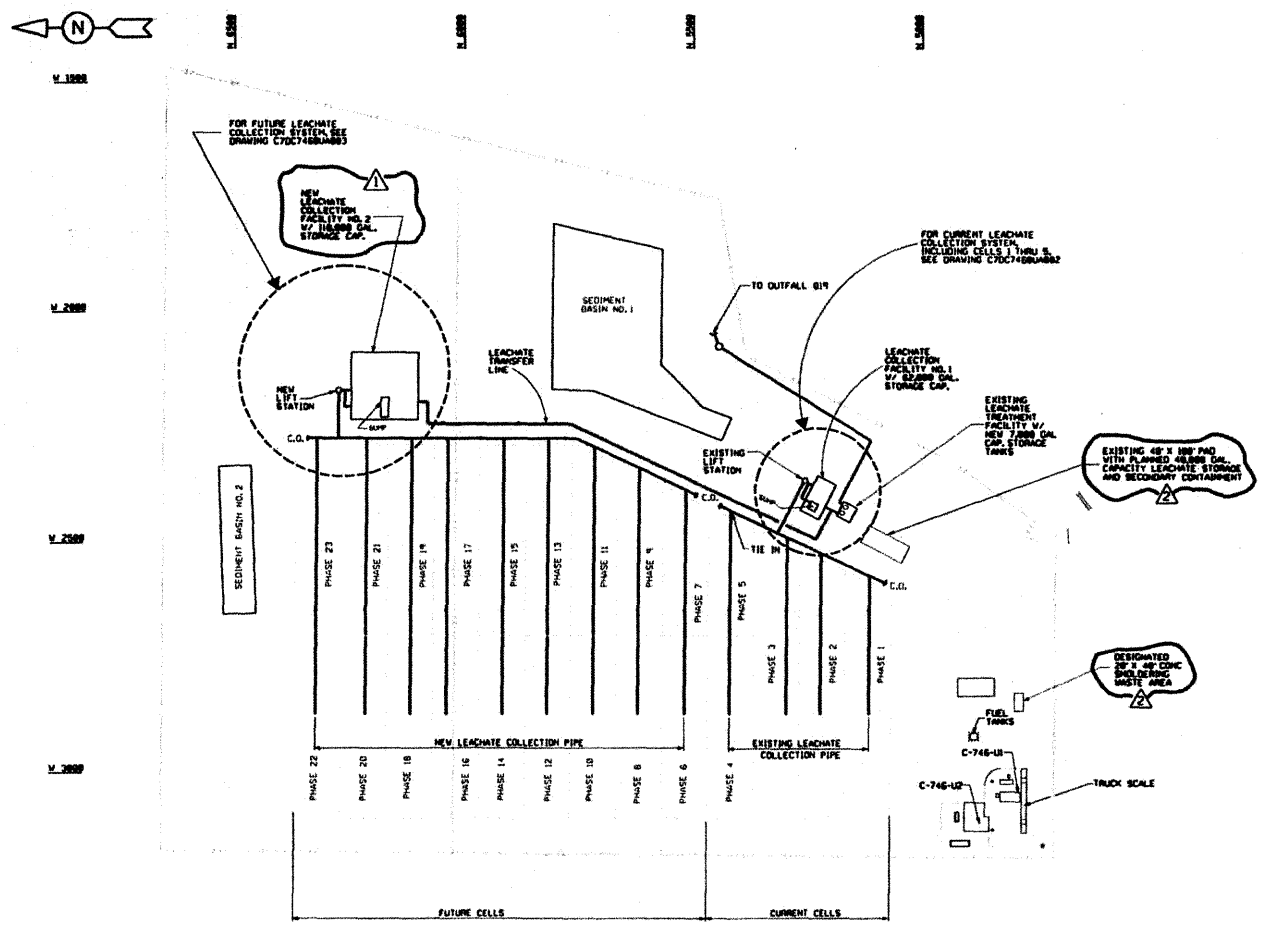

SITE PLAN

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SCALE: 1"=125'

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2	6/13/07	REVISED FOR KDWM HOD-3 REQUIREMENTS	JWP	---	DLA	---	KLH	---	---	---	PEC
1	4/16/07	ISSUED FOR KDWM APPROVAL	JWP	---	DLA	---	KLH	---	---	---	PEC

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U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

PADUCAH Remediation Services
A Portsmouth Shaw Joint Venture Company
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-06EW05001
Paducah, Kentucky

TETRA TECH, INC
KEVIL, KENTUCKY
(270) 462-4500
FAX (270) 462-4501

DOE CONTRACT NO. DE-AC30-06EW05001

PROJECT NAME:
WASTE DISPOSAL PROJECT

TITLE:
C-746-U SOLID WASTE LANDFILL
SITE LEACHATE COLLECTION SYSTEM
CELLS 1 THRU 23 SITE PLAN

CAD FILE NAME	BUILDING	PLANT	CLASS
C7DC7460UA001 REV 2.DGN	C-746-U	PGDP	U

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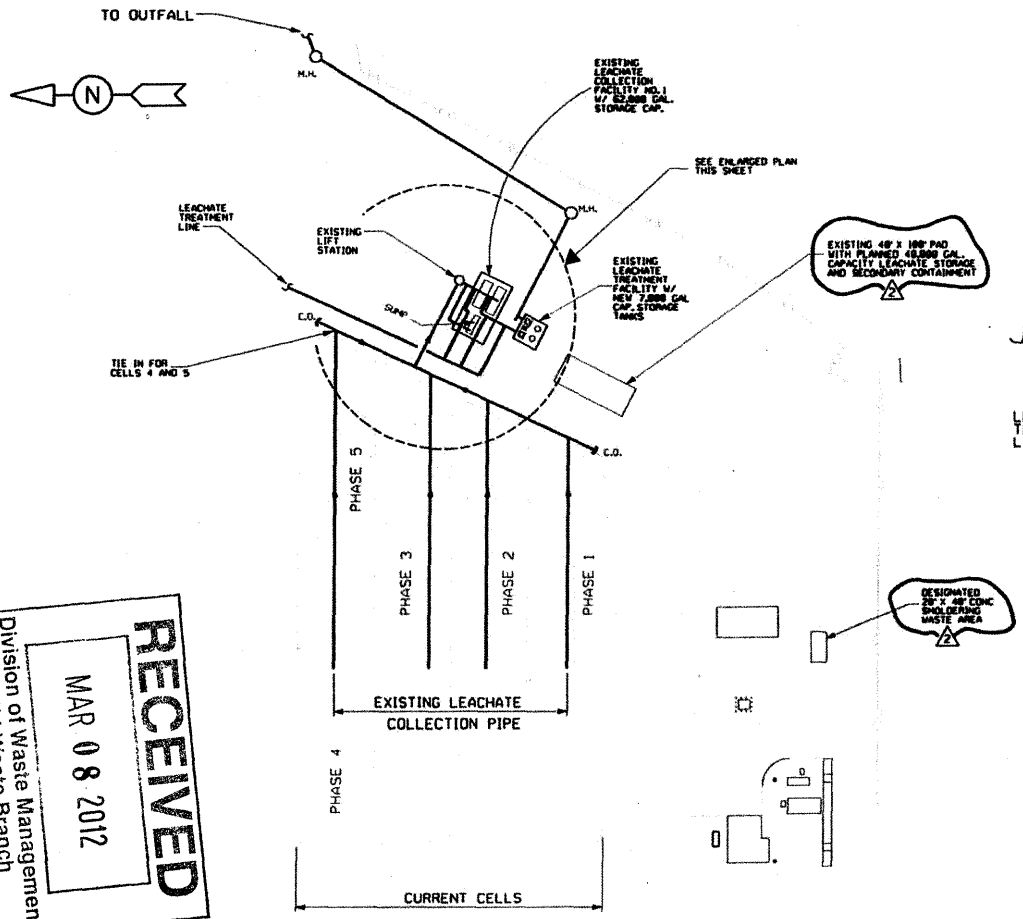

SITE PLAN

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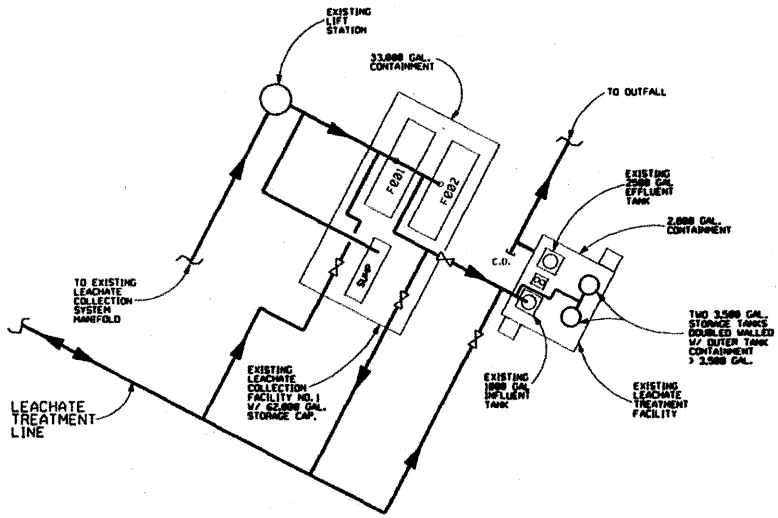

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DOE CONTRACT NO. DE-AC30-06EW05001

PROJECT NAME:
WASTE DISPOSAL PROJECT

TITLE:
C-746-U SOLID WASTE LANDFILL
SITE LEACHATE COLLECTION SYSTEM
CELLS 1 THRU 5 SITE PLAN

CAD FILE NAME	BUILDING	PLANT	CLASS
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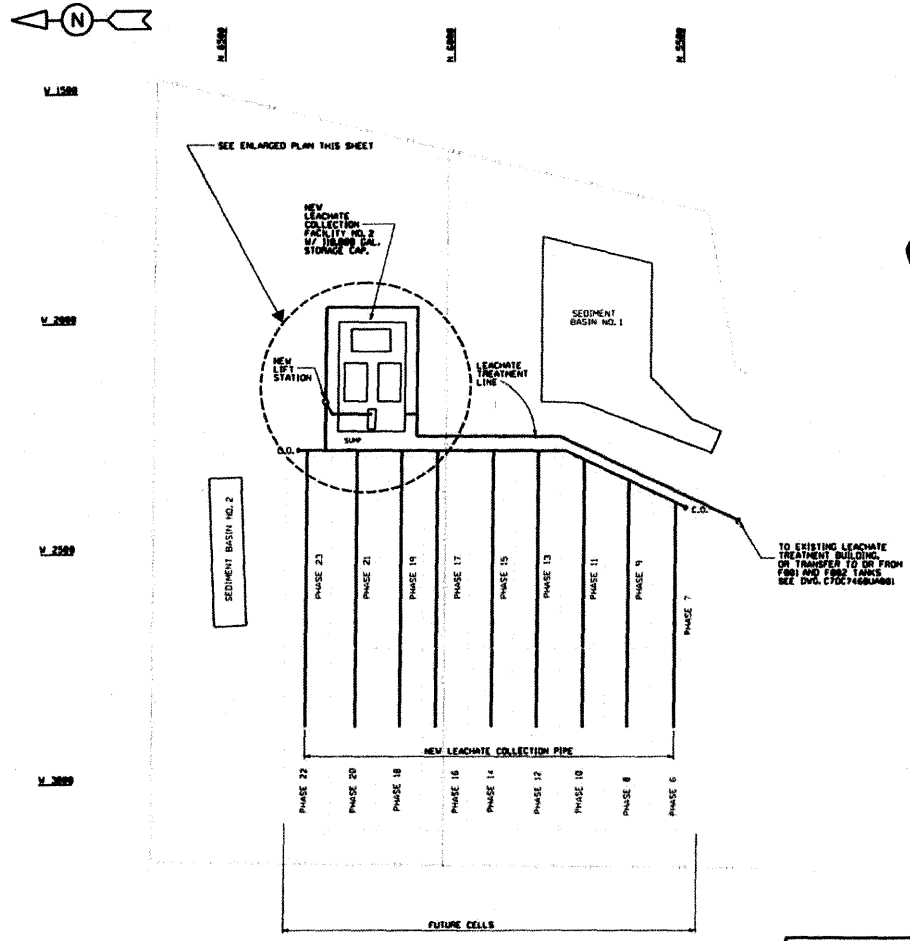

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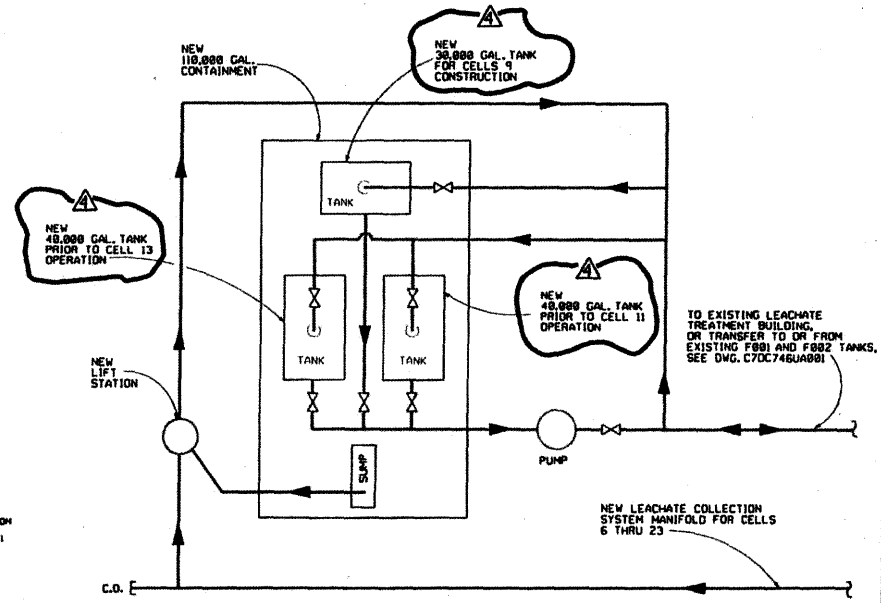

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3	6/10/08	ISSUED FOR KDWM APPROVAL (6/08)	JWP	---	DLA	---	JKL	---	---	--- PEC
2		ADDED ELECT. ACTUATED VALVE								
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0	4/18/07	ISSUED FOR KDWM APPROVAL	JWP	---	DLA	---	KLH	---	---	--- PEC

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-06EW05001
Paducah, Kentucky

TETRA TECH, INC
KEVIL, KENTUCKY
(270) 462-4680
FAX (270) 462-4681

DOE CONTRACT NO. DE-AC30-06EW05001

PROJECT NAME:
WASTE DISPOSAL PROJECT

TITLE:
C-746-U SOLID WASTE LANDFILL
SITE LEACHATE COLLECTION SYSTEM
CELLS 6 THRU 23 SITE PLAN

CAD FILE NAME	BUILDING	PLANT	CLASS
C7DC7460UA003 REV 4.DGN	C-746-U	PGDP	U

SCALE:	DRAWING NUMBER	REV
NOTED	C7DC7460UA003	4

C7DC7460UA003 REV 4.dgn 12/03/2008 10:14:02 AM

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APPENDIX B
TO REVISED ATTACHMENT 16

HELP Model with Leachate Storage Requirements

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CALCULATION COVERSHEET
PRS Paducah Project

Project Title Materials Disposition **Job No.** N/A

Area/Building/Location C-746-U

Discipline Civil **Calc. No.** CAC-PH746U-P001

Subject C-746-U Landfill HELP Model Revision and Required Leachate Storage

Computer Program Hydrological Evaluation of Landfill Performance (HELP) **Program No.** Version 3.07

Committed Calculation ☐ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	1-9	J.K. Thorn	Mary M. Hensley	N/A	Lance Fleming	06/12/08
1	1-9	J.K. Thorn	Kendall L. Holt	N/A	Kendall L. Holt	07/08/08

SUMMARY OF REVISION

0	Initial Issue for Submission to Kentucky Division of Waste Management
1	Revised to clarify interpretation of maximum leachate head in Scenario 1 page 4 of 9

STATE OF KENTUCKY J. KEITH THORN 18000 LICENSED PROFESSIONAL ENGINEER 10/16/08

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

(PA-1026 – Attachment D – Rev. 0 – 10/02)

CALCULATION COVERSHEET
PRS Paducah Project

Project Title Materials Disposition **Job No.** N/A

Area/Building/Location C-746-U

Discipline Civil **Calc. No.** CAC-PH746U-P001

Subject C-746-U Landfill HELP Model Revision and Required Leachate Storage

Computer Program Hydrological Evaluation of Landfill Performance (HELP) **Program No.** Version 3.07

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1	1-9	J.K. Thorn	Kendall L. Holt	N/A	Kendall L. Holt	07/08/08

SUMMARY OF REVISION

0	Initial Issue for Submission to Kentucky Division of Waste Management
1	Revised to clarify interpretation of maximum leachate head in Scenario 1 page 4 of 9

STATE OF KENTUCKY J. KEITH THORN 18809 LICENSED PROFESSIONAL ENGINEER 07/08/08

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

(PA-1026 – Attachment D – Rev. 0 – 10/02)

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CALCULATION COVERSHEET

Project Title Material Disposition **Job No.** N/A

Area/Building/Location C-746-U

Discipline Civil ***Calc. No.** CAC-PH746U-P001

Subject C-746-U Landfill HELP Model Revision and Required Leachate Storage

Computer Program Hydrological Evaluation of Landfill Performance (HELP) **Program No.** Ver. 3.07

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	1-9	J.K. Thorn	Mary M. Hensley	N/A	Lance Fleming	06/12/08
1	1-9	J.K. Thorn	Kendall L. Holt	N/A	Kendall L. Holt	07/08/08
2	1-9	J.K. Thorn	Kendall L. Holt	N/A	Randall E. Scott	02/23/11

SUMMARY OF REVISION

0	Initial Issue for Submission to Kentucky Division of Waste Management
1	Revised to clarify interpretation of maximum leachate head in Scenario 1 page 4 of 9
2	Revised to show LATA Environmental Services of Kentucky in lieu of Paducah Remediation Services. Revised to show 60-mil HDPE in final cap in lieu of 40-mil VLDPE pages 4 and 8 of Attachment 'F', 8 pages. Revised the average annual leachate collected for Scenario 1 on page 8 of 9 from 96252 ft^3 to 102415 ft^3. Changes have no effect of conclusions of this Calculation. Attachments 'A', 1 page; 'B', 20 pages; 'C', 18 pages; 'D', 18 pages; 'E', 33 pages; 'G', 8 pages; 'H' 2 pages; 'J', 7 pages; 'K', 7 pages; and 'L', 16 pages are unrevised.

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

CALCULATION SHEET

Originator J. Keith Thorn | Date Feb. 23, 2011 | Calc. No. CAC-PH746U-P001 | Rev. No. 2

Project Material Disposition | Job No. N/A | Checked Kendall L. Holt | Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

1.0 PURPOSE:

The purpose of this calculation is to revise the Hydrological Evaluation of Landfill Performance (HELP) Model analysis for the PGDP C-746-U Solid Waste Landfill, last revised in October 2007. The output from the revised HELP Model analysis will be used to calcuate the required storage to contain the 15 day Peak Leachate Production required by State regulations.

2.0 INPUT DATA:

The data to be used for this calculation shall be taken from the sources below.

2.1 The weather information for the city of Evansville, IN is used as the basis to generate synthetic data for Precipitation, Temperature, Solar Radiation, and Evapotranspiration. The Normal Mean Monthly Precipitation Values, The Normal Mean Monthly Temperature Values, and the Station Latitude were adjusted in accordance with the data given in Reference 4.3 for Paducah, KY. The synthetic daily precipitation values generated by the HELP Model were manually overwritten during a specific 15 day period to ensure that both the 25 year - 24 hour and 25 year - 15 day precipitation events were captured.

2.2 The 25 year - 24 hour (with a 90% probability not to be exceeded) precipitation value of 6.53 inches was obtained from Reference 4.2.

2.3 The 25 year - 15 day (with a 90% probability not to be exceeded) precipitation value of 12.69 inches was obtained by interpolation from the table in Reference 4.2.

3.0 ASSUMPTIONS:

In this calculation the following assumptions were made:

3.1 The Landfill Cross Section Schematics shown on Pages 1 - 4 of Attachment 'F' is valid.

3.2 The Soil Types used in HELP Modeling as shown on Pages 5 - 8 of Attachment 'F' is valid.

4.0 REFERENCES:

4.1 Hydrological Evaluation of Landfill Performance Modeling for the Paducah C-746-U Landfill, Shaw Environmental, Inc., October 2007.

4.2 Point Precipitation Frequency Estimates from National Oceanic and Atmospheric Administration (NOAA) Atlas 14, NOAA, 2004.(Attachment 'G')

4.3 United States Climate Normals 1971-2000, Climatology of the United States No. 81, Kentucky, NOAA. (Attachment 'H')

4.4 Hydrological Evaluation of Landfill Performance (HELP) Model Engineering Document for Version 3.

4.5 The PGDP Solid Waste Landfill Leachate Log Oct. 31, 2007 thru June 3, 2008 (as modified to calculated daily leachate generated). (Attachment 'K')

4.6 National Weather Service Preliminary Local Climate Data Form F-6 for Paducah, Kentucky Station ASOS, Nov. 2007 thru June 2008. (Attachment 'L')

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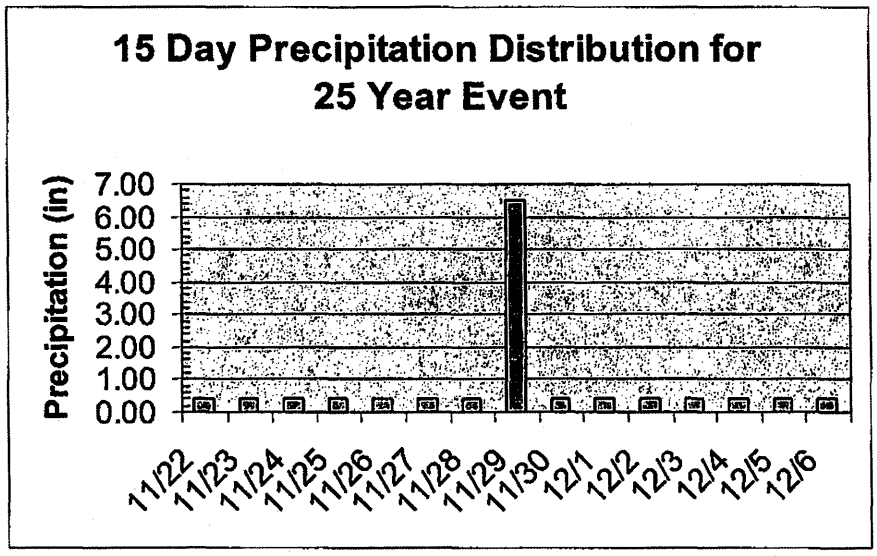
Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.0 CALCULATIONS:

5.1 Distribution of Precipitation During the 25 Year - 15 Day Event



In determining a "worst case" plausable scenario for decribing a 25 Year - 15 Day event which includes the 25 Year - 24 Hour event as well, the approach taken is shown in the graphic above. The 25 Year - 24 Hour event was assumed to have occured on the 8th day. One half of the balance of the 15 day precipitation is placed on each of the preceeding days. The result is a 15 day period that begins with the first seven days being 0.44 inches, the 8th day being 6.53 inches, and the last seven days being 0.44 inches. These prescipitation values were manually superimposed over the syntheticly generated values during Novemeber 22 to December 6 of the 9th year.

5.2 HELP Model Scenario 1 - Daily/Intermediate Cover Conditions

The daily cover operations were modeled as a series of 2 ft thicklayers of waste covered by 6 inches of daily cover material with a maximum thickness of 10 feet as shown on Page 1 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Bare ground condition was used. The Maximum Leaf Index is 1.0. The Evaporative Zone Depth is 18 inches. 70% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (assumed bare ground, slope of 50%, and slope length of 50 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

As a permit requirement, PGDP has committed to maintain a maximum head of leachate on the HDPE liner of no greater than 12 inches. The results of the HELP Model Peak Daily Values shown on Page 19 of 20 indicate that the modeled scenario (2.73 acres) would result in a MAXIMUM HEAD ON LAYER 11 of 1.394 feet. However, in practice the landfill will never have the entire area of any given phase or pair of phases configured with daily/intermediate cover (limited in this analysis to 0.5 acres), the leachate head will dissipate into the adjacent areas of the drainage layer which underlie more impervious cover material. These adjacent layers all have maximum heads of well under 12 inches. Therefore, the maximum head in a composite analysis would be no greater than 12 inches.

5.3 HELP Model Scenario 1 - Daily/Intermediate Cover Results

Attachment 'B' is the HELP Model run which calculates the peak daily leachate production rate of 910 ft^3 for Phases 2&3 (2.73 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 10 and can be found on Page 19 of 20.

To change the units of this value from ft^3 / day for Phases 2&3 to gallons/acre/day

$$\frac{910ft^3}{1.0day}\cdot\frac{7.48gal}{1.0ft^3}\cdot\frac{1}{2.73acre}=2493.33\frac{gal}{acre\cdot day}$$

5.4 HELP Model Scenario 2 - Long Term Cover Conditions

The long term cover operations were modeled as a 15 ft thick layer of waste covered by 30 inches of long term cover material as shown on Page 2 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Poor vegetative condition was used. The corresponding Maximum Leaf Index is 1.05. The Evaporative Zone Depth is 18 inches. 80% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (slope of 10%, and slope length of 50 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

5.5 HELP Model Scenario 2 - Long Term Cover Results

Attachment 'C' is the HELP Model run which calculates the peak daily leachate production rate of 422 ft^3 for Phases 1, 2&3 (3.94 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 4 and can be found on Page 17 of 18.

To change the units of this value from ft^3 / day for Phases 1, 2&3 to gallons/acre/day

$$\frac{422ft^3}{1.0day}\cdot\frac{7.48gal}{1.0ft^3}\cdot\frac{1}{3.94acre}=801.16\frac{gal}{acre\cdot day}$$

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Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.6 HELP Model Scenario 3 - Operational Cover Conditions

The operation cover conditions were modeled as a 48 in thick layer of soil cover installed over the 18 inch protection layer with no waste in between as shown on Page 3 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Fair vegetative condition was used. The corresponding Maximum Leaf Index is 2.0. The Evaporative Zone Depth is 18 inches. 98% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (slope of 20%, and slope length of 12 feet.) The initial water content of the leachate collection system and operational cover material were set at the field capacity of the respective materials.

5.7 HELP Model Scenario 3 - Operational Cover Results

Attachment 'D' is the HELP Model run which calculates the peak daily leachate production rate of 294 ft^3 for Phases 4/5 (1.53 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 4 and can be found on Page 17 of 18.

To change the units of this value from ft^3 / acre/day to gallons/acre/day

$$\frac{294ft^3}{1.0day \cdot 1.53acre} \cdot \frac{7.48gal}{1.0ft^3} = 1437.33 \frac{gal}{acre \cdot day}$$

5.8 HELP Model Scenario 4 - Final Cover Conditions

The final cover conditions were modeled as a 60 ft thick layer of waste covered by a final cap system as shown in Exhibit 1 of Attachment 'F'. This scenario was modeled for a 30 year elapsed time. Good vegetative condition was used. The corresponding Maximum Leaf Index is 3.5 The Evaporative Zone Depth is 24 inches. 100% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (assumed bare ground, slope of 11%, and slope length of 145 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

Originator J. Keith Thorn Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.9 HELP Model Scenario 4 - Final Cover Results

Attachment 'E' is the HELP Model run which calculates the peak daily leachate production rate of 2.33 ft^3 for a Unit Area (1.0 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 9 and can be found on Page 32 of 33.

To change the units of this value from ft^3 / acre/day to gallons/acre/day

$$\frac{2.80ft^3}{1.0day \cdot 1.0acre} \cdot \frac{7.48gal}{1.0ft^3} = 20.94 \frac{gal}{acre \cdot day}$$

5.10 Calculate Required Leachate Storage Throughout the Life of the Landfill

The values calculated in Sections 5.3, 5.5, 5.7 and 5.9 above are intended to be representative of the leachate production to be expected for the Daily/Intermediate, Long Term, Operational and Final Cover conditions respectively. With that as a basis, the spreadsheet shown in Attachment 'A' calculates the volume of leachate to be generated by the landfill under the criteria listed at the top of the spreadsheet.

5.11 Demonstrate the Correlation between the Model and the Actual Data

To establish the correlation between the HELP Model results and the actual rainfall and leachate data being collected for the current landfill operation we shall compare the ratio of actual leachate collected vs. gross rainfall over the landfill area. There were several improvements to correct grading that was inconsistent with the physical data in the HELP Model. These improvements were made at the beginning of April and have dramatically reduced leachate production. The Rain to Leachate Ratio ($Ratio_{Actual}$) calulated below will be for the months of April and May 2008 since the landfill configuration during that period is more accurately represented in the current HELP Model.

The total rainfall received by the landfill during April and May 2008 (See Attachment 'J') is

$$Rain_{AprilMay08Depth} := 12.42in$$

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Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.11 (Continued)

We will convert that depth into a volume received by the landfill area Phases 1-3 (3.94 acres)

$$Rain_{AprilMay08Volume} := \left(\frac{Rain_{AprilMay08Depth}}{12\frac{in}{ft}}\right)\cdot\left(43560\cdot\frac{ft^2}{acre}\right)\cdot(3.94acre)\cdot\left(7.48\frac{gal}{ft^3}\right)$$

$$Rain_{AprilMay08Volume} = 1328697.26\,gal$$

The total leachate collected by the landfill during April and May 2008 (See Attachment 'J') is

$$Leachate_{AprilMay08Actual} := 138780.00gal$$

The ratio of leachate collected to rainfall received is

$$Ratio_{Actual} := \frac{Leachate_{AprilMay08Actual}}{Rain_{AprilMay08Volume}} \qquad Ratio_{Actual} = 10.44\%$$

The Long Term Cover Scenario 2 is based on the HELP Model run included as Attachment 'C'. In that model 3.94 acres is the area being modeled. The average annual precipitation for the 15 year period being modeled is 684561 ft^3, and can be found on Page 16 of 18 . We will now calculate a value of precipitation per acre for the Long Term Cover condition analyzed in the HELP Model..

$$Area_{LTC} := 3.94acre$$

$$Rain_{HELP\_LTC} := \frac{684561ft^3}{Area_{LTC}} \qquad Rain_{HELP\_LTC} = 173746.45\frac{ft^3}{acre}$$

The Daily/Interim Cover Scenario 1 is based on the HELP Model run included as Attachment 'B'. In that model 2.73 acres is the area being modeled. The average annual precipitation for the 15 year period being modeled is 474327 ft^3, and can be found on Page 18 of 20 . We will now calculate a value of precipitation per acre for the Daily/Interim Cover condition analyzed in the HELP Model..

$$Area_{DC} := 2.73acre$$

$$Rain_{HELP\_DC} := \frac{474327ft^3}{Area_{DC}} \qquad Rain_{HELP\_DC} = 173746.15\frac{ft^3}{acre}$$

Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.11 (Continued)

Current landfill configuration is comprised of Phases 1-3 with a total area of 3.94 acres. Of that total approximately 3.44 acres is under Long Term Cover and approximately 0.50 acres is under Daily/Interim Cover. We will now calculate the average total amount of rainfall received by both the Long Term Cover area and Daily/Interim Cover area combined.

$$Rain_{HELP\_DC} \cdot 0.5acre + Rain_{HELP\_LTC} \cdot 3.44acre = 684560.85\ ft^3$$

Recall Attachment 'C', In the Scenario 2 model, 3.94 acres is the area being modeled. The average annual leachate collected for the 15 year period being modeled is 8322 ft^3 , and can be found on Page 16 of 18. We will now calculate a value of leachate collected per acre for the Long Term Cover condition analyzed in the HELP Model..

$$Leachate_{HELP\_LTC} := \frac{8322ft^3}{Area_{LTC}} \qquad Leachate_{HELP\_LTC} = 2112.18\ \frac{ft^3}{acre}$$

Recall Attachment 'B', In the Scenario 1 model, 2.73 acres is the area being modeled. The average annual leachate collected for the 15 year period being modeled is 102415 ft^3 , and can be found on Page 18 of 20. We will now calculate a value of leachate collected per acre for the Daily/Interim Cover condition analyzed in the HELP Model..

$$Leachate_{HELP\_DC} := \frac{102415ft^3}{Area_{DC}} \qquad Leachate_{HELP\_DC} = 37514.65\ \frac{ft^3}{acre}$$

As previously stated, current landfill configuration is comprised of Phases 1-3 with a total area of 3.94 acres. Of that total approximately 3.44 acres is under Long Term Cover and approximately 0.50 acres is under Daily/Interim Cover. Since the HELP Model is not capable of modeling muliple cover conditions at the same time, we will take the per acre values calculated above and apply them to the areas which represent the current landfill configuration to generate a composite calculation of the average annual leachate production predicted by the HELP Model.

$$Leachate_{HELP\_DC} \cdot 0.5acre + Leachate_{HELP\_LTC} \cdot 3.44acre = 194667.3\ gal$$

The ratio of Leachate predicted to rainfall applied in the HELP Model is

$$Ratio_{HELP} := \frac{Leachate_{HELP\_DC} + Leachate_{HELP\_LTC}}{Rain_{HELP\_DC} + Rain_{HELP\_LTC}}$$

$$Ratio_{HELP} = 11.4\%$$

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Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

6.0 CONCLUSION:

This calculation utilizes the HELP Model to calculate Peak Daily leachate production values for four different cover conditions (Daily/Intermediate, Long Term, Operational, Final). Those values are then applied using a rational approach to calculate leachate storage requirements for the spectrum of landfill configurations anticipated (See Attachment 'A').

Of particular near-term interest are the values of approximately 60,000 gallons for the present landfill configuration of Phases 1-3 and approximately 88,000 gallons for the operation of Phases 1-5, as well as, approximately 154,000 gallons for operation of Phases 1-11.

To establish the correlation between the HELP Model results and the actual rainfall and leachate data being collected for the current landfill operation, we compared the ratio of actual leachate collected to gross rainfall over the landfill area ($Ratio_{Actual}$) with the ratio of Leachate predicted to rainfall applied in the HELP Model ($Ratio_{HELP}$).

$$Ratio_{Actual} = 10.44\%$$

$$Ratio_{HELP} = 11.4\%$$

This comparison seems to support a good correlation of the HELP Model to actual conditions.

Attachment 'A'
Paducah Remediation Services

Originator J. Keith Thorn Date July 08, 2008 Calc. No. CAC-PH746U-P001 Rev. No. 1

Project Material Disposition Job No. N/A Checked Mary M. Hensley Date July 08, 2008

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Peak Infiltration Rates from Help Model

801 gal/acre/day for Long-Term cover
2493 gal/acre/day for Daily/Intermediate cover
21 gal/acre/day for Final cover
1437 gal/acre/day for Operational cover

Variables affecting cover assumptions

0.50 (Acre) Area of newly opened Phase assumed to be as effective as Daily/Intermediate cover

Attachment A

C-746-U Landfill Leachate Generation - Tank Installations

Phase	Acreage per Phase	Leachate Generated under Long Term Cover (gal/15 day period)	Leachate Generated under Intermediate/ Daily Cover (gal/15 day period)	Leachate Generated under Final Cover (gal/15 day period)	Leachate Generated under Operational Cover (gal/15 day period)	Projected Leachate Generation-Tank Installations and Two Step Final Cap		
						Projected Leachate (gal.)	Tank Capacity (gal.)	PRS Action
1	1.21	14,538		381				
2	1.31	15,740		413				
3	1.42	17,061		447		60,029	62,000	
4	0.95	11,414	35,525	299	20,477			
5	0.58	6,969	21,689	183	12,502	88,238	109,000	Install two 3,500 gal. leachate tanks, plus a min. of 40,000 gal. of storage
6	0.95	11,414	35,525	299	20,477			
7	0.68	8,170	25,429	214	14,657	108,777	109,000	
8	0.95	11,414	35,525	299	20,477			
9	0.8	9,612	29,916	252	17,244	130,948	139,000	Install a minimum of 30,000 gallons of storage
10	0.95	11,414	35,525	299	20,477			
11	0.9	10,814	33,656	284	19,400	154,130	179,000	Install a minimum of 40,000 gallons of storage
12	0.95	11,414	35,525	299	20,477			
13	0.95	11,414	35,525	299	20,477	177,435	219,000	Install a minimum of 40,000 gallons of storage
14	0.95	11,414	35,525	299	20,477			
15	0.95	11,414	35,525	299	20,477	200,264	219,000	Install Final Cap over Phase 1-15
16	0.95	11,414	35,525	299	20,477			
17	0.95	11,414	35,525	299	20,477	53,442	219,000	
18	0.95	11,414	35,525	299	20,477			
19	0.95	11,414	35,525	299	20,477	76,271	219,000	
20	0.95	11,414	35,525	299	20,477			
21	0.95	11,414	35,525	299	20,477	99,099	219,000	
22	0.95	11,414	35,525	299	20,477			
23	0.95		20,207		20,477	121,928	219,000	Install Remaining Final Cap

Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\HELP3\PREC15DA.D4
TEMPERATURE DATA FILE:        C:\HELP3\PADTEMP.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\PADSOLAR.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\EVAPLT.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\DAILYCOV.D10
OUTPUT DATA FILE:             C:\HELP3\PH23DC.OUT


TIME:  11:26      DATE:   6/10/2008


******************************************************************************

     TITLE:  Paducah Landfill - Daily Cover (6-inches) - Phase 2 - 3

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3980 VOL/VOL
          FIELD CAPACITY             =      0.2440 VOL/VOL
          WILTING POINT              =      0.1360 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.80
       FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.1680 VOL/VOL
FIELD CAPACITY              =      0.0730 VOL/VOL
WILTING POINT               =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0190 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                    LAYER  3
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  10
THICKNESS                   =      6.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC


                    LAYER  4
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.1680 VOL/VOL
FIELD CAPACITY              =      0.0730 VOL/VOL
WILTING POINT               =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0190 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
```

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

```
                    LAYER  5
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  10
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC


                    LAYER  6
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.1680 VOL/VOL
FIELD CAPACITY               =      0.0730 VOL/VOL
WILTING POINT                =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0190 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                    LAYER  7
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  10
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC


                    LAYER  8
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                    =     24.00   INCHES
```

```
POROSITY                      =      0.1680 VOL/VOL
FIELD CAPACITY                =      0.0730 VOL/VOL
WILTING POINT                 =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0190 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000005000E-02 CM/SEC


                        LAYER  9
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  24
THICKNESS                     =     18.00   INCHES
POROSITY                      =      0.3650 VOL/VOL
FIELD CAPACITY                =      0.3050 VOL/VOL
WILTING POINT                 =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.270000010000E-05 CM/SEC


                        LAYER 10
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                     =     12.00   INCHES
POROSITY                      =      0.4170 VOL/VOL
FIELD CAPACITY                =      0.0450 VOL/VOL
WILTING POINT                 =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.999999978000E-02 CM/SEC
SLOPE                         =     11.00   PERCENT
DRAINAGE LENGTH               =     50.0    FEET


                        LAYER 11
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                     =      0.08   INCHES
POROSITY                      =      0.0000 VOL/VOL
FIELD CAPACITY                =      0.0000 VOL/VOL
WILTING POINT                 =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
```

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```
FML PINHOLE DENSITY          =      2.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 12

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

```
THICKNESS                    =     36.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 50. AND A SLOPE LENGTH OF 50. FEET.

```
SCS RUNOFF CURVE NUMBER              =     94.80
FRACTION OF AREA ALLOWING RUNOFF     =     70.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      2.730   ACRES
EVAPORATIVE ZONE DEPTH               =     18.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      1.692   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      4.404   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.044   INCHES
INITIAL SNOW WATER                   =      0.000   INCHES
INITIAL WATER IN LAYER MATERIALS     =     29.082   INCHES
TOTAL INITIAL WATER                  =     29.082   INCHES
TOTAL SUBSURFACE INFLOW              =      0.00    INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Evansville Indiana

Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

STATION LATITUDE	=	37.05 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	96
END OF GROWING SEASON (JULIAN DATE)	=	300
EVAPORATIVE ZONE DEPTH	=	18.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.31 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.47	3.93	4.27	4.95	4.75	4.51
4.45	2.99	3.56	3.45	4.53	4.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.90	38.10	47.60	57.00	65.90	74.50
78.20	76.20	69.10	58.00	46.80	36.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA
AND STATION LATITUDE = 37.03 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.94	445350.906	100.00

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RUNOFF	7.498	74302.898	16.68
EVAPOTRANSPIRATION	28.177	279230.125	62.70
DRAINAGE COLLECTED FROM LAYER 10	1.9633	19455.957	4.37
PERC./LEAKAGE THROUGH LAYER 12	0.000044	0.434	0.00
AVG. HEAD ON TOP OF LAYER 11	0.0431		
CHANGE IN WATER STORAGE	7.302	72361.508	16.25
SOIL WATER AT START OF YEAR	29.082	288199.687	
SOIL WATER AT END OF YEAR	36.384	360561.187	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.017	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.57	540783.250	100.00
RUNOFF	12.659	125448.844	23.20
EVAPOTRANSPIRATION	25.605	253741.641	46.92
DRAINAGE COLLECTED FROM LAYER 10	17.6333	174744.312	32.31
PERC./LEAKAGE THROUGH LAYER 12	0.000382	3.787	0.00
AVG. HEAD ON TOP OF LAYER 11	0.3915		
CHANGE IN WATER STORAGE	-1.327	-13155.349	-2.43
SOIL WATER AT START OF YEAR	36.384	360561.187	
SOIL WATER AT END OF YEAR	35.056	347405.844	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.031	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.47	569522.000	100.00
RUNOFF	13.134	130151.797	22.85
EVAPOTRANSPIRATION	32.868	325721.187	57.19
DRAINAGE COLLECTED FROM LAYER 10	12.3295	122183.844	21.45
PERC./LEAKAGE THROUGH LAYER 12	0.000274	2.719	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2769		
CHANGE IN WATER STORAGE	-0.862	-8537.650	-1.50
SOIL WATER AT START OF YEAR	35.056	347405.844	
SOIL WATER AT END OF YEAR	33.791	334863.937	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.404	4004.265	0.70
ANNUAL WATER BUDGET BALANCE	0.0000	0.096	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.30	399369.000	100.00

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RUNOFF	6.805	67441.391	16.89
EVAPOTRANSPIRATION	28.487	282299.437	70.69
DRAINAGE COLLECTED FROM LAYER 10	5.6559	56049.355	14.03
PERC./LEAKAGE THROUGH LAYER 12	0.000136	1.350	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1264		
CHANGE IN WATER STORAGE	-0.648	-6422.616	-1.61
SOIL WATER AT START OF YEAR	33.791	334863.937	
SOIL WATER AT END OF YEAR	33.547	332445.562	
SNOW WATER AT START OF YEAR	0.404	4004.265	1.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.097	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.87	474386.844	100.00
RUNOFF	8.357	82819.391	17.46
EVAPOTRANSPIRATION	28.655	283968.906	59.86
DRAINAGE COLLECTED FROM LAYER 10	9.4561	93709.266	19.75
PERC./LEAKAGE THROUGH LAYER 12	0.000215	2.126	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2090		
CHANGE IN WATER STORAGE	1.401	13887.296	2.93
SOIL WATER AT START OF YEAR	33.547	332445.562	
SOIL WATER AT END OF YEAR	34.948	346332.875	

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.141	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.37	499161.719	100.00
RUNOFF	8.999	89175.328	17.87
EVAPOTRANSPIRATION	30.629	303529.969	60.81
DRAINAGE COLLECTED FROM LAYER 10	8.9618	88810.062	17.79
PERC./LEAKAGE THROUGH LAYER 12	0.000210	2.079	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1998		
CHANGE IN WATER STORAGE	1.780	17644.336	3.53
SOIL WATER AT START OF YEAR	34.948	346332.875	
SOIL WATER AT END OF YEAR	36.729	363977.219	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.019	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PRECIPITATION	50.14	496882.406	100.00
RUNOFF	10.926	108278.109	21.79
EVAPOTRANSPIRATION	26.258	260216.156	52.37
DRAINAGE COLLECTED FROM LAYER 10	12.8753	127592.555	25.68
PERC./LEAKAGE THROUGH LAYER 12	0.000284	2.819	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2895		
CHANGE IN WATER STORAGE	0.080	792.768	0.16
SOIL WATER AT START OF YEAR	36.729	363977.219	
SOIL WATER AT END OF YEAR	36.514	361853.781	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.294	2916.178	0.59
ANNUAL WATER BUDGET BALANCE	0.0000	0.021	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.20	418197.719	100.00
RUNOFF	8.471	83944.789	20.07
EVAPOTRANSPIRATION	25.773	255412.156	61.07
DRAINAGE COLLECTED FROM LAYER 10	8.8447	87650.289	20.96
PERC./LEAKAGE THROUGH LAYER 12	0.000199	1.975	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1976		
CHANGE IN WATER STORAGE	-0.889	-8811.446	-2.11
SOIL WATER AT START OF YEAR	36.514	361853.781	
SOIL WATER AT END OF YEAR	35.919	355958.531	

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT START OF YEAR	0.294	2916.178	0.70
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.042	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	67.92	673080.312	100.00
RUNOFF	14.934	147999.078	21.99
EVAPOTRANSPIRATION	30.655	303792.062	45.13
DRAINAGE COLLECTED FROM LAYER 10	16.1478	160022.672	23.77
PERC./LEAKAGE THROUGH LAYER 12	0.000353	3.499	0.00
AVG. HEAD ON TOP OF LAYER 11	0.3611		
CHANGE IN WATER STORAGE	6.182	61263.090	9.10
SOIL WATER AT START OF YEAR	35.919	355958.531	
SOIL WATER AT END OF YEAR	41.287	409147.812	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.815	8073.813	1.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.048	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT

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PRECIPITATION	40.07	397089.687	100.00
RUNOFF	6.550	64912.723	16.35
EVAPOTRANSPIRATION	28.664	284055.437	71.53
DRAINAGE COLLECTED FROM LAYER 10	12.1741	120644.602	30.38
PERC./LEAKAGE THROUGH LAYER 12	0.000266	2.637	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2735		
CHANGE IN WATER STORAGE	-7.318	-72525.437	-18.26
SOIL WATER AT START OF YEAR	41.287	409147.812	
SOIL WATER AT END OF YEAR	34.783	344696.187	
SNOW WATER AT START OF YEAR	0.815	8073.813	2.03
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.256	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.73	492819.406	100.00
RUNOFF	8.038	79651.430	16.16
EVAPOTRANSPIRATION	25.594	253629.344	51.46
DRAINAGE COLLECTED FROM LAYER 10	12.2598	121493.242	24.65
PERC./LEAKAGE THROUGH LAYER 12	0.000270	2.672	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2753		
CHANGE IN WATER STORAGE	3.839	38042.625	7.72
SOIL WATER AT START OF YEAR	34.783	344696.187	

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SOIL WATER AT END OF YEAR	36.728	363975.156	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.893	18763.637	3.81
ANNUAL WATER BUDGET BALANCE	0.0000	0.103	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.27	349522.187	100.00
RUNOFF	6.584	65250.012	18.67
EVAPOTRANSPIRATION	23.766	235515.469	67.38
DRAINAGE COLLECTED FROM LAYER 10	8.2164	81423.344	23.30
PERC./LEAKAGE THROUGH LAYER 12	0.000186	1.842	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1821		
CHANGE IN WATER STORAGE	-3.297	-32668.361	-9.35
SOIL WATER AT START OF YEAR	36.728	363975.156	
SOIL WATER AT END OF YEAR	35.325	350070.437	
SNOW WATER AT START OF YEAR	1.893	18763.637	5.37
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.119	0.00

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ANNUAL TOTALS FOR YEAR 13

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Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.98	406107.656	100.00
RUNOFF	10.518	104231.000	25.67
EVAPOTRANSPIRATION	21.689	214934.266	52.93
DRAINAGE COLLECTED FROM LAYER 10	8.6390	85611.500	21.08
PERC./LEAKAGE THROUGH LAYER 12	0.000199	1.975	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1920		
CHANGE IN WATER STORAGE	0.134	1328.861	0.33
SOIL WATER AT START OF YEAR	35.325	350070.437	
SOIL WATER AT END OF YEAR	35.459	351399.312	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.066	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	51.77	513035.594	100.00
RUNOFF	11.198	110974.266	21.63
EVAPOTRANSPIRATION	30.326	300523.969	58.58
DRAINAGE COLLECTED FROM LAYER 10	8.7522	86733.125	16.91
PERC./LEAKAGE THROUGH LAYER 12	0.000198	1.966	0.00
AVG. HEAD ON TOP OF LAYER 11	0.1943		
CHANGE IN WATER STORAGE	1.494	14802.097	2.89
SOIL WATER AT START OF YEAR	35.459	351399.312	

Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SOIL WATER AT END OF YEAR	36.953	366201.406	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.208	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.36	439603.219	100.00
RUNOFF	11.019	109200.820	24.84
EVAPOTRANSPIRATION	24.067	238500.250	54.25
DRAINAGE COLLECTED FROM LAYER 10	11.1104	110102.750	25.05
PERC./LEAKAGE THROUGH LAYER 12	0.000248	2.460	0.00
AVG. HEAD ON TOP OF LAYER 11	0.2476		
CHANGE IN WATER STORAGE	-1.837	-18203.182	-4.14
SOIL WATER AT START OF YEAR	36.953	366201.406	
SOIL WATER AT END OF YEAR	35.116	347998.219	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.129	0.00

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Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 15

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.47	3.62	4.18	4.45	4.38	4.96
	4.46	3.28	4.16	2.59	4.56	3.76
STD. DEVIATIONS	2.31	1.69	1.97	2.32	1.98	2.38
	2.03	2.48	2.31	1.48	3.85	1.83
RUNOFF						
TOTALS	0.943	0.895	0.724	0.704	0.714	0.963
	0.816	0.646	0.932	0.522	0.985	0.870
STD. DEVIATIONS	0.991	0.808	0.599	0.697	0.560	0.741
	0.717	0.836	0.780	0.551	1.523	1.100
EVAPOTRANSPIRATION						
TOTALS	0.891	1.278	2.536	3.357	3.079	3.579
	3.197	2.566	2.373	1.523	1.656	1.379
STD. DEVIATIONS	0.333	0.467	0.518	0.927	0.883	1.258
	1.288	1.336	0.762	0.848	0.637	0.259
LATERAL DRAINAGE COLLECTED FROM LAYER 10						
TOTALS	1.4981	1.4933	1.4946	1.2180	0.6853	0.6598
	0.5450	0.3299	0.2773	0.4949	0.5841	1.0541
STD. DEVIATIONS	1.0122	0.9953	0.9905	0.7175	0.5714	0.7159
	0.4388	0.3456	0.2278	0.6135	0.4457	0.8591
PERCOLATION/LEAKAGE THROUGH LAYER 12						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

Attachment 'B'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DAILY AVERAGE HEAD ON TOP OF LAYER 11

AVERAGES	0.3922	0.4296	0.3912	0.3295	0.1794	0.1785
	0.1427	0.0864	0.0750	0.1295	0.1580	0.2759
STD. DEVIATIONS	0.2650	0.2872	0.2593	0.1941	0.1496	0.1937
	0.1149	0.0905	0.0616	0.1606	0.1206	0.2249

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 15

	INCHES		CU. FEET	PERCENT
PRECIPITATION	47.86	(8.223)	474327.4	100.00
RUNOFF	9.713	(2.5846)	96252.12	20.292
EVAPOTRANSPIRATION	27.414	(3.0684)	271671.34	57.275
LATERAL DRAINAGE COLLECTED FROM LAYER 10	10.33463	(3.89048)	102415.125	21.59165
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00023	(0.00008)	2.289	0.00048
AVERAGE HEAD ON TOP OF LAYER 11	0.231	(0.087)		
CHANGE IN WATER STORAGE	0.402	(3.6130)	3986.57	0.840

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 15

	(INCHES)	(CU. FT.)
PRECIPITATION	6.53	64711.648
RUNOFF	2.570	25471.6621
DRAINAGE COLLECTED FROM LAYER 10	0.09184	910.11658
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000002	0.01904
AVERAGE HEAD ON TOP OF LAYER 11	0.745	
MAXIMUM HEAD ON TOP OF LAYER 11	1.394	
LOCATION OF MAXIMUM HEAD IN LAYER 10 (DISTANCE FROM DRAIN)	2.7 FEET	
SNOW WATER	6.93	68681.8516

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2414
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0580

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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Attachment 'B'
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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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FINAL WATER STORAGE AT END OF YEAR 15

LAYER	(INCHES	(VOL/VOL
1	1.1785	0.1964
2	1.4656	0.0611
3	1.5966	0.2661
4	1.7520	0.0730
5	1.7015	0.2836
6	1.7520	0.0730
7	1.6960	0.2827
8	1.7520	0.0730
9	6.1444	0.3414
10	0.7056	0.0588
11	0.0000	0.0000
12	15.3720	0.4270
SNOW WATER	0.000	

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\PREC15DA.D4
TEMPERATURE DATA FILE:       C:\HELP3\PADTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\PADSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\EVAPLT.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\PH1-3LTC.D10
OUTPUT DATA FILE:            C:\HELP3\PH1-3LTC.OUT


TIME:  16:31      DATE:   6/10/2008


******************************************************************************

     TITLE:  Paducah Landfill - Long Term Cover (30-inches) - Phase 1 - 3

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
          THICKNESS                  =      30.00   INCHES
          POROSITY                   =       0.3650 VOL/VOL
          FIELD CAPACITY             =       0.3050 VOL/VOL
          WILTING POINT              =       0.2020 VOL/VOL
```

Attachment 'C'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

```
INITIAL SOIL WATER CONTENT  =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.270000010000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  1.85
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                   =    180.00   INCHES
POROSITY                    =      0.1680 VOL/VOL
FIELD CAPACITY              =      0.0730 VOL/VOL
WILTING POINT               =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC


                    LAYER  3
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  24
THICKNESS                   =     18.00   INCHES
POROSITY                    =      0.3650 VOL/VOL
FIELD CAPACITY              =      0.3050 VOL/VOL
WILTING POINT               =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.270000010000E-05 CM/SEC


                    LAYER  4
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
SLOPE                       =     11.00   PERCENT
DRAINAGE LENGTH             =     50.0    FEET
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                         LAYER  5
                         --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.08    INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      2.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                         LAYER  6
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     36.00    INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #24 WITH A
         POOR STAND OF GRASS, A SURFACE SLOPE OF 10.%
         AND A SLOPE LENGTH OF   50. FEET.

SCS RUNOFF CURVE NUMBER              =     94.30
FRACTION OF AREA ALLOWING RUNOFF     =     80.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      3.940   ACRES
EVAPORATIVE ZONE DEPTH               =     18.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      5.490   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      6.570   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      3.636   INCHES
```

Attachment 'C'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	43.692	INCHES
TOTAL INITIAL WATER	=	43.692	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

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EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Evansville Indiana

STATION LATITUDE	=	37.05	DEGREES
MAXIMUM LEAF AREA INDEX	=	1.05	
START OF GROWING SEASON (JULIAN DATE)	=	96	
END OF GROWING SEASON (JULIAN DATE)	=	300	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.31	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.47	3.93	4.27	4.95	4.75	4.51
4.45	2.99	3.56	3.45	4.53	4.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.90	38.10	47.60	57.00	65.90	74.50
78.20	76.20	69.10	58.00	46.80	36.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

COEFFICIENTS FOR EVANSVILLE INDIANA
AND STATION LATITUDE = 37.03 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.94	642740.875	100.00
RUNOFF	21.717	310594.469	48.32
EVAPOTRANSPIRATION	23.607	337637.812	52.53
DRAINAGE COLLECTED FROM LAYER 4	0.4886	6987.498	1.09
PERC./LEAKAGE THROUGH LAYER 6	0.000015	0.211	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0108		
CHANGE IN WATER STORAGE	-0.873	-12479.181	-1.94
SOIL WATER AT START OF YEAR	43.692	624890.875	
SOIL WATER AT END OF YEAR	42.819	612411.687	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.070	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.57	780471.062	100.00
RUNOFF	30.580	437355.969	56.04
EVAPOTRANSPIRATION	24.057	344063.656	44.08

DRAINAGE COLLECTED FROM LAYER 4	0.1467	2098.825	0.27
PERC./LEAKAGE THROUGH LAYER 6	0.000006	0.082	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0032		
CHANGE IN WATER STORAGE	-0.213	-3047.408	-0.39
SOIL WATER AT START OF YEAR	42.819	612411.687	
SOIL WATER AT END OF YEAR	42.606	609364.125	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.179	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.055	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.47	821947.437	100.00
RUNOFF	31.886	456040.344	55.48
EVAPOTRANSPIRATION	25.682	367312.844	44.69
DRAINAGE COLLECTED FROM LAYER 4	0.0246	351.376	0.04
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.033	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0005		
CHANGE IN WATER STORAGE	-0.123	-1757.032	-0.21
SOIL WATER AT START OF YEAR	42.606	609364.125	
SOIL WATER AT END OF YEAR	42.079	601828.187	
SNOW WATER AT START OF YEAR	0.000	0.179	0.00
SNOW WATER AT END OF YEAR	0.404	5779.049	0.70

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ANNUAL WATER BUDGET BALANCE	0.0000	-0.078	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.30	576378.687	100.00
RUNOFF	18.693	267350.906	46.38
EVAPOTRANSPIRATION	21.864	312706.406	54.25
DRAINAGE COLLECTED FROM LAYER 4	0.0014	20.646	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000001	0.019	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.259	-3699.277	-0.64
SOIL WATER AT START OF YEAR	42.079	601828.187	
SOIL WATER AT END OF YEAR	42.225	603908.000	
SNOW WATER AT START OF YEAR	0.404	5779.049	1.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.028	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.87	684646.187	100.00
RUNOFF	24.295	347475.906	50.75

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

EVAPOTRANSPIRATION	22.359	319778.906	46.71
DRAINAGE COLLECTED FROM LAYER 4	0.5049	7220.855	1.05
PERC./LEAKAGE THROUGH LAYER 6	0.000015	0.209	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0112		
CHANGE IN WATER STORAGE	0.711	10170.645	1.49
SOIL WATER AT START OF YEAR	42.225	603908.000	
SOIL WATER AT END OF YEAR	42.936	614078.625	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.293	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.37	720401.937	100.00
RUNOFF	25.828	369403.094	51.28
EVAPOTRANSPIRATION	24.001	343269.250	47.65
DRAINAGE COLLECTED FROM LAYER 4	0.0050	70.827	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.023	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0001		
CHANGE IN WATER STORAGE	0.535	7658.659	1.06
SOIL WATER AT START OF YEAR	42.936	614078.625	
SOIL WATER AT END OF YEAR	43.471	621737.312	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

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ANNUAL WATER BUDGET BALANCE	0.0000	0.103	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.14	717112.375	100.00
RUNOFF	28.357	405562.094	56.55
EVAPOTRANSPIRATION	20.252	289654.594	40.39
DRAINAGE COLLECTED FROM LAYER 4	0.8322	11902.586	1.66
PERC./LEAKAGE THROUGH LAYER 6	0.000022	0.321	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0187		
CHANGE IN WATER STORAGE	0.699	9992.896	1.39
SOIL WATER AT START OF YEAR	43.471	621737.312	
SOIL WATER AT END OF YEAR	43.840	627013.625	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.330	4716.537	0.66
ANNUAL WATER BUDGET BALANCE	0.0000	-0.114	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.20	603552.750	100.00
RUNOFF	23.435	335177.000	55.53

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

EVAPOTRANSPIRATION	19.630	280753.969	46.52
DRAINAGE COLLECTED FROM LAYER 4	0.7689	10997.458	1.82
PERC./LEAKAGE THROUGH LAYER 6	0.000021	0.304	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0173		
CHANGE IN WATER STORAGE	-1.634	-23375.785	-3.87
SOIL WATER AT START OF YEAR	43.840	627013.625	
SOIL WATER AT END OF YEAR	42.536	608354.375	
SNOW WATER AT START OF YEAR	0.330	4716.537	0.78
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.172	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	67.92	971405.312	100.00
RUNOFF	38.967	557311.250	57.37
EVAPOTRANSPIRATION	24.305	347612.719	35.78
DRAINAGE COLLECTED FROM LAYER 4	1.3889	19863.975	2.04
PERC./LEAKAGE THROUGH LAYER 6	0.000035	0.506	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0307		
CHANGE IN WATER STORAGE	3.259	46617.102	4.80
SOIL WATER AT START OF YEAR	42.536	608354.375	
SOIL WATER AT END OF YEAR	44.980	643319.187	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

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SNOW WATER AT END OF YEAR	0.815	11652.316	1.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.252	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.07	573089.187	100.00
RUNOFF	19.734	282234.750	49.25
EVAPOTRANSPIRATION	21.774	311413.125	54.34
DRAINAGE COLLECTED FROM LAYER 4	1.6815	24048.439	4.20
PERC./LEAKAGE THROUGH LAYER 6	0.000043	0.621	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0376		
CHANGE IN WATER STORAGE	-3.119	-44607.832	-7.78
SOIL WATER AT START OF YEAR	44.980	643319.187	
SOIL WATER AT END OF YEAR	42.624	609622.125	
SNOW WATER AT START OF YEAR	0.815	11652.316	2.03
SNOW WATER AT END OF YEAR	0.052	741.546	0.13
ANNUAL WATER BUDGET BALANCE	0.0000	0.067	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.73	711248.500	100.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

RUNOFF	24.503	350452.750	49.27
EVAPOTRANSPIRATION	20.888	298739.469	42.00
DRAINAGE COLLECTED FROM LAYER 4	1.3081	18708.734	2.63
PERC./LEAKAGE THROUGH LAYER 6	0.000033	0.479	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0290		
CHANGE IN WATER STORAGE	3.031	43346.996	6.09
SOIL WATER AT START OF YEAR	42.624	609622.125	
SOIL WATER AT END OF YEAR	43.809	626558.625	
SNOW WATER AT START OF YEAR	0.052	741.546	0.10
SNOW WATER AT END OF YEAR	1.898	27152.033	3.82
ANNUAL WATER BUDGET BALANCE	0.0000	0.122	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.27	504438.594	100.00
RUNOFF	18.687	267259.156	52.98
EVAPOTRANSPIRATION	18.508	264698.562	52.47
DRAINAGE COLLECTED FROM LAYER 4	0.8797	12581.082	2.49
PERC./LEAKAGE THROUGH LAYER 6	0.000024	0.339	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0195		
CHANGE IN WATER STORAGE	-2.804	-40100.633	-7.95
SOIL WATER AT START OF YEAR	43.809	626558.625	
SOIL WATER AT END OF YEAR	42.903	613610.000	
SNOW WATER AT START OF YEAR	1.898	27152.033	5.38

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SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.119	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.98	586104.125	100.00
RUNOFF	24.444	349601.969	59.65
EVAPOTRANSPIRATION	16.579	237120.687	40.46
DRAINAGE COLLECTED FROM LAYER 4	0.0014	19.987	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000001	0.019	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.045	-638.553	-0.11
SOIL WATER AT START OF YEAR	42.903	613610.000	
SOIL WATER AT END OF YEAR	42.859	612971.437	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.010	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	51.77	740425.000	100.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

RUNOFF	28.220	403606.031	54.51
EVAPOTRANSPIRATION	23.200	331805.062	44.81
DRAINAGE COLLECTED FROM LAYER 4	0.0020	28.629	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.022	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.349	4985.016	0.67
SOIL WATER AT START OF YEAR	42.859	612971.437	
SOIL WATER AT END OF YEAR	43.207	617956.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.292	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.36	634445.687	100.00
RUNOFF	26.203	374765.437	59.07
EVAPOTRANSPIRATION	18.193	260200.516	41.01
DRAINAGE COLLECTED FROM LAYER 4	0.6938	9923.364	1.56
PERC./LEAKAGE THROUGH LAYER 6	0.000019	0.277	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0155		
CHANGE IN WATER STORAGE	-0.730	-10443.928	-1.65
SOIL WATER AT START OF YEAR	43.207	617956.500	
SOIL WATER AT END OF YEAR	42.477	607512.562	

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.016	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 15

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.47	3.62	4.18	4.45	4.38	4.96
	4.46	3.28	4.16	2.59	4.56	3.76
STD. DEVIATIONS	2.31	1.69	1.97	2.32	1.98	2.38
	2.03	2.48	2.31	1.48	3.85	1.83
RUNOFF						
TOTALS	2.209	2.212	2.127	2.096	2.089	2.519
	2.224	1.758	2.368	1.411	2.438	2.253
STD. DEVIATIONS	1.832	1.471	1.321	1.519	1.221	1.547
	1.375	1.804	1.627	1.083	2.805	2.395
EVAPOTRANSPIRATION						
TOTALS	0.814	1.205	2.350	3.115	2.534	2.495
	2.237	1.608	1.664	1.147	1.312	1.179
STD. DEVIATIONS	0.286	0.360	0.522	0.688	0.708	0.975
	0.835	0.709	0.555	0.570	0.434	0.229
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0357	0.0634	0.1971	0.1654	0.1042	0.0157
	0.0001	0.0001	0.0001	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.1331	0.1106	0.2740	0.1535	0.1153	0.0334
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003

Attachment 'C'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0094	0.0182	0.0516	0.0447	0.0273	0.0042
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0348	0.0316	0.0717	0.0415	0.0302	0.0090
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 15

	INCHES		CU. FEET	PERCENT
PRECIPITATION	47.86	(8.223)	684560.5	100.00
RUNOFF	25.703	(5.4223)	367612.78	53.701
EVAPOTRANSPIRATION	21.660	(2.6128)	309784.47	45.253
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.58184	(0.56341)	8321.619	1.21561
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00002	(0.00001)	0.231	0.00003
AVERAGE HEAD ON TOP OF LAYER 5	0.013	(0.013)		
CHANGE IN WATER STORAGE	-0.081	(1.7484)	-1158.55	-0.169

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 15

	INCHES	(CU. FT.)
PRECIPITATION	6.53	93393.367
RUNOFF	4.250	60779.9414
DRAINAGE COLLECTED FROM LAYER 4	0.02953	422.41367
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000001	0.00985
AVERAGE HEAD ON TOP OF LAYER 5	0.240	
MAXIMUM HEAD ON TOP OF LAYER 5	0.466	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.8 FEET	
SNOW WATER	6.95	99403.4062

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3633
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.2020

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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Attachment 'C'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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FINAL WATER STORAGE AT END OF YEAR 15

LAYER	(INCHES)	(VOL/VOL)
1	7.9348	0.2645
2	13.1400	0.0730
3	5.4900	0.3050
4	0.5400	0.0450
5	0.0000	0.0000
6	15.3720	0.4270
SNOW WATER	0.000	

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Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      C:\HELP3\PREC15DA.D4
TEMPERATURE DATA FILE:        C:\HELP3\PADTEMP.D7
SOLAR RADIATION DATA FILE:    C:\HELP3\PADSOLAR.D13
EVAPOTRANSPIRATION DATA:      C:\HELP3\EVAPOC.D11
SOIL AND DESIGN DATA FILE:    C:\HELP3\PH45OC.D10
OUTPUT DATA FILE:             C:\HELP3\PH45OC.OUT


TIME:  10:36      DATE:    6/ 6/2008


******************************************************************************

     TITLE:  Paducah - Add. 4 Ditches to Op. Cover - 48in avg. - Ph4&5

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  24
          THICKNESS                  =      48.00   INCHES
          POROSITY                   =       0.3650 VOL/VOL
          FIELD CAPACITY             =       0.3050 VOL/VOL
          WILTING POINT              =       0.2020 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.270000010000E-05 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
        FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
             MATERIAL TEXTURE NUMBER  24
THICKNESS                   =     18.00   INCHES
POROSITY                    =      0.3650 VOL/VOL
FIELD CAPACITY              =      0.3050 VOL/VOL
WILTING POINT               =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.270000010000E-05 CM/SEC


                    LAYER  3
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
             MATERIAL TEXTURE NUMBER   1
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4170 VOL/VOL
FIELD CAPACITY              =      0.0450 VOL/VOL
WILTING POINT               =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
SLOPE                       =     11.00   PERCENT
DRAINAGE LENGTH             =     50.0    FEET


                    LAYER  4
                    --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
             MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.08   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      2.00   HOLES/ACRE
```

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

```
FML INSTALLATION DEFECTS      =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD
```

LAYER 5

```
TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER  16
THICKNESS                     =     36.00   INCHES
POROSITY                      =      0.4270 VOL/VOL
FIELD CAPACITY                =      0.4180 VOL/VOL
WILTING POINT                 =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #24 WITH A
         FAIR STAND OF GRASS, A SURFACE SLOPE OF 20.
         AND A SLOPE LENGTH OF   12. FEET.

SCS RUNOFF CURVE NUMBER                =     92.10
FRACTION OF AREA ALLOWING RUNOFF       =     98.0     PERCENT
AREA PROJECTED ON HORIZONTAL PLANE     =      1.530   ACRES
EVAPORATIVE ZONE DEPTH                 =     18.0     INCHES
INITIAL WATER IN EVAPORATIVE ZONE      =      5.490   INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE     =      6.570   INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE     =      3.636   INCHES
INITIAL SNOW WATER                     =      0.000   INCHES
INITIAL WATER IN LAYER MATERIALS       =     36.042   INCHES
TOTAL INITIAL WATER                    =     36.042   INCHES
TOTAL SUBSURFACE INFLOW                =      0.00    INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         Evansville            Indiana

     STATION LATITUDE                          =  37.05 DEGREES
```

Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	96	
END OF GROWING SEASON (JULIAN DATE)	=	300	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.31	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	70.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	54.00	%

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NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.47	3.93	4.27	4.95	4.75	4.51
4.45	2.99	3.56	3.45	4.53	4.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.90	38.10	47.60	57.00	65.90	74.50
78.20	76.20	69.10	58.00	46.80	36.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR EVANSVILLE INDIANA AND STATION LATITUDE = 37.03 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.94	249592.250	100.00
RUNOFF	19.239	106851.656	42.81

EVAPOTRANSPIRATION	24.279	134845.391	54.03
DRAINAGE COLLECTED FROM LAYER 3	1.5348	8523.980	3.42
PERC./LEAKAGE THROUGH LAYER 5	0.000040	0.223	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0341		
CHANGE IN WATER STORAGE	-0.113	-628.962	-0.25
SOIL WATER AT START OF YEAR	36.042	200173.312	
SOIL WATER AT END OF YEAR	35.929	199544.359	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.038	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.57	303076.312	100.00
RUNOFF	28.475	158148.469	52.18
EVAPOTRANSPIRATION	24.653	136918.781	45.18
DRAINAGE COLLECTED FROM LAYER 3	1.7872	9925.703	3.27
PERC./LEAKAGE THROUGH LAYER 5	0.000047	0.259	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0396		
CHANGE IN WATER STORAGE	-0.345	-1916.886	-0.63
SOIL WATER AT START OF YEAR	35.929	199544.359	
SOIL WATER AT END OF YEAR	35.584	197627.469	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.017	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.47	319182.625	100.00
RUNOFF	29.716	165038.859	51.71
EVAPOTRANSPIRATION	26.323	146197.406	45.80
DRAINAGE COLLECTED FROM LAYER 3	1.5645	8689.070	2.72
PERC./LEAKAGE THROUGH LAYER 5	0.000041	0.227	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0346		
CHANGE IN WATER STORAGE	-0.134	-742.929	-0.23
SOIL WATER AT START OF YEAR	35.584	197627.469	
SOIL WATER AT END OF YEAR	35.046	194640.391	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.404	2244.148	0.70
ANNUAL WATER BUDGET BALANCE	0.0000	0.001	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.30	223822.187	100.00

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RUNOFF	15.715	87278.781	38.99
EVAPOTRANSPIRATION	23.938	132950.016	59.40
DRAINAGE COLLECTED FROM LAYER 3	0.8258	4586.218	2.05
PERC./LEAKAGE THROUGH LAYER 5	0.000024	0.131	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0183		
CHANGE IN WATER STORAGE	-0.179	-993.046	-0.44
SOIL WATER AT START OF YEAR	35.046	194640.391	
SOIL WATER AT END OF YEAR	35.271	195891.500	
SNOW WATER AT START OF YEAR	0.404	2244.148	1.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.078	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.87	265865.125	100.00
RUNOFF	22.446	124660.680	46.89
EVAPOTRANSPIRATION	22.351	124132.687	46.69
DRAINAGE COLLECTED FROM LAYER 3	1.8272	10148.218	3.82
PERC./LEAKAGE THROUGH LAYER 5	0.000046	0.257	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0407		
CHANGE IN WATER STORAGE	1.247	6923.349	2.60
SOIL WATER AT START OF YEAR	35.271	195891.500	
SOIL WATER AT END OF YEAR	36.518	202814.844	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.061	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.37	279749.969	100.00
RUNOFF	23.505	130543.562	46.66
EVAPOTRANSPIRATION	25.299	140505.937	50.23
DRAINAGE COLLECTED FROM LAYER 3	1.6963	9421.048	3.37
PERC./LEAKAGE THROUGH LAYER 5	0.000045	0.248	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0377		
CHANGE IN WATER STORAGE	-0.130	-720.932	-0.26
SOIL WATER AT START OF YEAR	36.518	202814.844	
SOIL WATER AT END OF YEAR	36.388	202093.906	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.105	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.14	278422.562	100.00

RUNOFF	26.582	147633.094	53.02
EVAPOTRANSPIRATION	20.779	115403.750	41.44
DRAINAGE COLLECTED FROM LAYER 3	1.6937	9406.900	3.38
PERC./LEAKAGE THROUGH LAYER 5	0.000044	0.243	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0379		
CHANGE IN WATER STORAGE	1.085	6028.594	2.16
SOIL WATER AT START OF YEAR	36.388	202093.906	
SOIL WATER AT END OF YEAR	37.178	206483.656	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.295	1638.847	0.59
ANNUAL WATER BUDGET BALANCE	0.0000	-0.034	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.20	234374.531	100.00
RUNOFF	21.553	119703.406	51.07
EVAPOTRANSPIRATION	20.605	114438.766	48.83
DRAINAGE COLLECTED FROM LAYER 3	1.8576	10316.858	4.40
PERC./LEAKAGE THROUGH LAYER 5	0.000046	0.257	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0420		
CHANGE IN WATER STORAGE	-1.816	-10084.718	-4.30
SOIL WATER AT START OF YEAR	37.178	206483.656	
SOIL WATER AT END OF YEAR	35.657	198037.797	

Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT START OF YEAR	0.295	1638.847	0.70
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.046	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	67.92	377220.844	100.00
RUNOFF	37.233	206787.000	54.82
EVAPOTRANSPIRATION	24.793	137700.266	36.50
DRAINAGE COLLECTED FROM LAYER 3	2.6335	14626.122	3.88
PERC./LEAKAGE THROUGH LAYER 5	0.000065	0.359	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0581		
CHANGE IN WATER STORAGE	3.260	18107.113	4.80
SOIL WATER AT START OF YEAR	35.657	198037.797	
SOIL WATER AT END OF YEAR	38.103	211620.016	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.815	4524.884	1.20
ANNUAL WATER BUDGET BALANCE	0.0000	-0.036	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PRECIPITATION	40.07	222544.766	100.00
RUNOFF	17.307	96123.375	43.19
EVAPOTRANSPIRATION	23.032	127915.445	57.48
DRAINAGE COLLECTED FROM LAYER 3	2.8825	16008.846	7.19
PERC./LEAKAGE THROUGH LAYER 5	0.000072	0.399	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0643		
CHANGE IN WATER STORAGE	-3.152	-17503.254	-7.87
SOIL WATER AT START OF YEAR	38.103	211620.016	
SOIL WATER AT END OF YEAR	35.763	198622.797	
SNOW WATER AT START OF YEAR	0.815	4524.884	2.03
SNOW WATER AT END OF YEAR	0.003	18.857	0.01
ANNUAL WATER BUDGET BALANCE	0.0000	-0.048	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.73	276195.469	100.00
RUNOFF	22.205	123326.008	44.65
EVAPOTRANSPIRATION	22.116	122828.992	44.47
DRAINAGE COLLECTED FROM LAYER 3	2.5014	13892.707	5.03
PERC./LEAKAGE THROUGH LAYER 5	0.000061	0.341	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0556		
CHANGE IN WATER STORAGE	2.907	16147.388	5.85
SOIL WATER AT START OF YEAR	35.763	198622.797	
SOIL WATER AT END OF YEAR	36.780	204272.734	

Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SNOW WATER AT START OF YEAR	0.003	18.857	0.01
SNOW WATER AT END OF YEAR	1.893	10516.307	3.81
ANNUAL WATER BUDGET BALANCE	0.0000	0.039	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.27	195886.047	100.00
RUNOFF	16.992	94369.820	48.18
EVAPOTRANSPIRATION	18.902	104981.648	53.59
DRAINAGE COLLECTED FROM LAYER 3	2.1963	12198.064	6.23
PERC./LEAKAGE THROUGH LAYER 5	0.000056	0.308	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0487		
CHANGE IN WATER STORAGE	-2.820	-15663.851	-8.00
SOIL WATER AT START OF YEAR	36.780	204272.734	
SOIL WATER AT END OF YEAR	35.853	199125.187	
SNOW WATER AT START OF YEAR	1.893	10516.307	5.37
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.053	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT

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PRECIPITATION	40.98	227598.797	100.00
RUNOFF	22.619	125625.297	55.20
EVAPOTRANSPIRATION	17.463	96987.133	42.61
DRAINAGE COLLECTED FROM LAYER 3	1.0179	5653.153	2.48
PERC./LEAKAGE THROUGH LAYER 5	0.000028	0.154	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0225		
CHANGE IN WATER STORAGE	-0.120	-666.949	-0.29
SOIL WATER AT START OF YEAR	35.853	199125.187	
SOIL WATER AT END OF YEAR	35.733	198458.234	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	51.77	287525.437	100.00
RUNOFF	26.303	146085.844	50.81
EVAPOTRANSPIRATION	24.972	138692.562	48.24
DRAINAGE COLLECTED FROM LAYER 3	0.1354	751.724	0.26
PERC./LEAKAGE THROUGH LAYER 5	0.000006	0.031	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0030		
CHANGE IN WATER STORAGE	0.359	1995.339	0.69
SOIL WATER AT START OF YEAR	35.733	198458.234	

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

SOIL WATER AT END OF YEAR	36.092	200453.578	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.071	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.36	246371.031	100.00
RUNOFF	25.530	141791.391	57.55
EVAPOTRANSPIRATION	18.175	100943.656	40.97
DRAINAGE COLLECTED FROM LAYER 3	1.6037	8906.818	3.62
PERC./LEAKAGE THROUGH LAYER 5	0.000042	0.234	0.00
AVG. HEAD ON TOP OF LAYER 4	0.0358		
CHANGE IN WATER STORAGE	-0.949	-5271.103	-2.14
SOIL WATER AT START OF YEAR	36.092	200453.578	
SOIL WATER AT END OF YEAR	35.143	195182.469	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.015	0.00

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Paducah Remediation Services

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 15

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.47	3.62	4.18	4.45	4.38	4.96
	4.46	3.28	4.16	2.59	4.56	3.76
STD. DEVIATIONS	2.31	1.69	1.97	2.32	1.98	2.38
	2.03	2.48	2.31	1.48	3.85	1.83
RUNOFF						
TOTALS	2.064	2.104	1.865	1.893	1.875	2.322
	2.030	1.613	2.240	1.306	2.302	2.080
STD. DEVIATIONS	1.786	1.470	1.298	1.494	1.180	1.495
	1.420	1.780	1.616	1.133	2.819	2.417
EVAPOTRANSPIRATION						
TOTALS	0.767	1.123	2.261	3.057	3.194	2.803
	2.389	1.772	1.683	1.154	1.251	1.058
STD. DEVIATIONS	0.232	0.383	0.467	0.687	0.743	1.164
	0.873	0.762	0.528	0.598	0.367	0.173
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0523	0.1289	0.3822	0.4106	0.3454	0.2429
	0.1373	0.0165	0.0001	0.0001	0.0000	0.0009
STD. DEVIATIONS	0.1590	0.2156	0.3805	0.2239	0.1561	0.1055
	0.0956	0.0355	0.0001	0.0001	0.0001	0.0018
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVERAGES	0.0137	0.0368	0.1001	0.1111	0.0904	0.0657
	0.0359	0.0043	0.0000	0.0000	0.0000	0.0002
STD. DEVIATIONS	0.0416	0.0608	0.0996	0.0606	0.0409	0.0285
	0.0250	0.0093	0.0000	0.0000	0.0000	0.0005

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 15

	INCHES		CU. FEET	PERCENT
PRECIPITATION	47.86	(8.223)	265831.8	100.00
RUNOFF	23.695	(5.6043)	131597.81	49.504
EVAPOTRANSPIRATION	22.512	(2.7737)	125029.51	47.033
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.71718	(0.70382)	9537.028	3.58762
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00004	(0.00002)	0.245	0.00009
AVERAGE HEAD ON TOP OF LAYER 4	0.038	(0.016)		
CHANGE IN WATER STORAGE	-0.060	(1.7766)	-332.72	-0.125

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 15

	(INCHES)	(CU. FT.)
PRECIPITATION	6.53	36266.969
RUNOFF	4.378	24316.4863
DRAINAGE COLLECTED FROM LAYER 3	0.05310	294.88861
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000001	0.00650
AVERAGE HEAD ON TOP OF LAYER 4	0.431	
MAXIMUM HEAD ON TOP OF LAYER 4	0.824	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN	1.6 FEET	
SNOW WATER	6.93	38495.3555

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3650

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2020

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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Attachment 'D'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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FINAL WATER STORAGE AT END OF YEAR 15

LAYER	(INCHES)	(VOL/VOL)
1	13.7413	0.2863
2	5.4900	0.3050
3	0.5400	0.0450
4	0.0000	0.0000
5	15.3720	0.4270
SNOW WATER	0.000	

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\PREC15DA.D4
TEMPERATURE DATA FILE:       C:\HELP3\PADTEMP.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\PADSOLAR.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\EVAPFC.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\FINCOVER.D10
OUTPUT DATA FILE:            C:\HELP3\FINCOVER.OUT


TIME:  10:59     DATE:   6/ 6/2008


******************************************************************************

     TITLE:  Paducah Landfill - Final Cover Conditions (1 - 30 years)

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3980 VOL/VOL
          FIELD CAPACITY             =      0.2440 VOL/VOL
          WILTING POINT              =      0.1360 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.3295 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
       FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                    LAYER  2
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  24
THICKNESS                   =     30.00   INCHES
POROSITY                    =      0.3650 VOL/VOL
FIELD CAPACITY              =      0.3050 VOL/VOL
WILTING POINT               =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3661 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.270000010000E-05 CM/SEC


                    LAYER  3
                    --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
THICKNESS.                  =      0.04   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      5.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  4 - POOR


                    LAYER  4
                    --------

          TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =      6.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
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                    LAYER  5
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  24
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3650 VOL/VOL
FIELD CAPACITY               =      0.3050 VOL/VOL
WILTING POINT                =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.270000010000E-05 CM/SEC


                    LAYER  6
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC


                    LAYER  7
                    --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  19
THICKNESS                    =    720.00   INCHES
POROSITY                     =      0.1680 VOL/VOL
FIELD CAPACITY               =      0.0730 VOL/VOL
WILTING POINT                =      0.0190 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0730 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                    LAYER  8
                    --------
```

```
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  24
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.3650 VOL/VOL
FIELD CAPACITY               =      0.3050 VOL/VOL
WILTING POINT                =      0.2020 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3050 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.270000010000E-05 CM/SEC


                        LAYER  9
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0452 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =     11.00   PERCENT
DRAINAGE LENGTH              =     50.0    FEET


                        LAYER 10
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      2.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER 11
                        --------

            TYPE 3 - BARRIER SOIL LINER
            MATERIAL TEXTURE NUMBER  16
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```
THICKNESS                    =     36.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 11. AND A SLOPE LENGTH OF 145. FEET.

```
SCS RUNOFF CURVE NUMBER              =     81.90
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      8.567  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      8.958  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      4.452  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     93.148  INCHES
TOTAL INITIAL WATER                  =     93.148  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Evansville Indiana

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STATION LATITUDE                          =  37.05 DEGREES
MAXIMUM LEAF AREA INDEX                   =   3.50
START OF GROWING SEASON (JULIAN DATE)     =     96
END OF GROWING SEASON (JULIAN DATE)       =    300
EVAPORATIVE ZONE DEPTH                    =  24.0  INCHES
AVERAGE ANNUAL WIND SPEED                 =   7.31 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  70.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY     =  67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY     =  72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY     =  54.00 %
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Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.47	3.93	4.27	4.95	4.75	4.51
4.45	2.99	3.56	3.45	4.53	4.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.90	38.10	47.60	57.00	65.90	74.50
78.20	76.20	69.10	58.00	46.80	36.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR EVANSVILLE INDIANA
AND STATION LATITUDE = 37.03 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.94	163132.187	100.00
RUNOFF	10.950	39748.270	24.37
EVAPOTRANSPIRATION	33.800	122694.672	75.21
PERC./LEAKAGE THROUGH LAYER 4	0.161168	585.040	0.36
AVG. HEAD ON TOP OF LAYER 3	25.5128		
DRAINAGE COLLECTED FROM LAYER 9	0.1617	587.034	0.36
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.029	0.00

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AVG. HEAD ON TOP OF LAYER 10	0.0036		
CHANGE IN WATER STORAGE	0.028	102.166	0.06
SOIL WATER AT START OF YEAR	93.148	338128.406	
SOIL WATER AT END OF YEAR	93.176	338230.594	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.020	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.57	198089.094	100.00
RUNOFF	22.840	82910.539	41.86
EVAPOTRANSPIRATION	31.267	113498.344	57.30
PERC./LEAKAGE THROUGH LAYER 4	0.169033	613.589	0.31
AVG. HEAD ON TOP OF LAYER 3	26.5726		
DRAINAGE COLLECTED FROM LAYER 9	0.1690	613.530	0.31
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.030	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0038		
CHANGE IN WATER STORAGE	0.294	1066.661	0.54
SOIL WATER AT START OF YEAR	93.176	338230.594	
SOIL WATER AT END OF YEAR	93.470	339297.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.005	0.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.47	208616.109	100.00
RUNOFF	17.475	63432.742	30.41
EVAPOTRANSPIRATION	39.803	144485.766	69.26
PERC./LEAKAGE THROUGH LAYER 4	0.168661	612.240	0.29
AVG. HEAD ON TOP OF LAYER 3	26.7020		
DRAINAGE COLLECTED FROM LAYER 9	0.1695	615.132	0.29
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.030	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0038		
CHANGE IN WATER STORAGE	0.023	82.444	0.04
SOIL WATER AT START OF YEAR	93.470	339297.250	
SOIL WATER AT END OF YEAR	93.089	337912.906	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.404	1466.764	0.70
ANNUAL WATER BUDGET BALANCE	0.0000	-0.011	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.30	146289.016	100.00

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RUNOFF	8.481	30786.656	21.05
EVAPOTRANSPIRATION	32.601	118343.422	80.90
PERC./LEAKAGE THROUGH LAYER 4	0.138455	502.593	0.34
AVG. HEAD ON TOP OF LAYER 3	22.1220		
DRAINAGE COLLECTED FROM LAYER 9	0.1379	500.725	0.34
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.026	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0031		
CHANGE IN WATER STORAGE	-0.921	-3341.806	-2.28
SOIL WATER AT START OF YEAR	93.089	337912.906	
SOIL WATER AT END OF YEAR	92.572	336037.875	
SNOW WATER AT START OF YEAR	0.404	1466.764	1.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.013	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	47.87	173768.062	100.00
RUNOFF	13.844	50254.324	28.92
EVAPOTRANSPIRATION	33.168	120400.516	69.29
PERC./LEAKAGE THROUGH LAYER 4	0.162592	590.208	0.34
AVG. HEAD ON TOP OF LAYER 3	25.7374		
DRAINAGE COLLECTED FROM LAYER 9	0.1623	589.284	0.34
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.029	0.00

AVG. HEAD ON TOP OF LAYER 10	0.0036		
CHANGE IN WATER STORAGE	0.695	2523.95	1.45
SOIL WATER AT START OF YEAR	92.572	336037.875	
SOIL WATER AT END OF YEAR	93.268	338561.844	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.042	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.37	182843.125	100.00
RUNOFF	11.024	40018.523	21.89
EVAPOTRANSPIRATION	38.963	141435.531	77.35
PERC./LEAKAGE THROUGH LAYER 4	0.148758	539.991	0.30
AVG. HEAD ON TOP OF LAYER 3	23.6894		
DRAINAGE COLLECTED FROM LAYER 9	0.1486	539.494	0.30
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0033		
CHANGE IN WATER STORAGE	0.234	849.590	0.46
SOIL WATER AT START OF YEAR	93.268	338561.844	
SOIL WATER AT END OF YEAR	93.502	339411.437	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.039	0.00

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	50.14	182008.219	100.00
RUNOFF	18.427	66889.719	36.75
EVAPOTRANSPIRATION	31.234	113381.11[illegible]	62.29
PERC./LEAKAGE THROUGH LAYER 4	0.160265	581.761	0.32
AVG. HEAD ON TOP OF LAYER 3	25.3927		
DRAINAGE COLLECTED FROM LAYER 9	0.1603	581.803	0.32
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.029	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0036		
CHANGE IN WATER STORAGE	0.318	1155.5[illegible]4	0.63
SOIL WATER AT START OF YEAR	93.502	339411.437	
SOIL WATER AT END OF YEAR	93.526	339498.812	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.294	1068.197	0.59
ANNUAL WATER BUDGET BALANCE	0.0000	-0.027	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	42.20	153185.969	100.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

RUNOFF	11.098	40285.605	26.30
EVAPOTRANSPIRATION	31.260	113473.250	74.08
PERC./LEAKAGE THROUGH LAYER 4	0.138257	501.874	0.33
AVG. HEAD ON TOP OF LAYER 3	22.0620		
DRAINAGE COLLECTED FROM LAYER 9	0.1395	506.337	0.33
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0031		
CHANGE IN WATER STORAGE	-0.297	-1079.192	-0.70
SOIL WATER AT START OF YEAR	93.526	339498.812	
SOIL WATER AT END OF YEAR	93.523	339487.812	
SNOW WATER AT START OF YEAR	0.294	1068.197	0.70
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.058	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	67.92	246549.562	100.00
RUNOFF	30.039	109042.109	44.23
EVAPOTRANSPIRATION	36.896	133931.453	54.32
PERC./LEAKAGE THROUGH LAYER 4	0.174643	633.956	0.26
AVG. HEAD ON TOP OF LAYER 3	27.4893		
DRAINAGE COLLECTED FROM LAYER 9	0.1742	632.359	0.26
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.030	0.00

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AVG. HEAD ON TOP OF LAYER 10	0.0039		
CHANGE IN WATER STORAGE	0.811	2943.566	1.19
SOIL WATER AT START OF YEAR	93.523	339487.812	
SOIL WATER AT END OF YEAR	93.519	339473.937	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.815	2957.441	1.20
ANNUAL WATER BUDGET BALANCE	0.0000	0.047	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.07	145454.094	100.00
RUNOFF	8.900	32307.178	22.21
EVAPOTRANSPIRATION	31.831	115546.117	79.44
PERC./LEAKAGE THROUGH LAYER 4	0.147738	536.289	0.37
AVG. HEAD ON TOP OF LAYER 3	23.5691		
DRAINAGE COLLECTED FROM LAYER 9	0.1470	533.473	0.37
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0033		
CHANGE IN WATER STORAGE	-0.808	-2932.709	-2.02
SOIL WATER AT START OF YEAR	93.519	339473.937	
SOIL WATER AT END OF YEAR	93.526	339498.656	
SNOW WATER AT START OF YEAR	0.815	2957.441	2.03
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.01	0.00

Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.73	180519.922	100.00
RUNOFF	13.708	49760.207	27.56
EVAPOTRANSPIRATION	33.989	123378.695	68.35
PERC./LEAKAGE THROUGH LAYER 4	0.139922	507.915	0.28
AVG. HEAD ON TOP OF LAYER 3	22.3907		
DRAINAGE COLLECTED FROM LAYER 9	0.1399	507.671	0.28
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0031		
CHANGE IN WATER STORAGE	1.893	6873.349	3.81
SOIL WATER AT START OF YEAR	93.526	339498.656	
SOIL WATER AT END OF YEAR	93.526	339498.875	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.893	6873.127	3.81
ANNUAL WATER BUDGET BALANCE	0.0000	-0.020	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	35.2[illegible]	128030.102	100.00

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RUNOFF	10.453	37942.590	29.64
EVAPOTRANSPIRATION	26.705	96938.570	75.72
PERC./LEAKAGE THROUGH LAYER 4	0.136374	495.039	0.39
AVG. HEAD ON TOP OF LAYER 3	21.6663		
DRAINAGE COLLECTED FROM LAYER 9	0.1364	495.128	0.39
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.026	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0030		
CHANGE IN WATER STORAGE	-2.024	-7346.236	-5.74
SOIL WATER AT START OF YEAR	93.526	339498.875	
SOIL WATER AT END OF YEAR	93.396	339025.781	
SNOW WATER AT START OF YEAR	1.893	6873.127	5.37
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.025	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.98	148757.391	100.00
RUNOFF	10.403	37762.937	25.39
EVAPOTRANSPIRATION	30.419	110422.305	74.23
PERC./LEAKAGE THROUGH LAYER 4	0.139112	504.977	0.34
AVG. HEAD ON TOP OF LAYER 3	22.2483		
DRAINAGE COLLECTED FROM LAYER 9	0.1391	505.069	0.34
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00

Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVG. HEAD ON TOP OF LAYER 10	0.0031		
CHANGE IN WATER STORAGE	0.018	67.049	0.05
SOIL WATER AT START OF YEAR	93.396	339025.781	
SOIL WATER AT END OF YEAR	93.414	339092.812	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.006	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	51.77	187925.125	100.00
RUNOFF	17.179	62358.016	33.18
EVAPOTRANSPIRATION	34.567	125478.937	66.77
PERC./LEAKAGE THROUGH LAYER 4	0.144152	523.272	0.28
AVG. HEAD ON TOP OF LAYER 3	22.8986		
DRAINAGE COLLECTED FROM LAYER 9	0.1442	523.394	0.28
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0032		
CHANGE IN WATER STORAGE	-0.120	-435.333	-0.23
SOIL WATER AT START OF YEAR	93.414	339092.812	
SOIL WATER AT END OF YEAR	93.294	338657.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.092	0.00

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	44.36	161026.812	100.00
RUNOFF	11.880	43123.137	26.78
EVAPOTRANSPIRATION	32.485	117921.539	73.23
PERC./LEAKAGE THROUGH LAYER 4	0.143416	520.601	0.32
AVG. HEAD ON TOP OF LAYER 3	22.9428		
DRAINAGE COLLECTED FROM LAYER 9	0.1434	520.535	0.32
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0032		
CHANGE IN WATER STORAGE	-0.148	-538.440	-0.33
SOIL WATER AT START OF YEAR	93.294	338657.500	
SOIL WATER AT END OF YEAR	93.146	338119.062	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.023	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.40	143021.984	100.00

RUNOFF	8.525	30947.562	21.64
EVAPOTRANSPIRATION	30.353	110182.437	77.04
PERC./LEAKAGE THROUGH LAYER 4	0.141202	512.562	0.36
AVG. HEAD ON TOP OF LAYER 3	22.4733		
DRAINAGE COLLECTED FROM LAYER 9	0.1411	512.254	0.36
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0031		
CHANGE IN WATER STORAGE	0.380	1379.750	0.96
SOIL WATER AT START OF YEAR	93.146	338119.062	
SOIL WATER AT END OF YEAR	93.526	339498.812	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.039	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	52.89	191990.719	100.00
RUNOFF	17.050	61890.223	32.24
EVAPOTRANSPIRATION	33.928	123158.852	64.15
PERC./LEAKAGE THROUGH LAYER 4	0.135073	490.316	0.26
AVG. HEAD ON TOP OF LAYER 3	21.6101		
DRAINAGE COLLECTED FROM LAYER 9	0.1350	490.222	0.26
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.026	0.00

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AVG. HEAD ON TOP OF LAYER 10	0.0030		
CHANGE IN WATER STORAGE	1.777	6451.403	3.36
SOIL WATER AT START OF YEAR	93.526	339498.812	
SOIL WATER AT END OF YEAR	93.526	339498.875	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.777	6451.320	3.36
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	53.61	194604.281	100.00
RUNOFF	20.324	73776.781	37.91
EVAPOTRANSPIRATION	35.166	127653.414	65.60
PERC./LEAKAGE THROUGH LAYER 4	0.156444	567.892	0.29
AVG. HEAD ON TOP OF LAYER 3	24.8313		
DRAINAGE COLLECTED FROM LAYER 9	0.1565	568.100	0.29
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0035		
CHANGE IN WATER STORAGE	-2.037	-7394.075	-3.80
SOIL WATER AT START OF YEAR	93.526	339498.875	
SOIL WATER AT END OF YEAR	93.266	338556.125	
SNOW WATER AT START OF YEAR	1.777	6451.320	3.32
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.041	0.00

Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	57.98	210467.391	100.00
RUNOFF	24.136	87612.195	41.63
EVAPOTRANSPIRATION	32.220	116957.133	55.57
PERC./LEAKAGE THROUGH LAYER 4	0.170009	617.132	0.29
AVG. HEAD ON TOP OF LAYER 3	26.7461		
DRAINAGE COLLECTED FROM LAYER 9	0.1699	616.885	0.29
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.030	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0038		
CHANGE IN WATER STORAGE	1.455	5281.178	2.51
SOIL WATER AT START OF YEAR	93.266	338556.125	
SOIL WATER AT END OF YEAR	93.526	339498.844	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	1.195	4338.450	2.06
ANNUAL WATER BUDGET BALANCE	0.0000	-0.042	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	55.53	201573.937	100.00

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RUNOFF	19.799	71872.133	35.66
EVAPOTRANSPIRATION	36.818	133650.594	66.30
PERC./LEAKAGE THROUGH LAYER 4	0.152449	553.389	0.27
AVG. HEAD ON TOP OF LAYER 3	24.2275		
DRAINAGE COLLECTED FROM LAYER 9	0.1524	553.379	0.27
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0034		
CHANGE IN WATER STORAGE	-1.240	-4502.181	-2.23
SOIL WATER AT START OF YEAR	93.526	339498.844	
SOIL WATER AT END OF YEAR	93.481	339335.125	
SNOW WATER AT START OF YEAR	1.195	4338.450	2.15
SNOW WATER AT END OF YEAR	0.000	0.000	0.0
ANNUAL WATER BUDGET BALANCE	0.0000	-0.013	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	45.48	165092.375	100.00
RUNOFF	6.927	25144.555	15.23
EVAPOTRANSPIRATION	38.608	140147.219	84.89
PERC./LEAKAGE THROUGH LAYER 4	0.150645	546.841	0.33
AVG. HEAD ON TOP OF LAYER 3	23.9660		
DRAINAGE COLLECTED FROM LAYER 9	0.1507	546.963	0.33
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00

Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVG. HEAD ON TOP OF LAYER 10	0.0034		
CHANGE IN WATER STORAGE	-0.206	-746.345	-0.45
SOIL WATER AT START OF YEAR	93.481	339335.125	
SOIL WATER AT END OF YEAR	93.275	338588.781	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.057	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	45.03	163458.875	100.00
RUNOFF	11.765	42707.785	26.13
EVAPOTRANSPIRATION	33.029	119894.227	73.35
PERC./LEAKAGE THROUGH LAYER 4	0.148478	538.976	0.33
AVG. HEAD ON TOP OF LAYER 3	23.6179		
DRAINAGE COLLECTED FROM LAYER 9	0.1485	538.899	0.33
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0033		
CHANGE IN WATER STORAGE	0.088	317.963	0.19
SOIL WATER AT START OF YEAR	93.275	338588.781	
SOIL WATER AT END OF YEAR	93.363	338906.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.036	0.00

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	52.54	190720.203	100.00
RUNOFF	18.562	67381.008	35.33
EVAPOTRANSPIRATION	34.190	124110.953	65.07
PERC./LEAKAGE THROUGH LAYER 4	0.167453	607.855	0.32
AVG. HEAD ON TOP OF LAYER 3	26.4192		
DRAINAGE COLLECTED FROM LAYER 9	0.1676	608.244	0.32
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.030	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0037		
CHANGE IN WATER STORAGE	-0.380	-1379.999	-0.72
SOIL WATER AT START OF YEAR	93.363	338906.750	
SOIL WATER AT END OF YEAR	92.983	337526.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.036	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.09	178196.672	100.00

RUNOFF	17.498	63517.371	35.64
EVAPOTRANSPIRATION	30.953	112359.312	63.05
PERC./LEAKAGE THROUGH LAYER 4	0.124747	452.830	0.25
AVG. HEAD ON TOP OF LAYER 3	19.9241		
DRAINAGE COLLECTED FROM LAYER 9	0.1247	452.810	0.25
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.025	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0028		
CHANGE IN WATER STORAGE	0.514	1867.177	1.05
SOIL WATER AT START OF YEAR	92.983	337526.750	
SOIL WATER AT END OF YEAR	93.497	339393.937	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.019	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	49.11	178269.281	100.00
RUNOFF	14.346	52075.070	29.21
EVAPOTRANSPIRATION	34.594	125574.969	70.44
PERC./LEAKAGE THROUGH LAYER 4	0.152982	555.324	0.31
AVG. HEAD ON TOP OF LAYER 3	24.2640		
DRAINAGE COLLECTED FROM LAYER 9	0.1540	559.173	0.31
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.028	0.00

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AVG. HEAD ON TOP OF LAYER 10	0.0034		
CHANGE IN WATER STORAGE	0.017	60.042	0.03
SOIL WATER AT START OF YEAR	93.497	339393.937	
SOIL WATER AT END OF YEAR	93.513	339453.969	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.007	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	37.59	136451.687	100.00
RUNOFF	9.684	35153.184	25.76
EVAPOTRANSPIRATION	27.775	100822.375	73.89
PERC./LEAKAGE THROUGH LAYER 4	0.120663	438.007	0.32
AVG. HEAD ON TOP OF LAYER 3	19.4731		
DRAINAGE COLLECTED FROM LAYER 9	0.1195	433.613	0.32
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.024	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0027		
CHANGE IN WATER STORAGE	0.012	42.484	0.03
SOIL WATER AT START OF YEAR	93.513	339453.969	
SOIL WATER AT END OF YEAR	93.525	339496.437	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.007	0.00

Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	52.92	192099.547	100.00
RUNOFF	17.028	61811.066	32.18
EVAPOTRANSPIRATION	35.805	129972.609	67.66
PERC./LEAKAGE THROUGH LAYER 4	0.145349	527.617	0.27
AVG. HEAD ON TOP OF LAYER 3	23.1848		
DRAINAGE COLLECTED FROM LAYER 9	0.1453	527.593	0.27
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0032		
CHANGE IN WATER STORAGE	-0.058	-211.781	-0.11
SOIL WATER AT START OF YEAR	93.525	339496.437	
SOIL WATER AT END OF YEAR	93.467	339284.656	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.040	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.55	143566.531	100.00

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RUNOFF	11.205	40674.551	28.33
EVAPOTRANSPIRATION	28.139	102143.797	71.15
PERC./LEAKAGE THROUGH LAYER 4	0.147767	536.396	0.37
AVG. HEAD ON TOP OF LAYER 3	23.3545		
DRAINAGE COLLECTED FROM LAYER 9	0.1477	536.304	0.37
PERC./LEAKAGE THROUGH LAYER 11	0.000008	0.027	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0033		
CHANGE IN WATER STORAGE	0.058	211.864	0.15
SOIL WATER AT START OF YEAR	93.467	339284.656	
SOIL WATER AT END OF YEAR	93.525	339496.531	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.017	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66	147595.781	100.00
RUNOFF	11.981	43492.152	29.47
EVAPOTRANSPIRATION	29.718	107875.609	73.09
PERC./LEAKAGE THROUGH LAYER 4	0.123341	447.729	0.30
AVG. HEAD ON TOP OF LAYER 3	19.8176		
DRAINAGE COLLECTED FROM LAYER 9	0.1240	450.077	0.30
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.025	0.00

AVG. HEAD ON TOP OF LAYER 10	0.0028		
CHANGE IN WATER STORAGE	-1.163	-4222.057	-2.86
SOIL WATER AT START OF YEAR	93.525	339496.531	
SOIL WATER AT END OF YEAR	92.362	335274.469	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.017	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.52	147087.625	100.00
RUNOFF	12.331	44759.965	30.43
EVAPOTRANSPIRATION	27.027	98109.648	66.70
PERC./LEAKAGE THROUGH LAYER 4	0.125749	456.469	0.31
AVG. HEAD ON TOP OF LAYER 3	20.2705		
DRAINAGE COLLECTED FROM LAYER 9	0.1251	454.172	0.31
PERC./LEAKAGE THROUGH LAYER 11	0.000007	0.025	0.00
AVG. HEAD ON TOP OF LAYER 10	0.0028		
CHANGE IN WATER STORAGE	1.037	3763.793	2.56
SOIL WATER AT START OF YEAR	92.362	335274.469	
SOIL WATER AT END OF YEAR	93.399	339038.281	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.030	0.00

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.17	3.73	4.56	4.70	4.65	4.41
	4.50	3.15	3.42	2.5[illegible]	4.01	4.80
STD. DEVIATIONS	1.90	1.62	1.99	1.89	1.77	2.04
	2.13	2.16	2.10	1.39	3.14	2.63
RUNOFF						
TOTALS	2.368	2.481	2.417	1.356	0.520	0.290
	0.242	0.116	0.209	0.339	1.382	2.874
STD. DEVIATIONS	1.941	1.603	1.780	1.260	0.801	0.510
	0.804	0.248	0.603	0.783	2.261	2.654
EVAPOTRANSPIRATION						
TOTALS	0.920	1.165	2.669	3.751	5.310	5.455
	4.570	2.997	2.150	1.336	1.382	1.206
STD. DEVIATIONS	0.300	0.400	0.349	0.620	0.624	1.304
	1.786	1.585	0.722	0.348	0.317	0.285
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0162	0.0149	0.0182	0.0164	0.0140	0.0082
	0.0070	0.0060	0.0067	0.0098	0.0131	0.0174
STD. DEVIATIONS	0.0041	0.0033	0.0010	0.0009	0.0016	0.0027
	0.0024	0.0004	0.0019	0.0047	0.0048	0.0029
LATERAL DRAINAGE COLLECTED FROM LAYER 9						
TOTALS	0.0164	0.0147	0.0182	0.0165	0.0144	0.0086
	0.0071	0.0061	0.0065	0.0095	0.0126	0.0172

STD. DEVIATIONS	0.0040	0.0033	0.0010	0.0009	0.0014	0.0028
	0.0025	0.0005	0.0016	0.0045	0.0048	0.0032

PERCOLATION/LEAKAGE THROUGH LAYER 11

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	29.6781	29.9572	33.2786	31.2689	26.2730	16.4025
	13.8600	12.0343	13.6019	18.7225	25.1349	31.8583
STD. DEVIATIONS	7.1216	6.3584	1.5891	1.5515	2.6521	4.9830
	4.2984	0.6666	3.5057	8.1671	8.5822	5.0472

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0043	0.0042	0.0048	0.0045	0.0038	0.0023
	0.0019	0.0016	0.0018	0.0025	0.0034	0.0045
STD. DEVIATIONS	0.0011	0.0010	0.0003	0.0002	0.0004	0.0008
	0.0007	0.0001	0.0004	0.0012	0.0013	0.0008

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	47.66	(7.384)	173013.1	100.00
RUNOFF	14.595	(5.3370)	52981.28	30.623
EVAPOTRANSPIRATION	32.910	(3.3769)	119464.77	69.050
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.14783	(0.01464)	536.623	0.31016

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

AVERAGE HEAD ON TOP OF LAYER 3	23.506	(2.189)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.14784	(0.01474)	536.655	0.31018
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00001	(0.00000)	0.02	0.00002
AVERAGE HEAD ON TOP OF LAYER 10	0.003	(0.000)		
CHANGE IN WATER STORAGE	0.008	(0.9227)	30.33	0.018

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Attachment 'E'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	6.53	23703.900
RUNOFF	3.596	13053.2168
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000643	2.33360
AVERAGE HEAD ON TOP OF LAYER 3	36.000	
DRAINAGE COLLECTED FROM LAYER 9	0.00077	2.79591
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000000	0.00012
AVERAGE HEAD ON TOP OF LAYER 10	0.006	
MAXIMUM HEAD ON TOP OF LAYER 10	0.010	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	9.8 FEET	
SNOW WATER	6.93	25158.1855

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3733

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1855

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.2281	0.3714
2	10.9829	0.3661
3	0.0000	0.0000
4	2.5620	0.4270
5	3.6600	0.3050
6	0.0020	0.0100
7	52.5600	0.0730
8	5.4900	0.3050
9	0.5419	0.0452
10	0.0000	0.0000
11	15.3720	0.4270
SNOW WATER	0.000	

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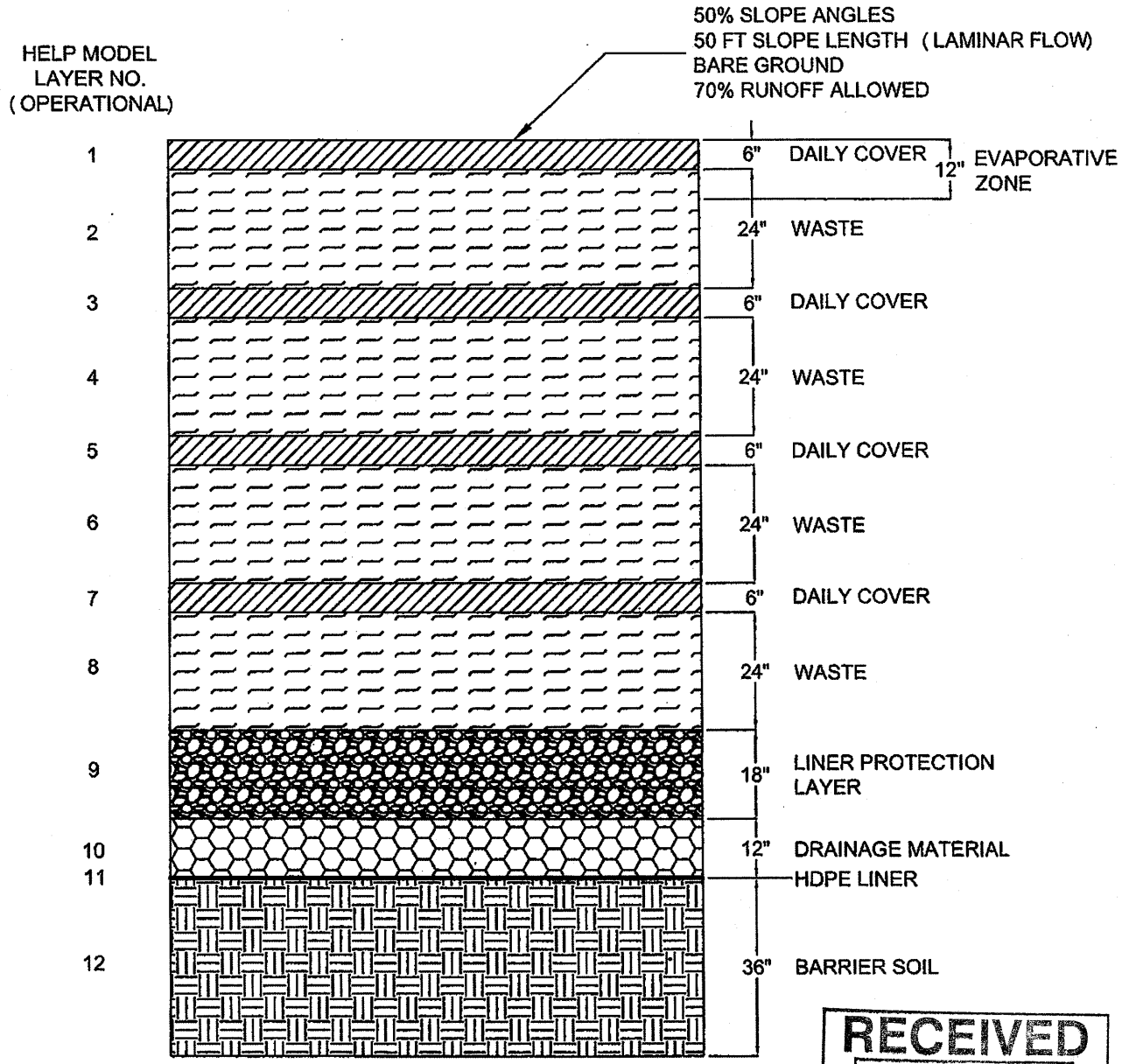
Attachment 'F'

LATA Environmental Services of Kentucky, LLC

Originator J. Keith Thorn Date February 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2[]

Project Materials Disposition Job No. N/A Checked Kendall L. Holt Date February 23, 2011 []



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LATA Environmental Services of Kentucky, LLC

PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
DAILY COVER

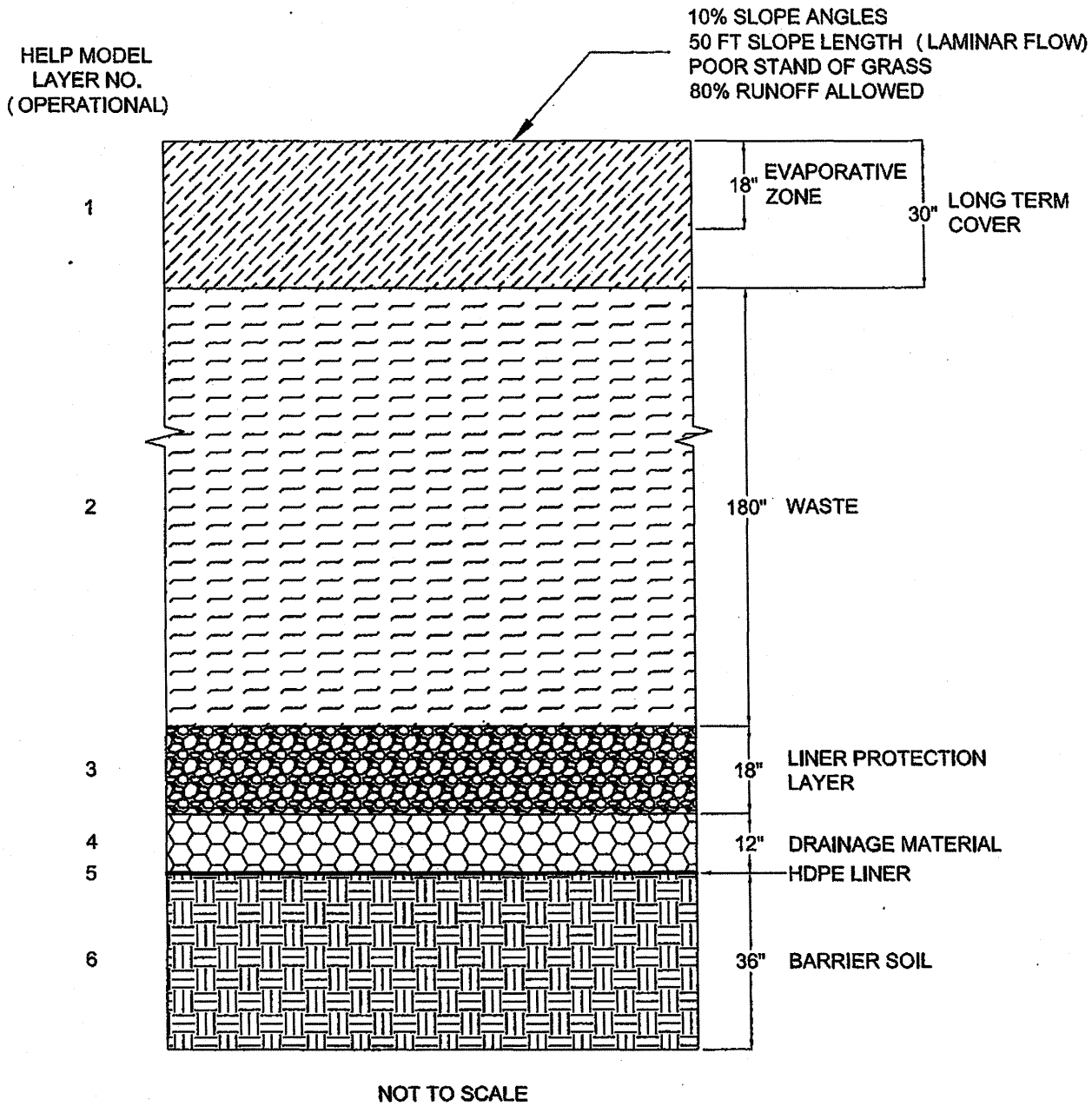
APPROVED BY:	PROJ. NO.:	DATE:

Attachment 'F'

LATA Environmental Services of Kentucky, LLC

Originator J. Keith Thorn Date February 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Materials Disposition Job No. N/A Checked Kendall L. Holt Date February 23, 2011



NOT TO SCALE

LATA Environmental Services of Kentucky, LLC

PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
LONG TERM COVER

APPROVED BY:	PROJ. NO.:	DATE:

Attachment 'F'

LATA Environmental Services of Kentucky, LLC

Originator J. Keith Thorn Date February 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Materials Disposition Job No. N/A Checked Kendall L. Holt Date February 23, 2011

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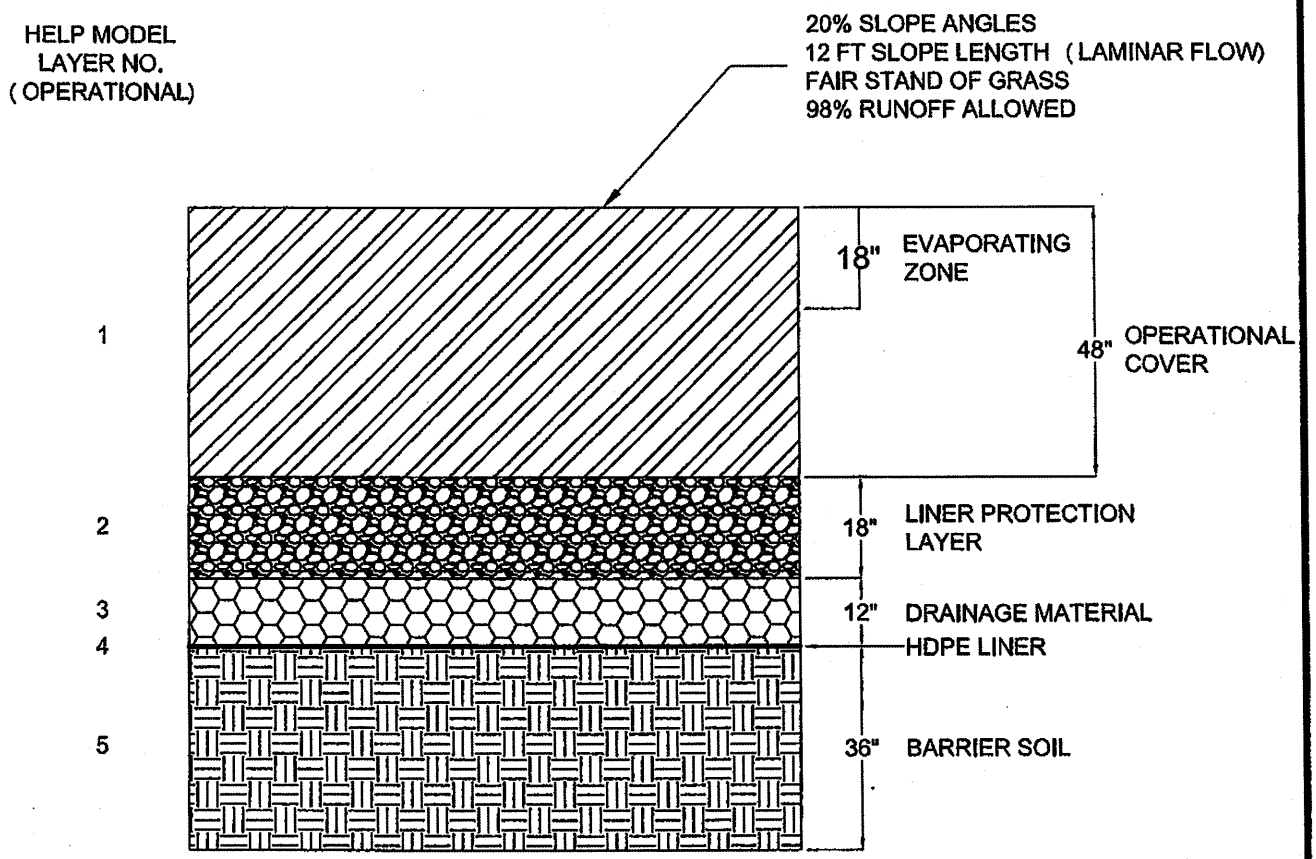


LATA Environmental Services of Kentucky, LLC

PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
OPERATIONAL COVER

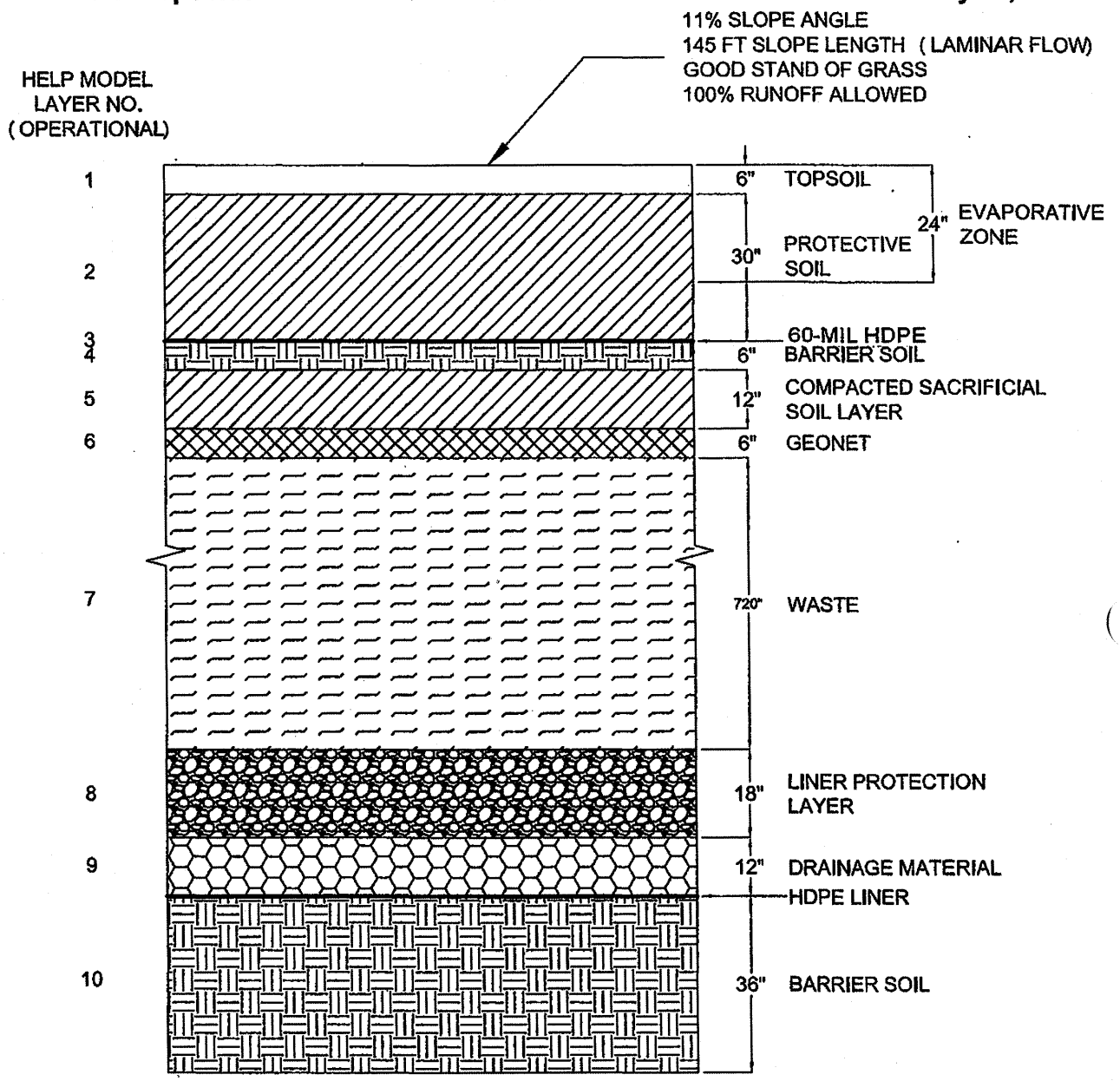
APPROVED BY:	PROJ. NO.:	DATE:

Attachment 'F'

LATA Environmental Services of Kentucky, LLC

Originator J. Keith Thorn Date February 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Materials Disposition Job No. N/A Checked Kendall L. Holt Date February 23, 2011



NOT TO SCALE

LATA Environmental Services of Kentucky, LLC

PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
FINAL COVER

APPROVED BY:	PROJ. NO.:	DATE:

Originator J. Keith Thorn **Date** February 23, 2011 **Calc. No.** CAC-PH746U-P001 **Rev. No.** 2

Project Materials Disposition **Job No.** N/A **Checked** Kendall L. Holt **Date** February 23, 2011

TITLE: LAYER TYPES AND DEFAULT TEXTURES FOR HELP MODELING

Purpose:

Select the appropriate HELP model default textures / soil properties for model input.

Scenario No. 1: Daily/Intermediate Cover Conditions

1. Page 1 of this Attachment shows the landfill layers for the daily/intermediate cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 1 – Daily/Intermediate Cover Conditions
Phases 2 – 3 (2.73 acres)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Daily Cover	SC	10
2	Waste	Municipal Solid Waste (channeling and dead zones)	19
3	Daily Cover	SC	10
4	Waste	Municipal Solid Waste (channeling and dead zones)	19
5	Daily Cover	SC	10
6	Waste	Municipal Solid Waste (channeling and dead zones)	19
7	Daily Cover	SC	10
8	Waste	Municipal Solid Waste (channeling and dead zones)	19
9	Liner Protection Layer	SC	24
10	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
11	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
12	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Scenario No. 2: Long Term Cover Conditions

1. Page 2 of this Attachment shows the landfill layers for long term cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 2 – Long Term Cover Conditions
Phases 1 – 3 (3.94 acres)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Long Term Cover	SC	24
2	Waste	Municipal Solid Waste (channeling and dead zones)	19
3	Liner Protection Layer	SC	24
4	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
5	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
6	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Scenario No. 3: Operational Cover Conditions:

1. Page 3 of this Attachment shows the landfill layers for final cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 3 – Operational Cover Conditions

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Operational Cover		
2	Liner Protection Layer	SC	24
3	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
4	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
5	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Scenario No. 4: Final Cover Conditions:

1. Page 4 of this Attachment shows the landfill layers for final cover conditions.

2. This Tablet shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 4 – Final Cover Conditions (Landfill Unit Acre)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Vegetative Layer	SC	10
2	Protective Layer	SC	24
3	Final Cover Geomembrane (High Density Polyethylene)	High Density Polyethylene	36
4	Final Cover Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16
5	Sacrificial Soil Layer	SC	24
6	Drainage Net (0.5 cm / 0.2 in) (k = 0.1 cm/s)	Drainage Net	0
7	Waste	Municipal Solid Waste (channeling and dead zones)	19
8	Liner Protection Layer	SC	24
9	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
10	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
11	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

NOAA Atlas 14

Precipitation-Frequency Atlas of the United States

Volume 2 Version 3.0: Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia

Geoffrey M. Bonnin, Deborah Martin, Bingzhang Lin, Tye Parzybok, Michael Yekta, David Riley

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Weather Service

Silver Spring, Maryland, 2004
revised 2006

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no.14
v 2
(2006)

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1. Abstract

NOAA Atlas 14 contains precipitation frequency estimates with associated confidence limits for the United States and is accompanied by additional information such as temporal distributions and seasonality. The Atlas is divided into volumes based on geographic sections of the country. The Atlas is intended as the official documentation of precipitation frequency estimates and associated information for the United States. It includes discussion of the development methodology and intermediate results. The Precipitation Frequency Data Server (PFDS) was developed and published in tandem with this Atlas to allow delivery of the results and supporting information in multiple forms via the Internet.

2. Preface to Volume 2

NOAA Atlas 14 Volume 2 contains precipitation frequency estimates for Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. These areas were addressed together in a single project focused on the Ohio River basin and surrounding states. The Atlas supercedes precipitation frequency estimates contained in Technical Paper No. 40 "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield, 1961), NWS HYDRO-35 "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al., 1977) and Technical Paper No. 49 "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al., 1964). The updates are based on more recent and extended data sets, currently accepted statistical approaches, and improved spatial interpolation and mapping techniques.

The work was performed by the Hydrometeorological Design Studies Center within the Office of Hydrologic Development of the National Oceanic and Atmospheric Administration's National Weather Service. Funding for the work was provided by the National Weather Service, the Ohio River Basin Commission and its member States, U.S. Army Corps of Engineers, Tennessee Valley Authority, Federal Emergency Management Administration, Natural Resources Conservation Service, and Bureau of Reclamation. Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Citation and Version History. This documentation and associated artifacts such as maps, grids, and point-and-click results from the PFDS, are part of a whole with a single version number and can be referenced as: "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3.0, G. M. Bonnin, D. Martin, B. Lin, T. Parzybok, M. Yekta, and D. Riley, NOAA, National Weather Service, Silver Spring, Maryland, 2006.

The version number has the format P.S where:

P is an integer representing successive releases of primary information. Primary information is essentially the data – the values of precipitation frequencies (in ASCII grids of the precipitation frequency estimates and output from the PFDS), shapefiles, cartographic maps, temporal distributions, and seasonality.

S is an integer representing successive releases of secondary information. S reverts to zero (or nothing; i.e., Version 2 and Version 2.0 are equivalent) when P is incremented. Secondary information includes documentation and metadata.

When new information is completed and added, such as draft documentation, *without changing any prior information*, the version number is not incremented.

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3. Introduction

3.1. Objective

NOAA Atlas 14 Volume 2 provides precipitation frequency estimates for the Ohio River basin and surrounding states which includes Delaware, District of Columbia, Illinois, Indiana, Kentucky, Maryland, New Jersey, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia. Figures 4.1.1 and 4.1.2 show the project core area where estimates are available (enclosed in the bold line) and also include all stations used in the analysis, even those outside the core area. This Atlas provides precipitation frequency estimates for 5-minute through 60-day durations at average recurrence intervals of 1-year through 1,000-year. The estimates are based on the analysis of annual maximum series and then converted to partial duration series results. The information in NOAA Atlas 14 Volume 2 supercedes precipitation frequency estimates contained in Technical Paper No. 40 "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield, 1961), NWS HYDRO-35 "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al., 1977) and Technical Paper No. 49 "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al., 1964). The results are provided at high spatial resolution and include confidence limits for the estimates. The Atlas includes temporal distributions designed for use with the precipitation frequency estimates (Appendix A.1) and seasonal information for heavy precipitation (Appendix A.2). In addition, the potential effects of climate change were examined (Appendix A.3).

The new estimates are based on improvements in three primary areas: denser data networks with a greater period of record, the application of regional frequency analysis using L-moments for selecting and parameterizing probability distributions and new techniques for spatial interpolation and mapping. The new techniques for spatial interpolation and mapping account for topography and have allowed significant improvements in areas of complex terrain.

NOAA Atlas 14 Volume 2 precipitation frequency estimates for the Ohio River basin and surrounding states are available via the Precipitation Frequency Data Server at http://hdsc.nws.noaa.gov/hdsc/pfds which provides the additional ability to download digital files. The types of results and information found there include:

- point estimates (via a point-and-click interface)
- ArcInfo© ASCII grids
- ESRI shapefiles
- color cartographic maps for each state
- associated Federal Geographic Data Committee-compliant metadata
- data series used in the analyses: annual maximum series and partial duration series
- temporal distributions of heavy precipitation (6-hour, 12-hour, 24-hour and 96-hour)
- seasonal exceedance graphs: counts of events that exceed the 1 in 2, 5, 10, 25, 50 and 100 annual exceedance probabilities for the 60-minute, 24-hour, 48-hour, and 10-day durations.

As discussed in Sections 4.8.4 and 4.8.5, the color cartographic maps and ESRI shapefiles were created to serve as visual aids and, unlike Technical Paper 40, are not recommended for interpolating final point or area precipitation frequency estimates. Users are urged to take advantage of the Precipitation Frequency Data Server or the underlying ArcInfo© ASCII grids for accessing estimates.

3.2. Terminology; Partial Duration and Annual Maximum Series

This publication adopts the terminology "average recurrence interval" (ARI) and "annual exceedance probability" (AEP) presented in Australian Rainfall and Runoff (Institute of Engineers, Australia, 1987) which in turn is based on Laurenson (1987). NOAA Atlas 14 is based on the analysis of annual maximum series data with the results converted to represent estimates based on partial

minute durations) were computed using an average ratio between the n-minute and 60-minute quantiles due to the small number of stations recording data at less than 60-minute intervals.

For the first time, the National Weather Service is providing confidence limits for the precipitation frequency estimates in the area covered by NOAA Atlas 14. Monte Carlo Simulation was used to produce upper and lower bounds at the 90% confidence level.

In the regional approach, the second and higher order moments are constant for each region resulting in a potential for discontinuities in the quantiles at regional boundaries. In order to avoid potential discontinuities and to achieve an effective spatial interpolation of quantiles between observing stations, the data series means at each station for each duration were spatially interpolated using PRISM technology by the Spatial Climate Analysis Service (SCAS) at Oregon State University (Appendix A.4). Because the mean was derived directly at each observing station from the data series and independently of the regional computations, it was not subject to the same discontinuities. The grid of quantiles for each successive average recurrence interval was then derived in an iterative process using a strong linear relationship between a particular duration and average recurrence interval and the next rarer average recurrence interval of the same duration (see Section 4.8.2). The resulting set of grids were tested and adjusted in cases where inconsistencies occurred between durations and frequencies. Computations were made over a geographic domain that was larger than the published domain to ensure continuity at the edges of the published domain.

Both the spatial interpolation and the point estimates were subject to external peer reviews (see Section 6 and Appendix A.5). Based on the results of the peer review, adjustments were made where necessary by the addition of new observations or removal of questionable ones. Adjustments were also made in the definition of regions.

Temporal precipitation patterns were extracted for use with the precipitation frequency estimates presented in the Atlas (Appendix A.1). The temporal patterns are presented in probabilistic terms and can be used in Monte Carlo development of ensembles of possible scenarios. They were specifically designed to be consistent with the definition of duration used for the precipitation frequency estimates.

The seasonality of heavy precipitation is represented in seasonal exceedance graphs that are available through the Precipitation Frequency Data Server. The graphs were developed for each region by tabulating the number of events exceeding the precipitation frequency estimate at each station for a given annual exceedance probability (Appendix A.2).

The 1-day annual maximum series were analyzed for linear trends in mean and variance and shifts in mean to determine whether climate change during the period of record was an issue in the production of this Atlas (Appendix A.3). The results showed little observable or geographically consistent impact of climate change on the annual maximum series during the period of record and so the entire period of record was used. The estimates presented in this Atlas make the necessary assumption that there is no effect of climate change in future years on precipitation frequency estimates. The estimates will need to be modified if that assumption proves quantifiably incorrect.

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Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

Precipitation Frequency Data Server

POINT PRECIPITATION
FREQUENCY ESTIMATES
FROM NOAA ATLAS 14

Kentucky 37.029 N 88.733 W 400 feet

Confidence Limits | Seasonality | Location Maps | Other Info | GIS data | Maps | Help | Doms | U S Mat

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.41	0.65	0.80	1.07	1.32	1.58	1.72	2.13	2.57	3.10	3.68	4.11	4.79	5.34	7.25	8.84	11.08	13.10
2	0.49	0.77	0.95	1.28	1.59	1.90	2.06	2.55	3.08	3.72	4.43	4.94	5.74	6.38	8.62	10.48	13.17	15.49
5	0.56	0.89	1.10	1.52	1.94	2.33	2.53	3.12	3.79	4.57	5.42	6.02	7.01	7.74	10.26	12.35	15.34	18.00
10	0.62	0.97	1.21	1.71	2.20	2.66	2.90	3.58	4.35	5.22	6.18	6.83	7.99	8.77	11.48	13.72	16.94	19.80
25	0.70	1.08	1.35	1.95	2.55	3.11	3.40	4.21	5.12	6.09	7.17	7.90	9.29	10.13	13.05	15.49	18.97	22.06
50	0.75	1.16	1.45	2.12	2.82	3.46	3.81	4.72	5.75	6.77	7.95	8.72	10.31	11.18	14.23	16.82	20.48	23.72
100	0.81	1.24	1.55	2.29	3.10	3.83	4.23	5.26	6.39	7.46	8.72	9.54	11.33	12.23	15.59	18.42	21.93	25.29
200	0.86	1.31	1.64	2.45	3.38	4.21	4.67	5.82	7.08	8.17	9.51	10.37	12.37	13.28	16.53	19.39	23.34	26.80
500	0.93	1.40	1.76	2.67	3.75	4.72	5.28	6.61	8.03	9.14	10.57	11.46	13.77	14.68	18.01	21.03	25.13	28.75
1000	0.98	1.47	1.84	2.84	4.05	5.13	5.76	7.24	8.80	9.89	11.39	12.30	14.84	15.76	19.12	22.25	26.46	30.17

Text version of table | These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval. Please refer to the ... for more information. NOTE: Formatting these estimates may cause them to appear as zero.

*** Upper bound of the 90% confidence interval**
Precipitation Frequency Estimates (inches)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.45	0.71	0.87	1.17	1.44	1.72	1.89	2.34	2.82	3.33	3.96	4.42	5.17	5.74	7.73	9.41	11.77	13.86
2	0.53	0.83	1.03	1.40	1.73	2.07	2.27	2.81	3.38	4.00	4.76	5.31	6.20	6.87	9.21	11.16	13.94	16.36
5	0.61	0.96	1.20	1.66	2.11	2.54	2.77	3.43	4.15	4.91	5.83	6.47	7.57	8.34	10.97	13.15	16.29	19.01
10	0.68	1.06	1.32	1.86	2.39	2.89	3.17	3.93	4.77	5.60	6.63	7.34	8.62	9.44	12.27	14.62	17.98	20.89
25	0.76	1.18	1.47	2.11	2.77	3.38	3.72	4.62	5.60	6.53	7.70	8.49	10.03	10.91	13.94	16.50	20.14	23.28
50	0.82	1.26	1.57	2.30	3.06	3.77	4.16	5.17	6.28	7.26	8.53	9.37	11.12	12.04	15.20	17.92	21.75	25.03
100	0.87	1.34	1.68	2.48	3.35	4.17	4.62	5.75	6.99	8.01	9.37	10.26	12.23	13.18	16.44	19.31	23.32	26.72
200	0.93	1.42	1.78	2.66	3.66	4.58	5.09	6.36	7.74	8.76	10.21	11.15	13.36	14.33	17.67	20.67	24.82	28.36
500	1.01	1.52	1.91	2.90	4.07	5.15	5.75	7.22	8.80	9.81	11.37	12.34	14.88	15.85	19.26	22.45	26.76	30.47
1000	1.06	1.60	2.00	3.08	4.40	5.60	6.29	7.91	9.66	10.62	12.27	13.27	16.07	17.03	20.48	23.77	28.19	32.01

* The upper bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are greater than.
** These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to the ... for more information. NOTE: Formatting these estimates may cause them to appear as zero.

*** Lower bound of the 90% confidence interval**
Precipitation Frequency Estimates (inches)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.38	0.60	0.74	0.99	1.22	1.45	1.57	1.95	2.35	2.88	3.42	3.82	4.44	4.96	6.79	8.32	10.40	12.27
2	0.45	0.71	0.87	1.19	1.47	1.74	1.89	2.33	2.82	3.47	4.11	4.59	5.32	5.93	8.08	9.88	12.33	14.62
5	0.52	0.82	1.01	1.41	1.78	2.12	2.31	2.85	3.46	4.25	5.04	5.59	6.50	7.19	9.60	11.63	14.39	16.99

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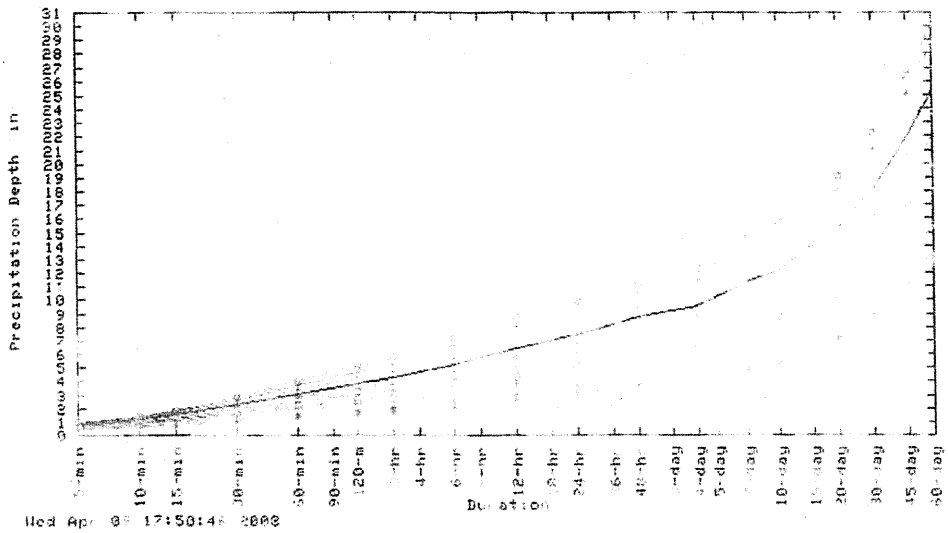
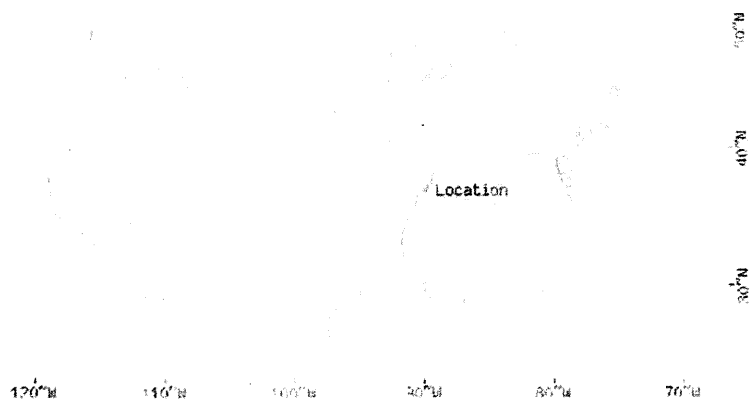
Precipitation Frequency Data Server

Partial duration based Point Precipitation Frequency Estimates Version: 5
37.029 N 88.733 W 400 ft



Average Recurrence Interval (years)
100

Maps -



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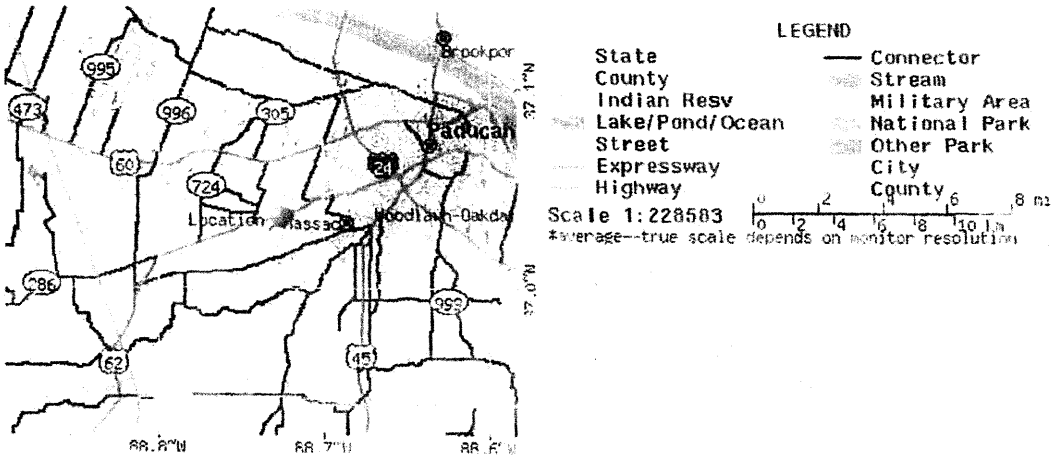
Precipitation Frequency Data Server



Other Maps/Photographs -

View USGS digital orthophoto quadrangle (DOQ) covering this location from TerraServer. USGS Aerial Photograph [illegible] available
from this site. A DOQ is a computer-generated image of an aerial photograph in which image displacement caused by terrain relief and camera tilts has been removed. It combines the image characteristics of a photograph with the geometric qualities of a map. [illegible] information.

Watershed/Stream Flow Information -

Find the Watershed for this location using the U.S. Environmental Protection Agency's site

Climate Data Sources -

Precipitation frequency results are based on data from a variety of sources, but largely NCDC. The [illegible] information
about observing sites in the area, regardless of whether they were used in this study. For detailed information, [illegible] study,
please refer to our documentation.

Using the National Climatic Data Center's (NCDC) station search engine, locate other climate stations within

+/-30 minutes .OR. +/-1 degree of the location (37.029,-88.7731). Digital ASCII data can be obtained directly from NCDC

Hydrometeorological Design Studies Center
DOC/NOAA/National Weather Service
1325 East-West Highway
Silver Spring, MD 20910
(301) 713-1669
[illegible]

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Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

United States Climate Normals 1971-2000

CLIMATOGRAPHY OF THE UNITED STATES NO. 81
Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days
1971-2000

KENTUCKY Page 10

TEMPERATURE NORMALS (Degrees Fahrenheit)

No.	Station Name	Element	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.2	[illegible]	85.8	[illegible]	68.3	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	43.0	[illegible]	[illegible]	[illegible]	75.8	74.6	68.0	56.3	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	39.7	49.9	59.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	58.4	[illegible]	[illegible]	[illegible]	86.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79.8	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	53.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] RIVER LAKE	MAX	[illegible]	[illegible]	58.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	71.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55.2
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
129	PADUCAH BARKLEY RGNL AP	MAX	41.9	[illegible]	58.1	68.4	76.9	86.2	89.6	87.4	81.2	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	32.9	38.1	47.6	57.0	65.9	74.5	78.2	76.2	69.1	58.0	46.8	36.9	56.8
		MIN	23.9	28.2	37.1	[illegible]	[illegible]	[illegible]	[illegible]	64.9	57.1	45.2	36.5	[illegible]	46.0
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	40.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.8
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	68.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.4	72.3	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	47.0	[illegible]	[illegible]	73.4	[illegible]	76.2	69.4	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43.0	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	76.0	79.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
139	PROVIDENCE	MAX	41.3	[illegible]	[illegible]	68.6	[illegible]	[illegible]	89.6	88.1	81.4	70.8	[illegible]	46.3	[illegible]
		MEAN	[illegible]	36.8	46.0	56.0	65.4	74.5	[illegible]	[illegible]	69.2	[illegible]	46.1	36.5	[illegible]
		MIN	22.3	[illegible]	34.2	43.4	53.2	62.9	67.0	64.8	58.9	[illegible]	[illegible]	[illegible]	44.8
141	ROCHESTER FERRY	MAX	42.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	88.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	47.0	56.4	[illegible]	[illegible]	[illegible]	[illegible]	70.2	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	25.4	27.8	[illegible]	44.4	54.0	63.6	68.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
142	ROUGH RIVER LAKE	MAX	40.3	46.3	56.4	67.2	76.1	84.5	88.6	87.6	81.2	[illegible]	[illegible]	45.4	[illegible]
		MEAN	[illegible]	34.2	43.7	53.6	62.6	71.6	75.7	74.0	67.1	55.0	44.7	[illegible]	[illegible]
		MIN	19.3	[illegible]	30.9	39.9	49.1	58.6	[illegible]	60.4	52.9	40.4	32.7	[illegible]	[illegible]
[illegible]	RUSSELLVILLE	MAX	[illegible]	47.9	[illegible]	[illegible]	76.8	[illegible]	88.9	87.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	37.4	[illegible]	[illegible]	65.0	[illegible]	77.6	[illegible]	69.2	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	24.6	26.9	[illegible]	43.6	[illegible]	61.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
145	SCOTTSVILLE [illegible]	MAX	43.5	50.1	60.0	69.5	76.2	82.9	86.3	85.4	79.2	69.4	[illegible]	47.4	[illegible]
		MEAN	35.7	40.9	49.9	58.7	66.4	73.5	77.2	76.0	70.0	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	27.8	[illegible]	39.8	[illegible]	56.5	64.0	68.0	66.6	60.7	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	SHELBYVILLE [illegible]	MAX	[illegible]	45.9	56.2	[illegible]	76.4	[illegible]	88.1	86.6	80.3	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	52.4	62.5	[illegible]	[illegible]	73.3	66.2	54.4	[illegible]	34.3	[illegible]
		MIN	[illegible]	[illegible]	29.8	[illegible]	48.5	57.3	62.0	60.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
152	SOMERSET 2 N	MAX	44.3	49.4	[illegible]	68.2	75.4	82.6	86.0	84.9	[illegible]	[illegible]	[illegible]	48.1	[illegible]
		MEAN	34.7	[illegible]	47.2	[illegible]	63.9	[illegible]	75.5	74.0	67.7	56.6	45.9	[illegible]	[illegible]
		MIN	[illegible]	27.9	35.7	[illegible]	52.4	60.9	64.9	63.1	[illegible]	[illegible]	36.4	[illegible]	[illegible]
[illegible]	STEARNS [illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	86.3	85.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	53.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	32.5	38.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	SUMMER SHADE	MAX	[illegible]	50.1	[illegible]	69.2	[illegible]	[illegible]	87.5	86.3	[illegible]	[illegible]	58.4	[illegible]	[illegible]
		MEAN	34.6	39.3	48.2	56.8	[illegible]	[illegible]	76.6	[illegible]	[illegible]	57.7	47.6	38.8	[illegible]
		MIN	25.0	28.5	36.6	44.3	53.4	61.5	65.6	63.8	57.5	45.5	36.7	29.0	[illegible]
[illegible]	TOMAHAWK [illegible]	MAX	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	87.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MEAN	[illegible]	[illegible]	[illegible]	53.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		MIN	[illegible]	[illegible]	28.9	37.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
159	WARSAW MARKLAND DAM	MAX	39.5	[illegible]	[illegible]	65.5	74.9	82.7	86.7	85.6	[illegible]	[illegible]	55.6	44.1	[illegible]
		MEAN	[illegible]	34.2	43.6	53.4	[illegible]	[illegible]	75.6	74.3	[illegible]	55.7	[illegible]	[illegible]	[illegible]
		MIN	20.7	23.8	32.4	41.3	51.3	60.1	64.5	62.9	[illegible]	43.3	[illegible]	25.8	43.0

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Solid Waste Branch

Attachment 'H'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

United States Climate Normals 1971-2000

CLIMATOGRAPHY OF THE UNITED STATES NO. 81
Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degree Days
1971-2000

KENTUCKY Page 13

PRECIPITATION NORMALS (Total in Inches)

No.	Station Name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
070	GLASGOW	4.29	[illegible]	5.12	4.37	[illegible]	4.89	4.78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
071	GLENDALE	[illegible]	[illegible]	4.83	4.19	4.83	3.99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
072	GOLDEN [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
073	GRAY [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
074	GRAYSON 3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
075	GRAYSON [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
076	GREENSBURG	[illegible]	[illegible]	[illegible]	[illegible]	5.68	4.87	4.63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
077	GREENSBURG [illegible]	[illegible]	3.99	4.64	[illegible]	5.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
078	HARDINSBURG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
079	HARLAN [illegible]	[illegible]	[illegible]	4.54	[illegible]	[illegible]	3.36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
080	HAZARD STATE POLICE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
081	HAZARD WATERWORKS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
082	HAZEL GREEN [illegible]	[illegible]	[illegible]	3.85	3.44	4.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
083	HEIDELBERG	[illegible]	[illegible]	4.41	3.87	[illegible]	4.16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
084	HENDERSON [illegible]	[illegible]	[illegible]	4.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
085	HENDERSON STATE POLICE	[illegible]	[illegible]	4.54	[illegible]	[illegible]	3.46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
086	HIGH BRIDGE [illegible]	[illegible]	[illegible]	4.78	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
087	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
088	HOPKINSVILLE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
089	HYDEN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
090	[illegible]	[illegible]	[illegible]	3.69	3.48	[illegible]	[illegible]	4.19	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
091	JACKSON CARROLL [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
092	JAMESTOWN [illegible]	[illegible]	[illegible]	4.95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
093	JEREMIAH [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
094	KEENE 1 WSW	3.49	[illegible]	4.63	3.66	5.04	4.35	4.66	3.64	[illegible]	[illegible]	[illegible]	4.47	[illegible]
095	LAGRANGE STATE POLICE	3.08	2.96	3.96	3.52	[illegible]	4.63	4.73	4.05	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
096	LANCASTER	3.65	3.37	4.72	3.90	[illegible]	4.66	4.28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
097	LEITCHFIELD [illegible]	[illegible]	[illegible]	4.53	4.25	4.91	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
098	LEXINGTON BLUE GRASS [illegible]	3.34	[illegible]	4.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
099	LIBERTY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	LLOYD GREENUP DAM	[illegible]	[illegible]	[illegible]	3.09	[illegible]	3.56	4.02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
101	LOCKPORT LOCK 2	[illegible]	[illegible]	4.33	4.21	[illegible]	4.44	[illegible]	4.40	[illegible]	3.05	[illegible]	[illegible]	[illegible]
102	LONDON CORBIN AP	4.01	3.72	4.61	[illegible]	4.69	[illegible]	4.39	3.36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
103	LONDON STATE POLICE	[illegible]	[illegible]	[illegible]	3.44	[illegible]	4.64	[illegible]	3.96	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
104	LOUISA 2 S	[illegible]	[illegible]	3.74	3.42	4.72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
105	LOUISVILLE STANDIFORD [illegible]	[illegible]	[illegible]	4.41	3.91	4.88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44.54
106	LOUISVILLE UPPER GAGE	[illegible]	2.99	4.14	3.88	4.49	3.77	[illegible]	3.32	[illegible]	2.66	[illegible]	[illegible]	[illegible]
107	LOVELACEVILLE	3.82	4.06	4.43	5.01	4.48	4.29	4.60	2.93	[illegible]	3.51	[illegible]	4.62	[illegible]
108	MADISONVILLE	3.69	3.78	4.51	4.05	4.95	3.80	4.21	3.23	3.36	3.26	4.22	4.21	[illegible]
109	MADISONVILLE [illegible]	3.78	3.85	4.60	4.33	4.81	4.16	4.25	3.39	3.23	[illegible]	[illegible]	[illegible]	[illegible]
110	MAMMOTH CAVE	[illegible]	3.82	5.04	4.18	5.22	4.65	[illegible]	3.62	[illegible]	[illegible]	[illegible]	[illegible]	51.99
111	MANCHESTER 4 [illegible]	[illegible]	3.65	4.59	4.15	[illegible]	[illegible]	5.22	[illegible]	[illegible]	3.22	[illegible]	[illegible]	[illegible]
112	MARION 1 NE	3.32	3.47	4.27	4.61	5.14	4.09	5.21	2.79	3.00	3.41	[illegible]	4.48	[illegible]
113	MARTIN 1 S	3.07	3.07	3.67	3.56	5.10	3.99	4.82	4.11	3.36	[illegible]	[illegible]	[illegible]	44.23
114	MAYFIELD RADIO WNGO	3.76	4.48	4.93	4.77	5.05	4.12	4.22	3.23	3.62	3.65	4.96	4.89	51.78
115	MAYFIELD STATE POLICE	[illegible]	[illegible]	4.38	[illegible]	[illegible]	[illegible]	[illegible]	3.27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
116	MAYSVILLE SEWAGE PLANT	[illegible]	4.24	4.10	3.94	4.87	3.98	[illegible]	3.79	[illegible]	2.84	[illegible]	[illegible]	[illegible]
117	MIDDLESBORO [illegible] N	4.86	3.91	5.25	3.91	5.08	4.63	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
118	MILLERSTOWN	3.87	4.04	4.80	4.48	5.26	4.26	4.57	3.55	4.01	[illegible]	[illegible]	4.90	[illegible]
119	MONTICELLO 3 NE	4.39	4.08	4.85	4.24	5.15	4.41	4.42	3.82	3.72	2.95	[illegible]	4.80	[illegible]
120	MOREHEAD STATE POLICE	3.48	2.65	4.32	3.55	4.44	4.11	4.97	3.15	2.81	2.86	[illegible]	[illegible]	[illegible]
121	MOUNT STERLING	3.56	3.39	[illegible]	3.66	4.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
122	MOUNT VERNON	4.32	3.84	[illegible]	4.18	5.56	[illegible]	4.64	3.94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
123	MUNFORDVILLE [illegible]	[illegible]	[illegible]	5.15	4.38	5.38	4.62	4.63	[illegible]	[illegible]	3.19	[illegible]	[illegible]	[illegible]
124	MURRAY	4.25	4.59	5.25	5.09	[illegible]	4.85	4.50	3.46	[illegible]	3.52	[illegible]	[illegible]	[illegible]
125	NOLIN RIVER LAKE	3.99	4.12	4.78	4.36	[illegible]	4.24	4.50	3.39	[illegible]	[illegible]	4.39	[illegible]	[illegible]
126	ONEIDA	3.91	[illegible]	4.57	4.05	4.96	4.69	4.47	4.16	3.37	[illegible]	[illegible]	[illegible]	[illegible]
127	OWENSBORO 3 [illegible]	[illegible]	3.65	[illegible]	4.66	4.78	3.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
128	OWENSBORO [illegible] E	[illegible]	[illegible]	[illegible]	4.61	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
129	PADUCAH BARKLEY RGNL AP	3.47	3.93	4.27	4.95	4.75	4.51	4.45	2.99	3.56	3.45	4.53	4.38	49.24
130	PADUCAH WALKER BOAT YAR	3.29	3.77	4.11	4.67	4.47	3.96	3.94	[illegible]	[illegible]	3.08	[illegible]	4.15	46.04
131	PAINTSVILLE 1 E	3.31	3.20	3.95	3.55	4.54	4.24	4.51	[illegible]	3.43	[illegible]	3.44	[illegible]	44.62
132	PARADISE STEAM PLANT	[illegible]	4.28	4.62	4.13	4.96	[illegible]	4.11	[illegible]	3.62	[illegible]	[illegible]	[illegible]	[illegible]
133	PARIS	[illegible]	[illegible]	4.41	3.72	4.91	[illegible]	4.46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
134	PHELPS 3 S	[illegible]	3.64	[illegible]	[illegible]	4.39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
135	PIKEVILLE [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
136	PINE MOUNTAIN [illegible]	4.40	[illegible]	4.87	4.56	6.20	4.76	4.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
137	PINEVILLE	[illegible]	3.30	4.80	[illegible]	4.35	[illegible]	4.18	4.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
138	PRINCETON [illegible] SE	4.01	4.48	4.70	4.70	5.01	4.06	4.52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Attachment 'J'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PGDP Solid Waste Landfill, Paducah, Kentucky
Comparison of Rainfall to Leachate Generation

* Leachate measuremnts are taken only on days in which the landfill is open (4-day work weeks) Therefore, to approximate data during the non-open periods, a uniform daily amount is calculated based on the measured amounts for the day prior to the weekend and the day following the weekend.

Date	Daily Rainfall (in)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
							Rain	Rain	Leachate
11/1/2007	0.00	0	600	61	33	47			
11/2/2007	0.00	0	600	65	30	48			
11/3/2007	0.00	0	600	65	32	49			
11/4/2007	0.00	0	600	65	33	49			
11/5/2007	0.00	0	0	76	45	61			
11/6/2007	0.00	0	900	50	28	39			
11/7/2007	0.00	0	0	50	24	37			
11/8/2007	0.00	0	225	61	38	50			
11/9/2007	0.00	0	225	66	36	51			
11/10/2007	0.00	0	225	58	30	44			
11/11/2007	0.19	20074	225	62	44	53			
11/12/2007	0.09	9509	0	68	57	63			
11/13/2007	0.09	9509	200	68	57	63			
11/14/2007	0.19	20074	600	67	47	57			
11/15/2007	0.00	0	0	50	29	40	0.56	59167	5000
11/16/2007	0.00	0	0	53	26	40	0.56	59167	4400
11/17/2007	0.00	0	0	63	37	50	0.56	59167	3800
11/18/2007	0.00	0	0	66	23	50	0.56	59167	3200
11/19/2007	0.00	0	1000	66	59	63	0.56	59167	3600
11/20/2007	0.00	0	633	71	58	65	0.56	59167	4233
11/21/2007	0.49	51771	633	67	42	55	1.05	110938	3967
11/22/2007	0.00	0	633	42	35	39	1.05	110938	4600
11/23/2007	0.00	0	633	41	24	33	1.05	110938	5008
11/24/2007	0.00	0	633	44	23	34	1.05	110938	5417
11/25/2007	0.96	101429	633	43	37	40	2.01	212367	5825
11/26/2007	0.10	10566	4100	46	34	40	1.92	202858	9700
11/27/2007	0.00	0	0	52	27	40	1.83	193349	9700
11/28/2007	0.00	0	2400	56	28	42	1.74	183840	11900
11/29/2007	0.00	0	925	49	25	37	1.55	163765	12225
11/30/2007	0.00	0	925	53	22	38	1.55	163765	13150
12/1/2007	0.00	0	925	62	35	49	1.55	163765	14075
12/2/2007	0.77	81354	925	64	34	49	2.32	245120	15000
12/3/2007	0.00	0	2700	41	27	34	2.32	245120	17700
12/4/2007	0.00	0	1700	50	25	38	2.32	245120	18400
12/5/2007	0.00	0	0	49	27	38	2.32	245120	17767
12/6/2007	0.02	2113	3350	37	20	29	1.85	195462	20483
12/7/2007	0.43	45432	3350	43	36	40	2.28	240893	23200
12/8/2007	0.03	3170	3350	44	40	42	2.31	244063	25917
12/9/2007	0.69	72902	3350	46	40	43	3.00	316965	28633

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PGDP Solid Waste Landfill, Paducah, Kentucky
Comparison of Rainfall to Leachate Generation

* Leachate measuremnts are taken only on days in which the landfill is open (4-day work weeks) Therefore, to approximate data during the non-open periods, a uniform daily amount is calculated based on the measured amounts for the day prior to the weekend and the day following the weekend.

Date	Daily Rainfall (In)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
12/10/2007	1.37	144747	11600	41	37	39	3.41	360284	39600
12/11/2007	0.21	22188	6400	67	41	54	3.52	371906	41900
12/12/2007	0.51	53884	5500	49	39	44	4.03	425790	47400
12/13/2007	0.30	31697	0	42	34	38	4.33	457486	45000
12/14/2007	0.00	0	11800	42	32	37	4.33	457486	55875
12/15/2007	2.05	216593	11800	39	32	36	6.38	674079	66750
12/16/2007	0.01	1057	9800	34	23	29	6.39	675135	75625
12/17/2007	0.00	0	3100	43	22	33	5.62	593781	77800
12/18/2007	0.00	0	4400	51	29	40	5.62	593781	79500
12/19/2007	0.00	0	1800	54	33	44	5.62	593781	79600
12/20/2007	0.22	23244	2467	49	36	43	5.84	617025	82067
12/21/2007	0.00	0	2467	52	46	49	5.82	614912	81183
12/22/2007	0.29	30640	2467	57	52	54	5.68	600120	80300
12/23/2007	0.01	1057	2467	48	30	39	5.66	598007	79417
12/24/2007	0.00	0	2467	47	28	38	4.97	525105	78533
12/25/2007	0.00	0	2467	51	23	37	3.60	380358	69400
12/26/2007	0.27	28527	1000	52	24	38	3.66	386697	64000
12/27/2007	0.00	0	2000	41	33	37	3.15	332813	60500
12/28/2007	0.19	20074	2000	47	32	32	3.04	321191	62500
12/29/2007	0.00	0	2000	42	27	27	3.04	321191	52700
12/30/2007	0.00	0	2000	47	27	27	0.99	104598	42900
12/31/2007	0.00	0	1600	56	31	31	0.98	103542	34700
1/1/2008	0.00	0	1600	36	19	28	0.98	103542	33200
1/2/2008	0.00	0	1600	22	11	17	0.98	103542	30400
1/3/2008	0.00	0	1050	31	10	21	0.98	103542	29650
1/4/2008	0.00	0	1050	46	21	34	0.76	80298	28233
1/5/2008	0.11	11622	1050	55	42	49	0.87	91920	26817
1/6/2008	0.00	0	1050	68	55	62	0.58	61280	25400
1/7/2008	0.02	2113	600	70	60	65	0.59	62336	23533
1/8/2008	1.53	161652	4600	67	44	56	2.12	223989	25667
1/9/2008	0.00	0	5000	51	36	44	2.12	223989	28200
1/10/2008	0.55	58110	3125	59	36	48	2.40	253572	30325
1/11/2008	0.00	0	3125	46	29	38	2.40	253572	31450
1/12/2008	0.10	10566	3125	53	26	40	2.31	244063	32575
1/13/2008	0.03	3170	3125	43	26	35	2.34	247233	33700
1/14/2008	0.00	0	2100	40	23	32	2.34	247233	33800
1/15/2008	0.00	0	2700	36	21	29	2.34	247233	34900
1/16/2008	0.14	14792	1500	40	24	32	2.48	262024	34800
1/17/2008	0.03	3170	1360	42	27	35	2.51	265194	34560

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

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PGDP Solid Waste Landfill, Paducah, Kentucky
Comparison of Rainfall to Leachate Generation

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Date	Daily Rainfall (in)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
1/18/2008	0.00	0	1360	39	19	29	2.51	265194	34870
1/19/2008	0.00	0	1360	31	14	23	2.51	265194	35180
1/20/2008	0.00	0	1360	25	10	18	2.40	253572	35490
1/21/2008	0.00	0	1360	43	14	29	2.40	253572	35800
1/22/2008	0.03	3170	400	40	20	30	2.41	254629	35600
1/23/2008	0.00	0	1400	37	15	26	0.88	92976	32400
1/24/2008	0.00	0	1175	28	14	21	0.88	92976	28575
1/25/2008	0.00	0	1175	31	10	21	0.33	34866	26625
1/26/2008	0.00	0	1175	38	28	33	0.33	34866	24675
1/27/2008	0.00	0	1175	47	30	39	0.23	24301	22725
1/28/2008	0.00	0	200	55	23	39	0.20	21131	19800
1/29/2008	0.26	27470	700	63	22	43	0.46	48601	18400
1/30/2008	0.00	0	300	37	18	28	0.46	48601	16000
1/31/2008	0.36	38036	2100	34	27	31	0.68	71845	16600
2/1/2008	0.02	2113	2100	33	22	28	0.67	70789	17340
2/2/2008	0.00	0	2100	55	21	38	0.67	70789	18080
2/3/2008	0.00	0	2100	60	28	44	0.67	70789	18820
2/4/2008	0.02	2113	2700	72	57	65	0.69	72902	20160
2/5/2008	0.70	73959	13900	76	57	67	1.39	146860	32700
2/6/2008	0.01	1057	10600	60	35	48	1.37	144747	42900
2/7/2008	0.00	0	4250	37	31	34	1.37	144747	45750
2/8/2008	0.00	0	4250	50	28	39	1.37	144747	48825
2/9/2008	0.00	0	4250	57	33	45	1.37	144747	51900
2/10/2008	0.00	0	4250	44	20	32	1.37	144747	54975
2/11/2008	1.15	121503	4700	33	20	27	2.52	266251	58500
2/12/2008	1.60	169048	19000	33	21	27	4.12	435299	77300
2/13/2008	0.00	0	6500	24	18	21	3.86	407828	83100
2/14/2008	0.00	0	0	48	19	34	3.86	407828	82800
2/15/2008	0.00	0	12800	43	34	39	3.50	369793	93500
2/16/2008	0.00	0	12800	49	34	42	3.48	367679	104200
2/17/2008	0.37	39092	12800	61	40	51	3.85	406772	114900
2/18/2008	0.00	0	5000	45	35	40	3.85	406772	117800
2/19/2008	0.00	0	3500	37	23	30	3.83	404659	118600
2/20/2008	0.00	0	4000	39	23	31	3.13	330700	108700
2/21/2008	0.85	89807	350	33	23	28	3.97	419450	98450
2/22/2008	0.26	27470	9383	33	28	31	4.23	446921	103583
2/23/2008	0.00	0	9383	34	26	30	4.23	446921	108717
2/24/2008	0.08	8452	9383	37	31	34	4.31	455373	113850
2/25/2008	0.03	3170	8900	52	35	44	4.34	458543	118500

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PGDP Solid Waste Landfill, Paducah, Kentucky
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Date	Daily Rainfall (in)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
2/26/2008	0.04	4226	5700	50	27	39	3.23	341266	119500
2/27/2008	0.00	0	3700	35	25	30	1.63	172218	104200
2/28/2008	0.00	0	0	48	24	36	1.63	172218	97700
2/29/2008	0.00	0	4200	65	33	49	1.63	172218	101900
3/1/2008	0.00	0	4200	62	25	44	1.63	172218	93300
3/2/2008	0.00	0	4200	75	49	62	1.63	172218	84700
3/3/2008	2.90	306400	12300	65	35	50	4.16	439525	84200
3/4/2008	0.15	15848	10900	36	32	34	4.31	455373	90100
3/5/2008	0.00	0	12500	50	30	40	4.31	455373	99100
3/6/2008	0.00	0	4775	38	30	34	4.31	455373	99875
3/7/2008	0.07	7396	4775	34	27	31	3.53	372962	104300
3/8/2008	0.04	4226	4775	34	22	28	3.31	349718	99692
3/9/2008	0.00	0	4775	51	27	39	3.31	349718	95083
3/10/2008	0.02	2113	4300	55	33	44	3.25	343379	90000
3/11/2008	0.00	0	2600	54	27	41	3.22	340209	83700
3/12/2008	0.00	0	1500	70	41	56	3.18	335983	79500
3/13/2008	0.00	0	2950	71	49	60	3.18	335983	78750
3/14/2008	0.26	27470	2750	62	46	54	3.44	363453	81500
3/15/2008	0.09	9509	2750	54	46	50	3.53	372962	80050
3/16/2008	0.00	0	2750	56	42	49	3.53	372962	78600
3/17/2008	0.00	0	2900	70	44	57	3.53	372962	77300
3/18/2008	3.21	339153	12500	71	53	62	3.84	405715	77500
3/19/2008	1.19	125729	24400	52	36	44	4.88	515596	91000
3/20/2008	0.00	0	17600	59	34	47	4.88	515596	96100
3/21/2008	0.00	0	233	70	44	57	4.88	515596	91558
3/22/2008	0.00	0	9533	56	38	47	4.81	508201	96317
3/23/2008	0.00	0	9533	49	28	39	4.77	503974	101075
3/24/2008	0.00	0	900	47	28	38	4.77	503974	97200
3/25/2008	0.00	0	3000	65	34	50	4.75	501861	95900
3/26/2008	0.00	0	1100	67	45	56	4.75	501861	94400
3/27/2008	0.00	0	1725	70	60	65	4.75	501861	94625
3/28/2008	0.27	28527	1725	70	42	56	5.02	530388	93400
3/29/2008	0.08	8452	1725	50	41	46	4.84	511370	92375
3/30/2008	0.20	21131	1725	64	48	56	4.95	522992	91350
3/31/2008	1.12	118334	1800	68	57	63	6.07	641326	90400
4/1/2008	0.00	0	5700				6.07	641326	93200
4/2/2008	0.01	1057	3750				2.87	303230	84450
4/3/2008	3.51	370849	7375				5.19	548349	67425
4/4/2008	0.79	83467	11508				5.98	631817	61333

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Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PGDP Solid Waste Landfill, Paducah, Kentucky
Comparison of Rainfall to Leachate Generation

* Leachate measuremnts are taken only on days in which the landfill is open (4-day work weeks) Therefore, to approximate data during the non-open periods, a uniform daily amount is calculated based on the measured amounts for the day prior to the weekend and the day following the weekend.

Date	Daily Rainfall (In)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
4/5/2008	0.00	0	11508				5.98	631817	72608
4/6/2008	0.00	0	11508				5.98	631817	74583
4/7/2008	0.00	0	0				5.98	631817	65050
4/8/2008	0.00	0	7100				5.98	631817	71250
4/9/2008	0.03	3170	2300				6.01	634987	70550
4/10/2008	1.70	179614	4875				7.71	814600	74325
4/11/2008	0.00	0	4875				7.71	814600	77475
4/12/2008	0.00	0	4875				7.44	786073	80625
4/13/2008	0.02	2113	4875				7.38	779734	83775
4/14/2008	0.00	0	3800				7.18	758603	85850
4/15/2008	0.00	0	1400				6.06	640269	85450
4/16/2008	0.00	0	2500				6.06	640269	82250
4/17/2008	0.00	0	1400				6.05	639213	79900
4/18/2008	0.35	36979	1400				2.89	305343	73925
4/19/2008	0.00	0	1400				2.10	221876	63817
4/20/2008	0.00	0	1400				2.10	221876	53708
4/21/2008	0.00	0	2000				2.10	221876	44200
4/22/2008	0.00	0	0				2.10	221876	44200
4/23/2008	0.00	0	700				2.10	221876	37800
4/24/2008	0.00	0	25				2.07	218706	35525
4/25/2008	0.35	36979	2225				0.72	76072	32875
4/26/2008	0.00	0	2225				0.72	76072	30225
4/27/2008	0.00	0	2225				0.72	76072	27575
4/28/2008	0.01	1057	0				0.71	75015	22700
4/29/2008	0.00	0	400				0.71	75015	19300
4/30/2008	0.00	0	500				0.71	75015	18400
5/1/2008	0.00	0	0				0.71	75015	15900
5/2/2008	0.65	68676	1800				1.36	143691	16300
5/3/2008	0.00	0	1800				1.01	106712	16700
5/4/2008	0.00	0	1800				1.01	106712	17100
5/5/2008	0.00	0	700				1.01	106712	16400
5/6/2008	0.02	2113	1100				1.03	108825	15500
5/7/2008	0.12	12679	5800				1.15	121503	21300
5/8/2008	0.11	11622	0				1.26	133125	20600
5/9/2008	0.00	0	1133				1.26	133125	21708
5/10/2008	0.42	44375	1133				1.33	140521	20617
5/11/2008	0.00	0	1133				1.33	140521	19525
5/12/2008	0.00	0	800				1.33	140521	18100
5/13/2008	0.31	32753	100				1.63	172218	18200

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

PGDP Solid Waste Landfill, Paducah, Kentucky
Comparison of Rainfall to Leachate Generation

* Leachate measuremnts are taken only on days in which the landfill is open (4-day work weeks) Therefore, to approximate data during the non-open periods, a uniform daily amount is calculated based on the measured amounts for the day prior to the weekend and the day following the weekend.

Date	Daily Rainfall (in)	Daily Rainfall (gal)	Daily* Leachate (gal)	Max. Temp. (Deg F)	Min. Temp. (Deg F)	Avg. Temp. (Deg F)	15 Day Rolling Total (in)	15 Day Rolling Total (gal)	15 Day Rolling Total (gal)
5/14/2008	0.02	2113	1100				1.65	174331	18900
5/15/2008	0.86	90863	0				2.51	265194	18400
5/16/2008	0.00	0	1350				2.51	265194	19750
5/17/2008	0.00	0	1350				1.86	196518	19300
5/18/2008	0.00	0	1350				1.86	196518	18850
5/19/2008	0.00	0	880				1.86	196518	17930
5/20/2008	0.00	0	0				1.86	196518	17230
5/21/2008	0.00	0	0				1.84	194405	16130
5/22/2008	0.03	3170	0				1.75	184896	10330
5/23/2008	0.00	0	725				1.64	173274	11055
5/24/2008	0.00	0	725				1.64	173274	10647
5/25/2008	0.30	31697	725				1.52	160596	10238
5/26/2008	2.10	221876	725				3.62	382471	9830
5/27/2008	0.59	62336	1560				4.21	444808	10590
5/28/2008	0.02	2113	2605				3.92	414168	13095
5/29/2008	0.00	0	0				3.90	412055	11995
5/30/2008	0.00	0	1512				3.04	321191	13507
5/31/2008	0.08	8452	1512				3.12	329644	13668
6/1/2008	0.02	2113	1512				3.14	331757	13830
6/2/2008	0.00	0	700				3.14	331757	13180
6/3/2008	0.00	0	1100				3.14	331757	13400

Totals for April and May 2008	**12.42**	**1312235**	**138780**

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Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

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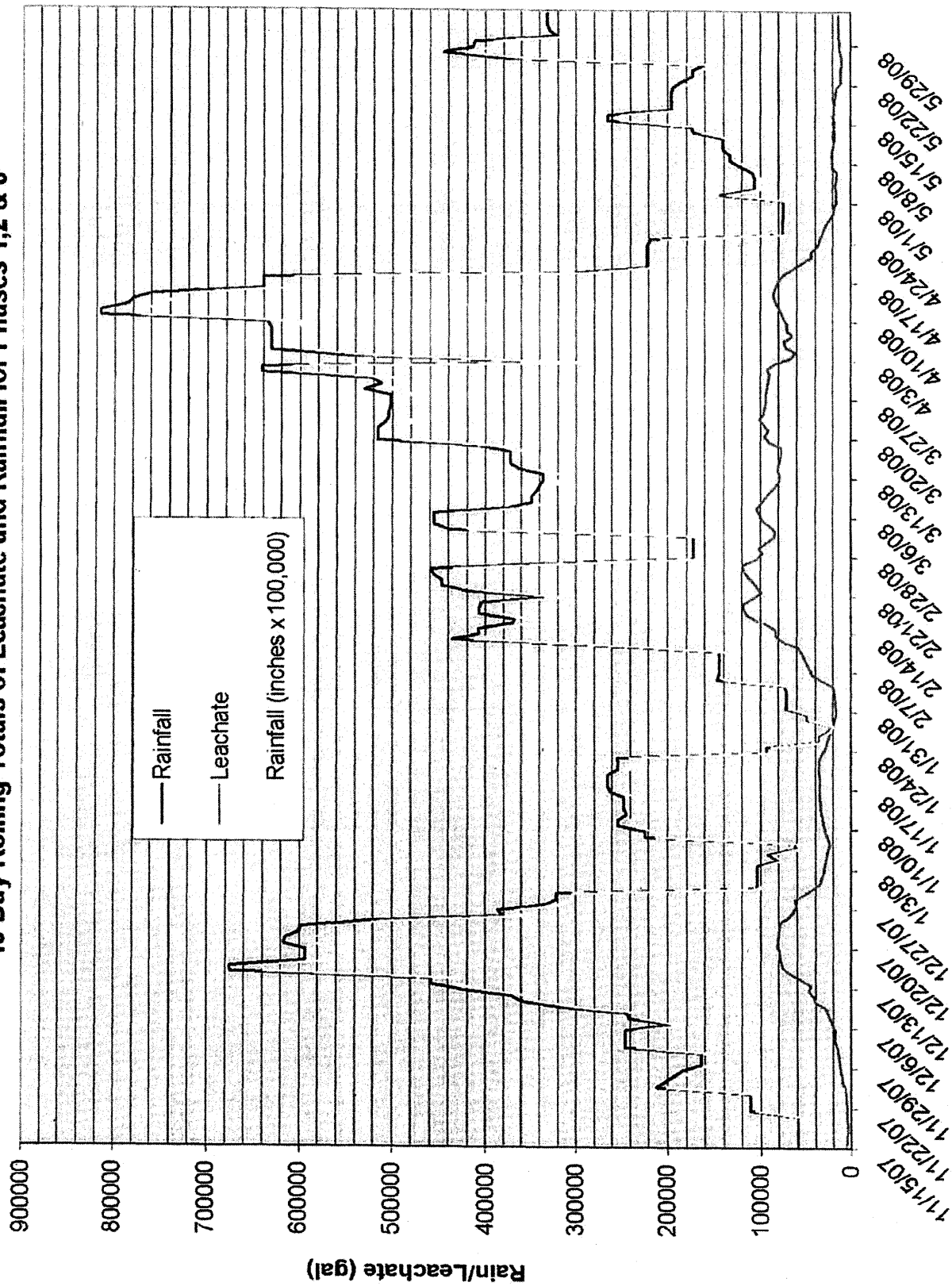

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
31-Oct-07		5000	4500	20000		16400	1700	9080				
1-Nov-07	600	500				14700	7600			600	0	600
2-Nov-07	600	1100				7100				600	0	600
3-Nov-07	600	1700				7100				600	0	600
4-Nov-07	600	2300				7100				600	0	600
5-Nov-07	0	2900				7100	3000			0	0	0
6-Nov-07	900	2900	1500			4100	3700			0	900	900
7-Nov-07	0	1400	1000			1300				0	0	0
8-Nov-07	225	400				1300				0	225	225
9-Nov-07	225	400				1525				0	225	225
10-Nov-07	225	400				1750				0	225	225
11-Nov-07	225	400				1975				0	225	225
12-Nov-07	0	400				2200				0	0	0
13-Nov-07	200	400				2200	1800			200	0	200
14-Nov-07	600	600				400				600	0	600
15-Nov-07	0	1200				400				0	0	0
16-Nov-07	0	1200				400				0	0	0
17-Nov-07	0	1200				400				0	0	0
18-Nov-07	0	1200				400				0	0	0
19-Nov-07	1000	1200				400				1000	0	1000
20-Nov-07	633	2200				400				633	0	633
21-Nov-07	633	2833				400				633	0	633
22-Nov-07	633	3467				400				633	0	633
23-Nov-07	633	4100				400				633	0	633
24-Nov-07	633	4733				400				633	0	633
25-Nov-07	633	5367				400				633	0	633
26-Nov-07	4100	6000	3600			400				0	4100	4100
27-Nov-07	0	2400	2000			4500	1000			0	0	0
28-Nov-07	2400	400				3500	3100			2400	0	2400
29-Nov-07	925	2800		8100		400		20200		925	0	925
30-Nov-07	925	3725				400				925	0	925

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
1-Dec-07	925	4650				400				925	0	925
2-Dec-07	925	5575				400				925	0	925
3-Dec-07	2700	6500	2300			400				1500	1200	2700
4-Dec-07	1700	5700	3400			1600				0	1700	1700
5-Dec-07	0	2300	1800			3300	1600			0	0	0
6-Dec-07	3350	500				1700	1300			3350	0	3350
7-Dec-07	3350	3850				400				3350	0	3350
8-Dec-07	3350	7200				400				3350	0	3350
9-Dec-07	3350	10550				400				3350	0	3350
10-Dec-07	11600	13900	4100			400				0	11600	11600
11-Dec-07	6400	9800	4300			12000				0	6400	6400
12-Dec-07	5500	5500	4400			18400				0	5500	5500
13-Dec-07	0	1100	700			23900	2200			0	0	0
14-Dec-07	11800	400				21700				11800	0	11800
15-Dec-07	11800	12200				21700				11800	0	11800
16-Dec-07	9800	24000				21700	2300			6200	3600	9800
17-Dec-07	3100	30200				23000	17800			0	3100	3100
18-Dec-07	4400	30200	19800			8300				0	4400	4400
19-Dec-07	1800	10400	10000			12700	5200			1800	0	1800
20-Dec-07	2467	2200				7500	4200			2467	0	2467
21-Dec-07	2467	4667				3300				2467	0	2467
22-Dec-07	2467	7133				3300				2467	0	2467
23-Dec-07	2467	9600				3300				2467	0	2467
24-Dec-07	2467	12067				3300				2467	0	2467
25-Dec-07	2467	14533				3300				2467	0	2467
26-Dec-07	1000	17000				3300				1000	0	1000
27-Dec-07	2000	18000				3300	2900			2000	0	2000
28-Dec-07	2000	20000				400				2000	0	2000
29-Dec-07	2000	22000				400				2000	0	2000
30-Dec-07	2000	24000				400				2000	0	2000
31-Dec-07	1600	26000	3100	53900		400		37500		0	1600	1600

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

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DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
1-Jan-08	1600	22900				2000				0	1600	1600
2-Jan-08	1600	22900	3600	L		3600				0	1600	1600
3-Jan-08	1050	19300	3000	L		5200				0	1050	1050
4-Jan-08	1050	16300				6250				0	1050	1050
5-Jan-08	1050	16300				7300				0	1050	1050
6-Jan-08	1050	16300				8350				0	1050	1050
7-Jan-08	600	16300	2200	L		9400				0	600	600
8-Jan-08	4600	14100				10000				4600	0	4600
9-Jan-08	5000	18700	9600	W	UL08-06	10000				0	5000	5000
10-Jan-08	3125	9100	8700	W		15000				0	3125	3125
11-Jan-08	3125	400				18125				0	3125	3125
12-Jan-08	3125	400				21250				0	3125	3125
13-Jan-08	3125	400				24375				0	3125	3125
14-Jan-08	2100	400	-27500			27500	27500			1700	400	2100
15-Jan-08	2700	29600	8500	W	UL08-07	400	1100	W		0	2700	2700
16-Jan-08	1500	21100	11100	W		2000				0	1500	1500
17-Jan-08	1360	10000	9600	W		3500				0	1360	1360
18-Jan-08	1360	400				4860				0	1360	1360
19-Jan-08	1360	400				6220				0	1360	1360
20-Jan-08	1360	400				7580				0	1360	1360
21-Jan-08	1360	400				8940				0	1360	1360
22-Jan-08	400	400				10300				0	400	400
23-Jan-08	1400	400				10700				0	1400	1400
24-Jan-08	1175	400				12100				0	1175	1175
25-Jan-08	1175	400				13275				0	1175	1175
26-Jan-08	1175	400				14450				0	1175	1175
27-Jan-08	1175	400				15625				0	1175	1175
28-Jan-08	200	400				16800	1000	L		200	0	200
29-Jan-08	700	600				15800	3800	L		700	0	700
30-Jan-08	300	1300				12000	3500	L		300	0	300
31-Jan-08	2100	1600			28,800	8500	2000	L	38,900	2100	0	2100

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Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
1-Feb-08	2100	3700				6500				2100	0	2100
2-Feb-08	2100	5800				6500				2100	0	2100
3-Feb-08	2100	7900				6500				2100	0	2100
4-Feb-08	2700	10000				6500	2900	L		2700	0	2700
5-Feb-08	13900	12700				3600	3200	L		13900	0	13900
6-Feb-08	10600	26600	3300	L		400				0	10600	10600
7-Feb-08	4250	23300	3300	L		11000				0	4250	4250
8-Feb-08	4250	20000				15250				0	4250	4250
9-Feb-08	4250	20000				19500				0	4250	4250
10-Feb-08	4250	20000				23750				0	4250	4250
11-Feb-08	4700	20000	1200	L		28000				2700	2000	4700
12-Feb-08	19000	21500	19000	Stored		30000				19000	0	19000
13-Feb-08	6500	21500	3500	W	UL08-09	30000	14000	W	UL08-08	6500	0	6500
14-Feb-08	0	24500	7800	L, W		16000	15600	W		0	0	0
15-Feb-08	12800	16700				400				2933	9867	12800
16-Feb-08	12800	19633				10267				2933	9867	12800
17-Feb-08	12800	22567				20133				2933	9867	12800
18-Feb-08	5000	25500	22000	L, W		30000				5000	0	5000
19-Feb-08	3500	8500	8500	L, W		30000	11000	W	UL08-10	3500	0	3500
20-Feb-08	4000	3500	1700	L		19000	14000	L, W		3200	800	4000
21-Feb-08	350	5000	2100	L		5800				0	350	350
22-Feb-08	9383	2900				6150				9033	350	9383
23-Feb-08	9383	11933				6500				9033	350	9383
24-Feb-08	9383	20967				6850				9033	350	9383
25-Feb-08	8900	30000				7200	2200	L		0	8900	8900
26-Feb-08	5700	30000	24000	W	UL08-11	13900	2100	L		0	5700	5700
27-Feb-08	3700	6000	5600	W		17500	8800	L, W	UL08-12	3700	0	3700
28-Feb-08	0	4100	800	L	83,800	8700	8300	W	82,100	0	0	0
29-Feb-08	4200	3300				400				4200	0	4200
1-Mar-08	4200	7500				400				4200	0	4200
2-Mar-08	4200	11700				400				4200	0	4200

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Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

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DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
3-Mar-08	12300	15900	1100	L		400				12300	0	12300
4-Mar-08	10900	27100	9300	L, W	UL08-13	400				0	10900	10900
5-Mar-08	12500	17800	17400	L, W		11300				0	12500	12500
6-Mar-08	4775	400				23800	13600	L, W	UL08-14	4775	0	4775
7-Mar-08	4775	5175				10200				4775	0	4775
8-Mar-08	4775	9950				10200				4775	0	4775
9-Mar-08	4775	14725				10200				4775	0	4775
10-Mar-08	4300	19500				10200	9400	W		4300	0	4300
11-Mar-08	2600	23800	12500	L, W	UL08-15	800	400	L		0	2600	2600
12-Mar-08	1500	11300	10400	L, W		3000	2200	L		300	1200	1500
13-Mar-08	2950	1200	200	L, W		2000				0	2950	2950
14-Mar-08	2750	1000				4950				-200	2950	2750
15-Mar-08	2750	800				7900				-200	2950	2750
16-Mar-08	2750	600				10850				-200	2950	2750
17-Mar-08	2900	400				13800	800	L		0	2900	2900
18-Mar-08	12500	400				15900	10600	L, W	UL08-16	12500	0	12500
19-Mar-08	24400	12900	4100	L, C-752-A		5300				13800	10600	24400
20-Mar-08	17600	22600	13400	W	UL08-17	15900	4200	W		0	17600	17600
21-Mar-08	233	9200	8800	W		29300				0	233	233
22-Mar-08	9533	400				29533				9300	233	9533
23-Mar-08	9533	9700				29767				9300	233	9533
24-Mar-08	900	19000	800	L		30000	10500	W	UL08-18	900	0	900
25-Mar-08	3000	19100	1200	L		19500	9500	W		3000	0	3000
26-Mar-08	1100	20900	5200	W	UL08-19	10000	9100	L, W		0	1100	1100
27-Mar-08	1725	15700	13500	L, W		2000				0	1725	1725
28-Mar-08	1725	2200				3725				0	1725	1725
29-Mar-08	1725	2200				5450				0	1725	1725
30-Mar-08	1725	2200				7175				0	1725	1725
31-Mar-08	1800	2200	1700	W	96,700	8900			70,300	0	1800	1800
1-Apr-08	5700	500				10700	400	L		0	5700	5700
2-Apr-08	3750	500				16000	1550	L		0	3750	3750

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Attachment 'K'

Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
3-Apr-08	7375	500				18200	1200	L	UL08-26	7375	0	7375
4-Apr-08	11508	7875				17000				7375	4133	11508
5-Apr-08	11508	15250				21133				7375	4133	11508
6-Apr-08	11508	22625				25267				7375	4133	11508
7-Apr-08	0	30000				29400	10700	L, W	UL08-28	0	0	0
8-Apr-08	7100	30000	3700	L, W	UL08-27	18700	18300	L, W		0	7100	7100
9-Apr-08	2300	26300	19000	L, W		7500				0	2300	2300
10-Apr-08	4875	7300	6800	L, W		9800				0	4875	4875
11-Apr-08	4875	500				14675				0	4875	4875
12-Apr-08	4875	500				19550				0	4875	4875
13-Apr-08	4875	500				24425				0	4875	4875
14-Apr-08	3800	500				29300	11100	W	UL08-29	3800	0	3800
15-Apr-08	1400	4300	700	L		18200	17800	W		1400	0	1400
16-Apr-08	2500	5000	1500	L		400				2500	0	2500
17-Apr-08	1400	6000				400				1400	0	1400
18-Apr-08	1400	7400				400				1400	0	1400
19-Apr-08	1400	8800				400				1400	0	1400
20-Apr-08	1400	10200				400				1400	0	1400
21-Apr-08	2000	11600	1200	L		400				2000	0	2000
22-Apr-08	0	12400	1800	L		400				0	0	0
23-Apr-08	700	10600				400				700	0	700
24-Apr-08	25	11300	3100	L		400				0	25	25
25-Apr-08	2225	8200				425				2200	25	2225
26-Apr-08	2225	10400				450				2200	25	2225
27-Apr-08	2225	12600				475				2200	25	2225
28-Apr-08	0	14800	2500	L		500				0	0	0
29-Apr-08	400	12300				500				400	0	400
30-Apr-08	500	12700	1000	L	41,300	500			61,050	500	0	500
1-May-08	0	12200	2000	L		500				0	0	0
2-May-08	1800	10200				500				1800	0	1800
3-May-08	1800	12000				500				1800	0	1800

Attachment 'K'

Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**

Project **Material Disposition** Job No. **N/A** Checked **Mary M. Hensley** Date **July 08, 2008**

DATE	Daily Net Gallons Collected	F-001 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	F-002 (gallons)	Discharged (gallons)	Method of Discharge	Total Gallons Discharged	Total Gallons Collected in F-001	Total Gallons Collected in F-002	Daily Net Gallons Collected
4-May-08	1800	13800				500				1800	0	1800
5-May-08	700	15600	1300	L		500				700	0	700
6-May-08	1100	15000	2500	L		500				1100	0	1100
7-May-08	5800	13600	8100	L, W		500				5800	0	5800
8-May-08	0	11300	2500	L		500				0	0	0
9-May-08	1133	8800				500				1133	0	1133
10-May-08	1133	9933				500				1133	0	1133
11-May-08	1133	11067				500				1133	0	1133
12-May-08	800	12200	2500	L		500				800	0	800
13-May-08	100	10500	2600	L		500				100	0	100
14-May-08	1100	8000	2600	L		500				1100	0	1100
15-May-08	0	6500	2500	L		500				0	0	0
16-May-08	1350	4000				500				1350	0	1350
17-May-08	1350	5350				500				1350	0	1350
18-May-08	1350	6700				500				1350	0	1350
19-May-08	880	8050	1130	L		500				880	0	880
20-May-08	0	7800				500				0	0	0
21-May-08	0	7800	3000	L		500				0	0	0
22-May-08	0	4800	2500	L		500				0	0	0
23-May-08	725	2300				500				725	0	725
24-May-08	725	3025				500				725	0	725
25-May-08	725	3750				500				725	0	725
26-May-08	725	4475				500				725	0	725
27-May-08	1560	5200				500				1560	0	1560
28-May-08	2605	6760	1300	L		500				2605	0	2605
29-May-08	0	8065	2650	L	37,180	500			0	0	0	0
30-May-08	1512	5415				500				1512	0	1512
31-May-08	1512	6927				500				1512	0	1512
1-Jun-08	1512	8438				500				1512	0	1512
2-Jun-08	700	9950	2650	L		500				700	0	700
3-Jun-08	1100	8000	2600	L		500				1100	0	1100

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

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Solid Waste Branch

WFO Monthly/Daily Climate Data

[illegible]
[illegible]
PRELIMINARY LOCAL CLIMATOLOGICAL DATA (CLIM) FORM: [illegible]

STATION: PADUCAH AP[illegible]
MONTH: NOVEMBER
YEAR: [illegible]
LATITUDE: [illegible] N
LONGITUDE: [illegible] 46 [illegible]

	TEMPERATURE (F):						:PCPN:		SNOW:	WIND				:SUNSHINE:	SKY		:PK WND	
	2	3	4	5	6A	6B	7	8	9	10	11	12	13	14	15	16	17	18
										AVG	MX	2MIN						
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	SPD	SPD	DIR	MIN	PSBL	S-S	WX	SPD	DR
1	61	33	47	-8	18	0	0.00	0.0	0	7.9	19	30	535	84	4		23	40
	65	30	48	-4	17	0	0.00	0.0	0	1.9	12	40	837	100	0		18	10
3	65	32	49	-2	16	0	0.00	0.0	0	2.4	12	320	370	90			16	330
4	6[illegible]	35	49	-2	16	0	0.00	0.0	0	5.2	17	320	625	99	0	18	25	310
5	76	45	61	10	4	0	0.00	0.0	0	11.4	26	350	469	74	[illegible]		3[illegible]	360
6	50	29	39	-11	26	0	0.00	0.0	0	6.1	22	340	629	100	0		29	340
	50	24	37	-13	28	0	0.00	0.0	0	2.5	9	190	603	96	0		12	190
8	61	38	5[illegible]	1	15	0	0.00	0.0	0	6.5	21	230	587	94	0		29	220
9	66	36	51	4	14	0	0.00	0.0	0	3.5	13	360	598	96	0		16	360
10	58	30	44	-5	21	0	0.00	0.0	0	3.4	10	120	333	54	0	18	14	120
11	62	44	53	5	12	0	0.19	0.0	0	5.9	15	170	375	61	5	18	20	170
12	68	57	63	15	2	0	0.09	0.0	0	6.6	17	220	443	72	4	1	23	230
13	68	57	63	15	[illegible]	0	0.09	0.0	0	6.1	12	220	405	33	8	138	20	210
14	67	47	57	10	3	0	0.19	0.0	0	8.2	13	340	503	33	7	138	32	300
15	50	39	[illegible]	-7	25	0	0.00	0.0	0	7.5	21	340	447	40	3		29	350
16	53	26	40	-7	25	0	0.00	0.0	0	3.2	13	230	580	95	0		19	210
17	63	37	50	4	15	0	0.00	0.0	0	5.0	15	230	600	100	0	1	17	230
18	66	33	50	[illegible]	15	0	0.00	0.0	0	3.6	10	130	350	58	[illegible]	[illegible]	[illegible]	110
19	66	59	63	17	[illegible]	0	T	0.0	0	6.8	18	30	370	45	8	1	23	170
20	61	56	65	20	[illegible]	0	0.00	0.0	0	6.2	16	220	471	[illegible]	6		[illegible]	220
21	67	43	55	10	[illegible]	0	0.49	0.0	0	8.8	22	290	178	30	8	138	30	290
22	42	35	39	-5	26	[illegible]	T	0.0	0	10.[illegible]	20	330	307	51	10		26	310
23	41	24	33	-11	32	0	T	T	0	5.1	17	40	360	69	4		[illegible]	[illegible]
24	44	23	34	-10	31	0	0.00	0.0	0	0.4	9	270	120	20	3		16	160
25	45	37	40	-3	25	0	0.98	0.0	0	5.5	13	50	0		10	18	15	60
26	46	34	40	-3	25	0	0.10	0.0	0	5.7	13	300	0		1	1	18	290
27	5[illegible]	37	47	-3	18	0	0.00	0.0	0	2.1	9	260	590	99	0	18	11	170

Originator J. Keith Thorn Date July 08, 2008 Calc. No. CAC-PH746U-P001 Rev. No. 1
Project Material Disposition Job No. N/A Checked N/A Date N/A


```
28  56  28  [illegible]       [illegible]  1.00  1.[illegible]   5.[illegible] 19 [illegible]
29  49  25  37  -5  28   [illegible]  0.00  0.0   6.2  22 340 28 [illegible]  1  31 340
30  53  [illegible]  [illegible]  -4  [illegible]   [illegible]            3.[illegible] [illegible]  4  351  [illegible]
========
SM 1[illegible]44 10[illegible]      533      .1[illegible]     16[illegible]     1[illegible]1[illegible]0    98
==============================================================================
AV 58.[illegible] 30.[illegible]                    [illegible].4 FASTST  PST[illegible]          MAX(MPH)
                       MISC ----   # 16  [illegible]                # 35  36[illegible]
==============================================================================
NOTES:
# LAST OF SEVERAL OCCURRENCES

COLUMN 17 PEAK WIND IN M.P.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6) , PAGE [illegible]

                                   STATION:    PADUCAH ASOS
                                   MONTH:      NOVEMBER
                                   YEAR:       [illegible]
                                   LATITUDE:   [illegible]
                                   LONGITUDE:  [illegible]

[TEMPERATURE DATA]        [PRECIPITATION DATA]      SYMBOLS USED IN COLUMN 16

AVERAGE MONTHLY: 4[illegible]   TOTAL FOR MONTH:   [illegible].11   1 = FOG OR MIST
DPTR FM NORMAL:  [illegible]    DPTR FM NORMAL:   -[illegible].4[illegible]  2 = FOG REDUCING VISIBILITY
HIGHEST:    [illegible]6 ON [illegible]5   GRTST 24HR [illegible]  ON [illegible]5-[illegible]6      TO 1/4 MILE OR LESS
LOWEST:     [illegible] ON 3[illegible]                             3 = THUNDER
                          SNOW, ICE PELLETS, HAIL   4 = ICE PELLETS
                          TOTAL MONTH:               5 = HAIL
                          GRTST 24HR    [illegible] ON [illegible]3-[illegible]3   6 = FREEZING RAIN OR DRIZZLE
                          GRTST DEPTH:   [illegible]          7 = DUSTSTORM OR SANDSTORM:
                                                         VSBY 1/2 MILE OR LESS
                                                    8 = SMOKE OR HAZE
[NO. OF DAYS WITH]        WEATHER - DAYS WITH       9 = BLOWING SNOW
                                                    X = TORNADO
MAX 32 OR BELOW:   [illegible]   0.01 INCH OR MORE:   [illegible]
MAX 90 OR ABOVE:   [illegible]   0.10 INCH OR MORE:   [illegible]
MIN 32 OR BELOW:  13   0.50 INCH OR MORE:   1
MIN  0 OR BELOW:   0   1.00 INCH OR MORE:

[HDD (BASE 65) ]
TOTAL THIS MO.    533   CLEAR  (SCALE 0-3)  1[illegible]
DPTR FM NORMAL      [illegible]   PTCLDY (SCALE 4-7)  1[illegible]
TOTAL FM JUL 1   [illegible]6   CLOUDY (SCALE 8-10)  4
DPTR FM NORMAL   -1[illegible]4

[CDD (BASE 65) ]
TOTAL THIS MO.
DPTR FM NORMAL     -1    [PRESSURE DATA]
TOTAL FM JAN 1   1[illegible]   HIGHEST SLP [illegible].5[illegible] ON [illegible]3
DPTR FM NORMAL    4[illegible]7   LOWEST  SLP [illegible]9.7[illegible] ON [illegible]1

[REMARKS]
#FINAL-11-[illegible]#
```

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

WFO Monthly/Daily Climate Data

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Division of Waste Management
Solid Waste Branch

[illegible]

STATION: PADUCAH ARO[illegible]
MONTH: DECEMBER
YEAR: [illegible]
LATITUDE: 37 [illegible] 4 [illegible]
LONGITUDE: [illegible] 6 [illegible]

	TEMPERATURE [illegible]F:								PCPN:	SNOW:	WIND						SUNSHINE:		SKY		WIND	
	[illegible]																					
												AVG	MX	[illegible]								
DY	MAX	MIN	AVG	DEP	HDD	CDD	PCP	SNW	DPTH	SPD	SPD	DIR	MIN	PSBL	S-S	WX	SPD	DR
1	62	35	48	5	16	[illegible]	1.00	0.0	0	7.4	18	190	453	77	4		29	160
[illegible]	6[illegible]	34	[illegible]	4	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	3[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39	330
3	41	[illegible]	[illegible]	-	3[illegible]	[illegible]	[illegible]	0.		6.8	19	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	350
4	[illegible]	[illegible]	38	-[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		4.8	[illegible]	[illegible]	389	[illegible]	[illegible]		18	140
5	49	[illegible]	3[illegible]	-[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	11.7	26	35[illegible]	4[illegible]1	51	[illegible]		36	350
6	37	[illegible]	[illegible]	-11	36	[illegible]	[illegible]	T	[illegible]	4.[illegible]	13	100	456	[illegible]	[illegible] 14		16	90
7	43	36	40	1	25	[illegible]	1.43	0.[illegible]	[illegible]	4.[illegible]	[illegible]	40	[illegible]	[illegible]	10 19		[illegible]	50
8	44	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	80	10	[illegible]	10 [illegible]		16	50
9	46	40	[illegible]	1	[illegible]		.69	0.	[illegible]	1.3	15	320	0	[illegible]	10 [illegible]		[illegible]	[illegible]
10	41	37	39	1	26	[illegible]	1.37	0.[illegible]	[illegible]	6.1	12	10	0	[illegible]	10 1		14	360
11	[illegible]	41	34	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	5.5	[illegible]	330	318	[illegible]	[illegible]		29	330
12	49	39	[illegible]	6	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	360	195	[illegible]	10 1		24	360
13	4	34	38	1	[illegible]		[illegible]	[illegible]	[illegible]	5.3	13	350	143	[illegible]	10 1		[illegible]	310
14	42	32	37	[illegible]	29	[illegible]	0.00	0.0	[illegible]	7.4	16	90	183	32	6		21	80
15	39	3[illegible]	36	-1	29	[illegible]	0.05	T	[illegible]	9.2	20	00	0	[illegible]	10 1		28	[illegible]
16	34	23	29	-[illegible]	36		.1	0.1	[illegible]	9.4	21	320	[illegible]	36	5 19		25	310
17	43	[illegible]	38	-[illegible]	[illegible]		.0	0.[illegible]	[illegible]	1.6	1[illegible]	[illegible]	5[illegible]8	[illegible]	[illegible] 18		14	50
18	51	29	40	4	25	[illegible]	0.00	0.0	[illegible]	6.9	20	220	366	63	4		29	210
19	54	33	44	[illegible]	21	[illegible]	0.00	0.[illegible]	[illegible]	[illegible]	15	250	176	43	4 [illegible]		11	250
20	49	36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.5	1[illegible]	170	1	1[illegible]	[illegible]		18	1[illegible]
21	52	46	49	14	16	[illegible]	[illegible]	0.[illegible]	[illegible]	3.[illegible]	8	120	[illegible]	[illegible]	1[illegible] 1[illegible]		[illegible]	120
22	57	51	54	19	[illegible]	[illegible]	.29	0.0	[illegible]	M	M	M	75	49	9 [illegible]		M	M
23	[illegible]	3[illegible]	3[illegible]	4	[illegible]		.1	T	[illegible]	16.	[illegible]	60	[illegible]	[illegible]	[illegible]		36	80
24	4	[illegible]	[illegible]	3	[illegible]		[illegible]	[illegible]	[illegible]	6.4	14	260	148	95			1	160
25	51	[illegible]	37	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	1.1	16	160	[illegible]	1[illegible]	[illegible]		[illegible]	140
26	51	14	[illegible]	4	[illegible]		[illegible]	[illegible]	[illegible]	4.[illegible]	15	340	470	[illegible]	[illegible] 1		19	340
[illegible]	41	33	[illegible]	3			.	.		3.6	9	1[illegible]	[illegible]		1[illegible] 1		[illegible]	[illegible]

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

18	47	32	10	6	15	[illegible]	1.19	[illegible]	[illegible]	[illegible]	7.0	18	180	3.9	[illegible]	55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	41	27	33	1	31	[illegible]	1.10	1.9	[illegible]	[illegible]	1.1	6	170	3.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	10
30	[illegible]	[illegible]	37	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	56	31	[illegible]	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SM 1[illegible] 994 [illegible] 6+ [illegible] 7.37 [illegible] 1. [illegible] [illegible] 9.0 [illegible] 17

AV 48. 32.1 6.2 FASTST [illegible] [illegible] [illegible] (MPH)
HIGH ---- # 30 [illegible] # [illegible]

NOTES:
LAST OF SEVERAL [illegible] OCCURRENCES

COLUMN 17 PEAK WIND IN M.P.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA [illegible] FORM: F-6[illegible] , P[illegible]

STATION: PADUCAH AGOS
MONTH: DECEMBER
YEAR: 2007
LATITUDE: [illegible]
LONGITUDE: [illegible]

[TEMPERATURE DATA]

AVERAGE MONTHLY: 4[illegible].0
DPTR FM NORMAL: 3.[illegible]
HIGHEST: [illegible] ON 11
LOWEST: [illegible] ON [illegible]

[PRECIPITATION DATA]

TOTAL FOR MONTH: [illegible].37
DPTR FM NORMAL: .69
GRTST 24HR [illegible]. 5 ON 15-1[illegible]

SNOW, ICE PELLETS, HAIL
TOTAL MONTH: .2 INCH
GRTST 24HR 0.2 ON M
GRTST DEPTH:

SYMBOLS USED IN COLUMN 16

1 = FOG OR MIST
= FOG REDUCING VISIBILITY TO 1/4 MILE OR LESS
3 = THUNDER
4 = ICE PELLETS
5 = HAIL
6 = FREEZING RAIN OR DRIZZLE
7 = DUSTSTORM OR SANDSTORM: VSBY 1/2 MILE OR LESS
8 = SMOKE OR HAZE
9 = BLOWING SNOW
X = TORNADO

[NO. OF DAYS WITH]

MAX 32 OR BELOW: [illegible]
MAX 90 OR ABOVE: [illegible]
MIN 32 OR BELOW: 17
MIN [illegible] OR BELOW: [illegible]

[WEATHER - DAYS WITH]

0.01 INCH OR MORE: 16
0.10 INCH OR MORE: 1[illegible]
0.50 INCH OR MORE: 5
1.00 INCH OR MORE: [illegible]

[HDD (BASE 65)]
TOTAL THIS MO. 68
DPTR FM NORMAL -87
TOTAL FM JUL 1 1474
DPTR FM NORMAL -191

CLEAR (SCALE 0-3) 11
PTCLDY (SCALE 4-[illegible]) [illegible]
CLOUDY (SCALE 8-1[illegible]) [illegible]

[CDD (BASE 65)]
TOTAL THIS MO. [illegible]
DPTR FM NORMAL [illegible]
TOTAL FM JAN 1 1958
DPTR FM NORMAL [illegible]

[PRESSURE DATA
HIGHEST SLP 30.27 ON 15
LOWEST SLP 29.75 ON 31

[REMARKS]

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

WFO Monthly/Daily Climate Data

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Solid Waste Branch

PRELIMINARY

STATION: PADUCAH ASOS
MONTH: JANUARY
YEAR: 2008
LATITUDE: 37 4 N
LONGITUDE: 88 46 W

	TEMPERATURE (°F)						PCPN	SNOW		WIND				SUNSHINE	SKY		PK WND	
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	AVG SPD	MX SPD	MN DIR	MIN	PSBL	S-S	WX	SPD	DR
1	36	19	28	-5	37	[illegible]	0.00	0.0	0	13.2	23	310	5.6	[illegible]	[illegible]		33	320
2	22	11	17	-16	48	0	T	T	0	7.[illegible]	16	300	160	79	8		23	310
3	31	10	21	-12	44	[illegible]	0.00	[illegible]	0	[illegible].8	1[illegible]	1[illegible]0	569	9[illegible]	0		1[illegible]	18[illegible]
4	46	21	34	1	31	0	0.00	0.0	0	8.8	1[illegible]	2[illegible]0	5[illegible]9	91	[illegible]		[illegible]	1[illegible]
5	55	42	49	16	16	[illegible]	0.11	0.0	0	9.[illegible]	15	130	143	[illegible]5	10		[illegible]5	21[illegible]
6	68	55	62	29	3	0	0.00	0.0	[illegible]	[illegible].8	2[illegible]	210	472	69	10		28	210
7	7[illegible]	60	65	32	[illegible]	[illegible]	0.00	0.0	0	11.3	20	180	4[illegible]	7[illegible]	7		28	160
8	6[illegible]	44	56	23	9	[illegible]	1.63	[illegible]	0	14.3	32	230	1[illegible]	2[illegible]	9	1[illegible]	45	28[illegible]
9	51	36	[illegible]	11	[illegible]	[illegible]	0.00	0.0	M	M	M	M	[illegible]	[illegible]	0		M	M
10	59	36	48	16	17	0	0.55	0.0	0	9.8	3[illegible]	270	216	37	5	1	40	280
11	46	[illegible]9	3[illegible]	6	[illegible]7	[illegible]	0.[illegible]0	[illegible].0	[illegible]	[illegible].6	14	250	[illegible]4	86			[illegible]	[illegible]0
12	53	26	4[illegible]	[illegible]	[illegible]5	[illegible]	[illegible].10	[illegible].0	[illegible]	3.[illegible]	0	50	[illegible]7	[illegible]6	1	[illegible]	23	[illegible]0
13	4[illegible]	26	3[illegible]	3	3[illegible]	[illegible]	0.[illegible]3	T	0	7.[illegible]	16	3[illegible]0	376	64	[illegible]	8	[illegible]1	31[illegible]
14	40	23	32	0	33	0	0.30	0.0	[illegible]	6.5	13	290	543	92	4		17	280
15	36	21	2[illegible]	-3	36	[illegible]	[illegible].0	[illegible].0	[illegible]	[illegible].[illegible]	14	330	5[illegible]	[illegible]	0		17	3[illegible]
16	40	24	3[illegible]	[illegible]	35	[illegible]	[illegible].14	[illegible].7	[illegible]	3.4	13	170	95	14	3	1[illegible]	17	170
17	4[illegible]	[illegible]	35	[illegible]	[illegible]	[illegible]	[illegible].[illegible]	[illegible].[illegible]	[illegible]	5.9	1[illegible]	[illegible]0	199	33	[illegible]	8	4	[illegible]0
18	39	19	29	-4	36	0	0.00	0.0	0	5.0	12	230	363	61	0		15	230
19	31	14	23	-10	42	0	0.00	0.0	[illegible]	10.2	20	350	343	57	2		25	10
20	2[illegible]	[illegible]	1[illegible]	-15	47	[illegible]	[illegible].0	[illegible].0	[illegible]	3.4	10	340	6[illegible]1	[illegible]	0		[illegible]	310
21	43	14	29	-4	36	[illegible]	T	0.0	0	7.2	15	160	509	84	3		20	180
22	4[illegible]	20	3[illegible]	-[illegible]	35	0	0.03	[illegible]	[illegible]	7.[illegible]	[illegible]	1[illegible]0	[illegible]74	45	6	1[illegible]	[illegible]	[illegible]0
23	37	[illegible]	26	-7	39	[illegible]	[illegible].0	[illegible].0	[illegible]	3.4	10	[illegible]40	[illegible]35	98	0	[illegible]	13	[illegible]
24	[illegible]	14	21	-1[illegible]	[illegible]4	0	T	T	[illegible]	1[illegible].3	2[illegible]	360	4[illegible]	[illegible]	2	8	30	340
25	31	10	21	-12	44	0	[illegible].0	[illegible].0	[illegible]	4.[illegible]	13	220	2[illegible]3	3[illegible]	4		16	240
26	38	28	3[illegible]	[illegible]	32	0	0.00	[illegible]	[illegible]	8.4	15	250	M	[illegible]	[illegible]	18	20	220
27	47	3[illegible]	[illegible]9	[illegible]	26	[illegible]	[illegible].[illegible]	[illegible]	[illegible]	6.3	1[illegible]	[illegible]50	[illegible]	6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]60

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data


```
16  55  13  39   5  26   0    T  0.[illegible]   0  7.[illegible] 17 17[illegible] 453   25   [illegible] 1[illegible]   30 [illegible]
23  63  22  43   9  21   0 0.26  0.7   0 14.8 43 270 330   5[illegible]   9 17    64 180
30  3   18  18  -6  37   0  .    0.        1.  1[illegible]  [illegible]  [illegible]  5                 20 [illegible]
31  34      31  -2  34     0.38   .6      8.9 13  80  59   1   1  146     1  [illegible]
==========================================================================================
SU 13[illegible]  [illegible]4       94       [illegible].1[illegible]     1.  [illegible] .7        116      1.8
==========================================================================================
AV 43.8  [illegible].0                                   [illegible].3 FASTST  FSL  [illegible]   4    MA[illegible]
                                        MISC ----   # 43 270                    # 64 [illegible]6
==========================================================================================
```

NOTES:
LAST [illegible] SEVERAL [illegible]

COLUMN 1 PEAK WIND [illegible] M.P.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6[illegible] , REV. [illegible]

STATION: PADUCAH ASOS
MONTH: JANUARY
YEAR: 2005
LATITUDE: 37 4[illegible]
LONGITUDE: 89 46 [illegible]

TEMPERATURE DATA	PRECIPITATION DATA	SYMBOLS USED IN COLUMN 16
AVERAGE MONTHLY: 51.3	TOTAL FOR MONTH: 3.16	1 = FOG OR MIST
DEPTR FM NORMAL: [illegible].4	DEPTR FM NORMAL: -0.81	2 = FOG REDUCING VISIBILITY
HIGHEST: [illegible] ON [illegible]	GRTST 24HR [illegible].33 ON [illegible]	TO 1/4 MILE OR LESS
LOWEST: [illegible] ON 25,		3 = THUNDER
	SNOW, ICE PELLETS, HAIL	4 = ICE PELLETS
	TOTAL MONTH: 1.7 INCHES	5 = HAIL
	GRTST 24HR [illegible].7 ON [illegible] M	6 = FREEZING RAIN OR DRIZZLE
	GRTST DEPTH: [illegible]	7 = DUSTSTORM OR SANDSTORM:
		VSBY 1/4 MILE OR LESS
		8 = SMOKE OR HAZE
NO. OF DAYS WITH:	WEATHER - DAYS WITH:	9 = BLOWING SNOW
		X = TORNADO
MAX 32 OR BELOW: 6	0.01 INCH OR MORE: 11	
MAX 90 OR ABOVE: [illegible]0	0.10 INCH OR MORE: 7	
MIN 32 OR BELOW: 25	0.50 INCH OR MORE: 2	
MIN [illegible] OR BELOW: [illegible]	1.00 INCH OR MORE: 1	

HDD (BASE 65)
TOTAL THIS MO. 94[illegible]
DEPTR FM NORMAL -1[illegible]
TOTAL SN JUL 1 [illegible]14
DEPTR FM NORMAL -135

CDD (BASE 65)
TOTAL THIS MO. 0
DEPTR FM NORMAL 0
TOTAL SN JAN 1 0
DEPTR FM NORMAL [illegible]

CLEAR (SCALE 0-3)	14
PTCLDY (SCALE 4-7)	1[illegible]
CLOUDY (SCALE 8-1[illegible])	7

PRESSURE DATA
HIGHEST SLP 30.69 ON 26
LOWEST SLP 9.[illegible] ON 1[illegible]

REMARKS

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

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MAR 08 2012
Division of Waste Management
Solid Waste Branch

WFO Monthly/Daily Climate Data

[illegible]

PLACE: [illegible]
MONTH: FEBRUARY
YEAR: [illegible]
LATITUDE: [illegible]
LONGITUDE: [illegible]

TEMPERATURE							PCPN:		SNOW:		WIND		SUNSHINE:						
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	SPD	SPD	DIR	MIN	PCT				PKD	DIR
1	33	22	28	-6	37	[illegible]	0.02	0.4	0	9.9	25	260	93		16	[illegible]	[illegible]	32	260
[illegible]	55	21	38	3	27	0	0.06	0.1	0	8.3	23	280	89		[illegible]	[illegible]	[illegible]	[illegible]	150
3	60	[illegible]	45	9	21	[illegible]	T	.	0	8.3	16	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	25	150
[illegible]	[illegible]	5[illegible]	6[illegible]	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	76	5[illegible]	[illegible]	3[illegible]	[illegible]	[illegible]	0.00	[illegible]	[illegible]	[illegible]	40	[illegible]	171		[illegible]	9	[illegible]	54	260
6	60	35	48	12	17	0	0.11	0.0	0	14.9	33	240	[illegible]		3[illegible]	10	19	44	240
7	37	31	34	-[illegible]	31	0	0.06	0.0	0	3.3	[illegible]	280	[illegible]		16	10		15	280
8	50	28	39	[illegible]	[illegible]	[illegible]	0.00	[illegible]	0	3.2	19	[illegible]	[illegible]		[illegible]	[illegible]	19	[illegible]	120
9	57	33	45	9	20	0	[illegible]	[illegible]	0	10.6	28	150	91		95	[illegible]	[illegible]	35	140
10	44	20	32	-5	33	0	0.00	0.0	0	9.6	[illegible]	360	88		9[illegible]	[illegible]		26	[illegible]
11	35	[illegible]	[illegible]	-1[illegible]	38	0	1.15	[illegible]	0	8.1	16	110	170		19	[illegible]	130	20	110
12	33	21	[illegible]	-1[illegible]	38	0	1.80	0.0	[illegible]	[illegible]	[illegible]	130	[illegible]			8	136	21	180
13	24	18	21	-17	44	[illegible]	T	T	0	4.3	[illegible]	330	1[illegible]		16	[illegible]	19	M	[illegible]
14	48	19	34	-4	31	0	[illegible]	0.0	0	5.7	14	170	58[illegible]		91	[illegible]	19	21	170
15	43	31	37	1	28		T	[illegible]	0	8.6	15	[illegible]	[illegible]		47	8	8	20	30
16	49	34	42	4	23	0	T	[illegible]	0	6.7	12	110	16		[illegible]	8	18	15	110
17	61	40	51	[illegible]	14		[illegible]	[illegible]	[illegible]	12.1	38	150	[illegible]		55	[illegible]	13[illegible]	4[illegible]	250
18	45	35	40	1	25	0	0.10	0.0	0	11.8	25	280	463		[illegible]	[illegible]		36	290
19	37	23	30	-9	35	[illegible]	0.00	0.0	[illegible]	[illegible]	16	[illegible]	[illegible]		[illegible]	4		21	140
20	39	23	31	-8	34		T	0.0	[illegible]	11.4	[illegible]	340	180		35	[illegible]		13	360
21	33	13	23	-12	37	[illegible]	0.35	[illegible]	0	9.5	13	160	[illegible]			10	16[illegible]	26	170
22	35	28	31	-9	34		[illegible] 6	0.0	[illegible]	6.3	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
23	31	26	3[illegible]	-1	35		[illegible] 0	[illegible]	[illegible]	4.7	13	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
24	3[illegible]	31	34	-[illegible]	31		[illegible]	[illegible]	[illegible]	1.5	9	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
25	52	35	44	5	21	[illegible]	[illegible] 3	[illegible]	[illegible]	4.8	16	150	[illegible]		[illegible]	[illegible]	[illegible]	21	[illegible]
26	50	27	39	-3	26	[illegible]	0.14	0.1	0	15.1	29	330	[illegible]		[illegible]	17	8	37	341
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		T	T	[illegible]	[illegible]	[illegible]	360	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data


```
26  41  24  36  -6.[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
19  65  55  38   7  18   [illegible]   T  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
==========================================================================================
SM 1343  851        794      [illegible]  1.6  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
==========================================================================================
AV 46.[illegible]  29.[illegible]                                [illegible]  FASTST  PSBL                MAX(MPH)
                                                    MTHS ----   # 4[illegible]                    # [illegible]
==========================================================================================
NOTES:
# LAST OF SEVERAL OCCURRENCES

[illegible] 1[illegible] [illegible] [illegible]

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6) , PAGE [illegible]

                                                STATION:  PADUCAH AP[illegible]
                                                MONTH:    FEBRUARY
                                                YEAR:     2008
                                                LATITUDE:   [illegible]  4
                                                LONGITUDE:  8[illegible]  46 [illegible]

(TEMPERATURE DATA)        (PRECIPITATION DATA)        SYMBOLS USED IN COLUMN 18

AVERAGE MONTHLY: 37.8     TOTAL FOR MONTH:    5.13     1 = FOG OR MIST
DEPTR FM NORMAL:  - [illegible]   DEPTR FM NORMAL:    1.[illegible]6     2 = FOG REDUCING VISIBILITY
HIGHEST:      6 ON [illegible]    GRTST 24HR   [illegible].69 ON 11-[illegible]      TO 1/4 MILE OR LESS
LOWEST:      19 ON 1[illegible]                                          3 = THUNDER
                          SNOW, ICE PELLETS, HAIL     4 = ICE PELLETS
                          TOTAL MONTH:   1.6 INCHES   5 = HAIL
                          GRTST 24HR   [illegible].5 ON [illegible]-1   6 = FREEZING RAIN OR DRIZZLE
                          GRTST DEPTH:                7 = DUSTSTORM OR SANDSTORM:
                                                        VSBY 1/4 MILE OR LESS
                                                      8 = SMOKE OR HAZE
(NO. OF DAYS WITH)        (WEATHER - DAYS WITH)       9 = BLOWING SNOW
                                                      X = TORNADO
MAX 32 OR BELOW:   1      0.01 INCH OR MORE:  [illegible]
MAX 90 OR ABOVE:   [illegible]    0.10 INCH OR MORE:   6
MIN 32 OR BELOW:  19      0.50 INCH OR MORE:   4
MIN  0 OR BELOW:   [illegible]    1.00 INCH OR MORE:   2

(HDD (BASE 65) )
TOTAL THIS MO.    794     (CLEAR  (SCALE  -3)  [illegible]
DEPTR FM NORMAL    34     PTCLDY (SCALE 4-7)  [illegible]
TOTAL FM JUL 1  3136      CLDY (SCALE 8-1[illegible])  [illegible]
DEPTR FM NORMAL  -[illegible]

(CDD (BASE 65) )
TOTAL THIS MO.     2
DEPTR FM NORMAL          (PRESSURE DATA
TOTAL FM JAN 1           HIGHEST SLP 3[illegible].5[illegible] ON 10
DEPTR FM NORMAL    2     LOWEST  SLP 29.38 ON 17

 REMARKS
#[illegible]-0[illegible] - [illegible]#
```

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

WFO Monthly/Daily Climate Data

RECEIVED
MAR 08 2012
Division of Waste Management
Solid Waste Branch

U.S. [illegible]
[illegible]PA
PRELIMINARY [illegible] CLIMATOLOGICAL [illegible] FOR: [illegible]

STATION: PADUCAH ASO[illegible]
MONTH: MARCH
YEAR: 2008
LATITUDE: [illegible] 4[illegible]
LONGITUDE: [illegible] 46 [illegible]

TEMPERATURE [illegible]:							:PCPN:	SNOW:	WIND				:SUNSHINE:	SKY		:[illegible] WND	
[illegible]	3	4		6A	6B		8	9	1	11	12	13	14	15	[illegible]	17	18
									AVG	MX	2MIN						
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	SPD	SPD	DIR	MIN	PSBL	S-S	WX	SPD	DR
1	62	25	44	1	21	0	0.00	0.0	0	4.6	12	160	560	82	[illegible]		16	180
2	75	49	[illegible]	19	3	[illegible]	[illegible].00	[illegible].0	0	8.3	26	340	601	9[illegible]	6		37	[illegible]
3	65	35	[illegible]	[illegible]	1[illegible]	[illegible]	2.90	[illegible]	0	13.3	26	30	0	[illegible]	[illegible]	13	3[illegible]	3[illegible]
4	36	3[illegible]	34	-10	31	[illegible]	[illegible].15	0.1	0	11.[illegible]	[illegible]	30	[illegible]	[illegible]	10	1[illegible]	[illegible]9	[illegible]
5	50	30	4[illegible]	-4	15	[illegible]	[illegible].00	0.0	[illegible]	3.4	9	130	6[illegible]	[illegible]	3		14	210
6	38	30	34	-10	31	0	0.00	0.0	[illegible]	8.8	18	20	50	[illegible]	[illegible]	18	23	10
7	34	27	31	-1[illegible]	34	0	0.07	1.3	1	19.3	28	20	0	[illegible]	10	1[illegible]	36	20
8	34	[illegible]2	28	-17	37	[illegible]	[illegible].04	[illegible].5	0	10.1	23	350	[illegible]9	54	3		30	350
9	51	2[illegible]	39	-6	26	[illegible]	0.00	0.0	0	4.[illegible]	15	1[illegible]0	[illegible]98	85	[illegible]		1	[illegible]0
10	55	33	44	-[illegible]	[illegible]1	0	0.02	0.0	0	6.0	15	350	499	71	3	18	21	350
11	54	[illegible]	41	-5	[illegible]4	[illegible]	0.[illegible]0	0.0	0	5.4	15	[illegible]50	[illegible]89	9[illegible]	0	18	1	60
12	[illegible]0	41	[illegible]6	10	9	0	0.00	[illegible].0	0	[illegible].[illegible]	16	250	449	51	0		21	250
13	71	49	60	13	5	[illegible]	T	0.0	0	[illegible].8	[illegible]0	230	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]0
14	62	46	54	7	11	0	0.26	0.0	0	4.0	13	70	137	19	4	18	16	70
15	54	46	50	3	15	[illegible]	[illegible].09	[illegible].[illegible]	0	8.4	[illegible]4	120	35	[illegible]	[illegible]	18	29	110
16	56	42	49	1	16	0	0.00	0.0	[illegible]	7.[illegible]	16	7[illegible]	[illegible]34	36	5	8	20	70
17	[illegible]0	41	5[illegible]	9	8	[illegible]	[illegible].00	[illegible].0	[illegible]	11.4	23	170	154	19	[illegible]		32	170
18	71	53	62	14	3	0	3.21	0.[illegible]	0	11.4	23	350	0	[illegible]	[illegible]	138	35	160
19	52	36	44	-5	21	0	1.19	T	0	13.2	26	10	M	M	8	135	35	[illegible]0
[illegible]	59	[illegible]	[illegible]	-2	18	[illegible]	[illegible].00	0.[illegible]	[illegible]	5.5	12	210	[illegible]3	19[illegible]	[illegible]	18	16	[illegible]
21	70	44	5[illegible]	[illegible]	8	0	0.00	0.0	[illegible]	11.[illegible]	29	240	6[illegible]	[illegible]	[illegible]		39	150
22	56	38	47	-3	18	[illegible]	0.[illegible]	0.0	[illegible]	11.[illegible]	23	350	6[illegible]	94	6	8	31	350
23	19	29	39	-11	26	[illegible]	T	T	[illegible]	6.5	[illegible]	31[illegible]	3[illegible]	4[illegible]	[illegible]		30	[illegible]
24	17	[illegible]	[illegible]	-1[illegible]	[illegible]	[illegible]	T	T	[illegible]	3.6	10	26[illegible]	330	4[illegible]	[illegible]		23	[illegible]
25	63	34	50	-1	15	[illegible]	0.00	0.0	0	12.7	29	230	63[illegible]	96	2		41	210
26	67	45	56	5	9	0	0.00	0.0	0	6.2	17	240	223	3[illegible]	7		24	230
27	[illegible]0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T	[illegible]	[illegible]	[illegible].[illegible]	[illegible]	22[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]

```
28  70  42  56   5   9   [illegible] 1.27 [illegible]   [illegible] .5 [illegible]  1.  [illegible] 13      35 320
29  50  41  46  -6  19   [illegible] .18  0.0   [illegible] 9.9 21  [illegible]  0   [illegible]  8 10      26  30
30  6[illegible]  48  56   4   9   [illegible] .   .   [illegible] .1 16  [illegible]  10  [illegible]    24 320
31  68  5[illegible]  6[illegible]  11  [illegible]  1.1[illegible]  .   [illegible] 1 [illegible] 16  1[illegible] [illegible]  31 1[illegible]
================================================================================
SM 1795 1193        516      9.6      1.[illegible]  6.[illegible]         9[illegible]8   [illegible]
================================================================================
AV 57.9 38.5                           9.9 FASTST   PSBL [illegible]    MAX(MPH)
                          MISC ----    # 29 240                   # 41  [illegible]1
================================================================================
NOTES:
# LAST OF SEVERAL OCCURRENCES

COLUMN 17 PEAK WIND IN M.P.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6) , PAGE

                                     STATION:   PADUCAH ASOS
                                     MONTH:     MARCH
                                     YEAR:      2008
                                     LATITUDE:  [illegible] 4
                                     LONGITUDE: [illegible] 46 4

[TEMPERATURE DATA]        [PRECIPITATION DATA]       SYMBOLS USED IN COLUMN 16

AVERAGE MONTHLY: [illegible]   TOTAL FOR MONTH:  [illegible]   1 = FOG OR MIST
DPTR FM NORMAL:   .6      DPTR FM NORMAL:    [illegible].33  2 = FOG REDUCING VISIBILITY
HIGHEST:   [illegible] ON [illegible]     GRTST 24HR [illegible] ON [illegible]     TO 1/4 MILE OR LESS
LOWEST:       ON [illegible]                                 3 = THUNDER
                          SNOW, ICE PELLETS, HAIL        4 = ICE PELLETS
                          TOTAL MONTH:   1.9 INCHES      5 = HAIL
                          GRTST 24HR   1.[illegible] ON  M         6 = FREEZING RAIN OR DRIZZLE
                          GRTST DEPTH:   1 ON            7 = DUSTSTORM OR SANDSTORM:
                                                             VSBY 1/2 MILE OR LESS
                                                         8 = SMOKE OR HAZE
[NO. OF DAYS WITH]        [WEATHER - DAYS WITH]          9 = BLOWING SNOW
                                                         X = TORNADO
MAX 32 OR BELOW:   [illegible]    0.01 INCH OR MORE:  13
MAX 90 OR ABOVE:   [illegible]    0.10 INCH OR MORE:   [illegible]
MIN 32 OR BELOW:  10    0.50 INCH OR MORE:   4
MIN  0 OR BELOW:   [illegible]    1.00 INCH OR MORE:   4

[HDD (BASE 65) ]
TOTAL THIS MO.    516    CLEAR  (SCALE 0-3)  11
DPTR FM NORMAL    -14    PTCLDY (SCALE 4-7)  1[illegible]
TOTAL FM JUL 1   3714    CLOUDY (SCALE 8-10) [illegible]
DPTR FM NORMAL   -113

[CDD (BASE 65) ]
TOTAL THIS MO.      [illegible]
DPTR FM NORMAL     -6    [PRESSURE DATA]
TOTAL FM JAN 1      [illegible]    HIGHEST SLP 30.46 ON 24
DPTR FM NORMAL     -4    LOWEST  SLP [illegible] ON [illegible]

[REMARKS]
```

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

WFO Monthly/Daily Climate Data

RECEIVED
MAR 08 2012
Division of Waste Management
Solid Waste Branch

[illegible]
[illegible]
[illegible] FORM: F-[illegible]

STATION: PADUCAH ASOS
MONTH: APRIL
YEAR: 2000
LATITUDE: 37 [illegible]
LONGITUDE: [illegible]

	TEMPERATURE IN F:						:PCPN:	SNOW:	WIND			:SUNSHINE:	SKY		:PK WND	
	3	[illegible]	[illegible]	60	65		[illegible]	[illegible]	1	11	12	13	[illegible]	[illegible]	16	[illegible]	19
									AVG	MX	2MIN						
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	SPD	SPD	DIR	MIN	PSBL	S-S	WX	SPD	DR
1	59	42	51	-2	14	[illegible]	0.00	0.0	0	11.4	18	340	453	60	6		25	10
[illegible]	59	37	[illegible]	-5	17	[illegible]	[illegible].01	0.0	0	7.8	16	80	6[illegible]	70	[illegible]	3	[illegible]	60
3	65	46	[illegible]	[illegible]	[illegible]		3.51	[illegible]	0	5.4	[illegible]	280	[illegible]	[illegible]	[illegible]	13	3	290
[illegible]	[illegible]	[illegible]	[illegible]	-2	13		[illegible].09	0.0	[illegible]	8.5	18	130	0	[illegible]	10	138	[illegible]	130
5	61	3[illegible]	49	-5	16		[illegible].00	0.0	[illegible]	5.2	15	60	694	9[illegible]	1	18	21	110
6	67	36	52	-2	13	[illegible]	0.00	0.0	[illegible]	3.3	13	220	6[illegible]6	[illegible]	1	18	18	220
7	76	46	61	6	4	0	0.00	0.0	[illegible]	[illegible].3	9	360	6[illegible]3	98	0	18	12	360
8	[illegible]1	[illegible]	[illegible]	8	2	0	T	0.0	[illegible]	9.0	20	160	247	[illegible]	8	[illegible]	[illegible]4	1[illegible]0
9	6[illegible]	50	59	4	6	[illegible]	[illegible].03	[illegible]	0	9.[illegible]	15	10	185	24	10	19	[illegible]0	10
10	78	5[illegible]	68	13	[illegible]	3	1.70	T	0	14.6	33	170	[illegible]1[illegible]	[illegible]7	6	138	46	170
11	69	4[illegible]	[illegible]9	[illegible]	6	[illegible]	0.00	[illegible].0	0	[illegible]5.5	30	[illegible]50	638	8[illegible]	3	3	43	[illegible]40
1[illegible]	50	39	45	-11	[illegible]	[illegible]	T	0.0	[illegible]	12.[illegible]	[illegible]3	260	[illegible]	[illegible]	[illegible]		30	[illegible]70
13	46	36	41	-15	24	[illegible]	[illegible].[illegible]2	T	0	8.1	18	[illegible]10	126	16	10	[illegible]	[illegible]4	320
14	50	35	4[illegible]	-14	22	0	0.00	0.0	0	[illegible].0	18	350	288	37	7		29	350
15	61	[illegible]9	[illegible]	-1[illegible]	[illegible]	[illegible]	[illegible].00	[illegible].[illegible]	[illegible]	[illegible]2.9	12	1[illegible]0	790	1[illegible]	[illegible]		17	12[illegible]
16	70	3[illegible]	54	-3	11	0	[illegible].00	0.0	0	8.7	20	180	565	71	0		28	2[illegible]0
1[illegible]	[illegible]3	5[illegible]	[illegible]	6	[illegible]	[illegible]	[illegible].0	[illegible].0	0	[illegible].9	20	230	[illegible]	[illegible]	1		[illegible]	[illegible]30
18	69	47	58	0	7	0	0.35	[illegible].0	0	10.5	21	240	[illegible]9	1	6	1	28	180
19	59	49	[illegible]	-5	12	0	T	0.0	0	6.6	20	260	18	2	10	[illegible]	24	250
2[illegible]	[illegible]1	43	[illegible]	-1	9		[illegible].00	0.0	0	[illegible].6	1[illegible]	[illegible]	[illegible]	66	[illegible]	[illegible]	[illegible]	[illegible]0
21	[illegible]	46	63	4	2	0	0.00	0.0	0	3.3	10	140	[illegible]	[illegible]	0	18	[illegible]4	17[illegible]
[illegible]	79	5[illegible]	66	7	[illegible]	[illegible]	T	[illegible]	0	4.1	[illegible]0	90	33[illegible]	41	[illegible]	[illegible]	[illegible]6	[illegible]80
[illegible]3	86	53	[illegible]	11	[illegible]	5	0.[illegible]0	[illegible]	0	[illegible]	[illegible]0	60	[illegible]5	96	1	1[illegible]	1[illegible]	1[illegible]
[illegible]4	[illegible]6	[illegible]9	[illegible]	9	[illegible]	3	[illegible].00	[illegible]	0	7.0	16	[illegible]20	[illegible]	[illegible]	3		[illegible]	[illegible]0
[illegible]	61	54	60	[illegible]	[illegible]	3	0.35	[illegible]	0	[illegible].1	36	[illegible]40	315	[illegible]	3	13	44	250
26	[illegible]	46	58	-2	7	0	T	0.0	[illegible]	5.2	15	30	596	73	6	3	20	330
[illegible]	[illegible]	[illegible]	[illegible]6	-4	[illegible]	[illegible]	[illegible].[illegible]	0.[illegible]	[illegible]	8.1	18	[illegible]60	[illegible]	13	[illegible]		[illegible]	[illegible]60

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data


```
28  61  41  51 -13  14    0 0.01  0.0    0  7.5 21  44 510    4    0 138    21 160
29  60  33  47 -14  14    0 0.00  0.0    0  2.7  9 110 617   73    0          14 160
30   8  39  49  -7   6      .00   0.0    0  3.8  7 114  82    1    0           1   1
==================================================================================
SM 2/15 1333        83  16  6.70          15.7        1 44    110
==================================================================================
SM 67.  4..                                   . FASTST  FOST            MAXWTH
                                    HIST ----   # 36 .40                # 46  .
==================================================================================
NOTES:
# LAST OF SEVERAL OCCURRENCES

CODE MO 17 PEAK WIND ..... H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA  WS FORM: F-6 , BASE 0

                                        STATION :  PADUCAH AGRO
                                        MONTH:     ALL
                                        YEAR:      2007
                                        LATITUDE:  37  4.
                                        LONGITUDE: 88 46 .

[TEMPERATURE DATA]        [PRECIPITATION DATA]        [WX CODES USED IN COLUMN 16]

AVERAGE MONTHLY: 55.8     TOTAL FOR MONTH:    0.7     1 = FOG OR MIST
DPTR FM NORMAL:  -1.      DPTR FM NORMAL:     1.      2 = FOG REDUCING VISIBILITY
HIGHEST:    86 ON 13      GRTST 24HR   0.1 ON 1-  .      TO 1/4 MILE OR LESS
LOWEST:     29 ON 15                                  3 = THUNDER
                          SNOW, ICE PELLETS, HAIL     4 = ICE PELLETS
                          TOTAL MONTH:    T           5 = HAIL
                          GRTST 24HR    T  ON 1 -13   6 = FREEZING RAIN OR DRIZZLE
                          GRTST DEPTH:                7 = DUSTSTORM OR SANDSTORM:
                                                          SEV 1/2 MILE OR LESS
                                                      8 = SMOKE OR HAZE
[NO. OF DAYS WITH]        [WEATHER - DAYS WITH]       9 = BLOWING SNOW
                                                      X = TORNADO
MAX 32 OR BELOW:    0     0.01 INCH OR MORE:    .
MAX 90 OR ABOVE:    0     0.10 INCH OR MORE:    5
MIN 32 OR BELOW:    1     0.50 INCH OR MORE:    3
MIN  0 OR BELOW:    0     1.00 INCH OR MORE:    .

[HDD (BASE 65) ]
TOTAL THIS MO.    183     CLEAR  (SCALE 0-3)   16
DPTR FM NORMAL     .      PTCLDY (SCALE 4-7)    7
TOTAL FM JUL 1   3993     CLOUDY (SCALE 8-1     6
DPTR FM NORMAL   -199

[CDD (BASE 65) ]
TOTAL THIS MO.     15
DPTR FM NORMAL    -17     [PRESSURE DATA]
TOTAL FM JAN 1     17     HIGHEST SLP 3..48 ON  2
DPTR FM NORMAL    -21     LOWEST  SLP 29.53 ON 21

 REMARKS
#FINAL-04-.0#
```

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

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MAR 08 2012
Division of Waste Management
Solid Waste Branch

WFO Monthly/Daily Climate Data

[illegible] 1
CF6PAH
PRELIMINARY [illegible] CLIMATE DATA [illegible]

STATION: PADUCAH AP[illegible]
MONTH: MAY
YEAR: 2008
LATITUDE: [illegible]
LONGITUDE: [illegible]

TEMPERATURE (F):								PCPN:	SNOW:		WIND				SUNSHINE:	SKY		PK WND	
1	2	3	4	5	6A	6B	7	8	9	10	11	12	13	14	15	16	17	18
											AVG	MX 2MI							
DY	MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNW	DPTH	SPD	SPD	DIR	MIN	PSBL	S-S	WX	SPD	DR
1	75	54	70	9		5	0.00	0.0	0	11.1	21	210	58	7	7		32	220
2	7[illegible]	62	67	6	[illegible]		[illegible].05	[illegible]	0	10.4	22	140	36	4	7	138	36	180
3	64	44	54	-5	11		[illegible].00	0.0	0	6.[illegible]	23	250	[illegible]	[illegible]	3	1	29	260
4	70	39	55	-3	1[illegible]		0.00	0.0	[illegible]	1.9	[illegible]	340	6[illegible]	[illegible]	0	1	14	290
5	78	44	61	-2	4		.00	0.0	0	3.[illegible]	12	280	514	93	0	18	15	220
6	7[illegible]	49	64	1	[illegible]		.02	0.0	0	4.1	13	190	603	72	3		17	220
7	76	61	69	6	[illegible]	4	0.[illegible]	0.0	0	6.0	16	160	51	6	7	18	[illegible]3	170
8	75	56	[illegible]	4	[illegible]	2	.11	0.0	0	8.3	16	140	288	4	[illegible]	13	1	340
9	73	55	64		1		0.00	0.0	0	4.7	14	30	19	[illegible]	10	1[illegible]	17	20
10	73	52	63	-1	[illegible]		0.42	0.0	0	7.8	17	150	306	36	4	139	24	150
11	65	46	56	-6	9		T	0.0	[illegible]	15.[illegible]	30	190	1	[illegible]	8	1	16	330
12	71	4[illegible]	57	-8	8		[illegible].0	0.0	[illegible]	3.4	9	350	61	[illegible]	0	[illegible]	14	330
13	71	45	58	-[illegible]	[illegible]		.31	0.0	0	6.1	19	1[illegible]0	127	15	[illegible]	138	40	180
14	69	59	64	-1	1		0.02	0.0	[illegible]	4.4	13	300	0	[illegible]	10	18	19	170
15	66	55	61	-5	4		.86	0.0	0	[illegible].8	20	340	0		10	138	29	[illegible]
16	69	52	61	-5	4		[illegible].00	0.0	0	7.5	15	30	510	[illegible]	4		21	10
17	[illegible]9	53	66	[illegible]	[illegible]	1	.00	0.0	0	12.1	24	240	853	[illegible]	[illegible]		[illegible]3	240
18	79	49	64	-1	1	0	0.00	0.0	[illegible]	6.4	22	290	720	84	2		29	290
19	82	47	65	-2	[illegible]	0	[illegible].00	0.0	[illegible]	6.9	18	260	690	79	1		26	240
[illegible]	[illegible]	56	6[illegible]	[illegible]	[illegible]		[illegible].00	[illegible].0	0	6.6	18	10	663	[illegible]9	1		23	20
21	[illegible]6	47	62	-5	3		[illegible].00	0.0	[illegible]	4.6	15	260	803	[illegible]	[illegible]		21	270
[illegible]	79	5[illegible]	65	-3	1	0	[illegible].[illegible]3	0.[illegible]	0	4.5	16	30	344	4[illegible]	[illegible]	3		21	20
23	[illegible]6	58	[illegible]2	4	[illegible]	7	0.30	[illegible].0	0	5.7	[illegible]	[illegible]0	[illegible]	[illegible]	[illegible]		23	70
24	7[illegible]	61	69	1		4	[illegible].00	[illegible].0	0	6.[illegible]	1[illegible]	110	745	[illegible]	[illegible]	[illegible]	[illegible]	110
25	87	59	73	4	[illegible]	8	0.30	[illegible].0	0	5.4	24	310	660	76	4	13[illegible]	32	300
26	79	66	73	4	[illegible]	[illegible]	2.1[illegible]	[illegible].0	0	4.2	21	10	[illegible]	[illegible]	3	13	25	10
[illegible]7	[illegible]	[illegible]5	[illegible]3	4		[illegible]	.59	[illegible]	[illegible]	4.9	16	40	[illegible]	[illegible]9	[illegible]	[illegible]	[illegible]	30

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data

28	76	58	67	-3		[illegible]	0.02	0.0	[illegible]	9.1	17	50	465	53	[illegible]	6	19	[illegible]	[illegible]
29	83	55	69	-1	[illegible]	4	.00	0.0	[illegible]	2.5	8	120	679	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	110
30	86	[illegible]	[illegible]	[illegible]		1[illegible]	[illegible]	[illegible]		7.3	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	88	[illegible]	79	[illegible]		14	[illegible]	[illegible]		5.4	14	150	M	[illegible]	[illegible]	[illegible]	38	[illegible]	[illegible]	[illegible]
SM	1360	1688			66	83	5.63	[illegible]	[illegible]	199.5			1[illegible]	4		11				
AV	75.[illegible]	54.5								6.4	FASTEST		PSBL	[illegible]	[illegible]		[illegible]	[illegible]		
									MISC ----	# [illegible]	[illegible]						# 46	[illegible]		

NOTES:
LAST OF SEVERAL [illegible] REPORTS

[illegible] 1[illegible] PEAK WIND [illegible] M.S.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6) , PAGE

STATION: PADUCAH AS[illegible]
MONTH: MA[illegible]
YEAR: 20[illegible]
LATITUDE: [illegible] 4[illegible]
LONGITUDE: [illegible] 46 [illegible]

TEMPERATURE DATA]

AVERAGE MONTHLY: [illegible]
DPTR FM NORMAL: -[illegible].6
HIGHEST: [illegible] ON [illegible]1
LOWEST: [illegible] ON 4

[PRECIPITATION DATA

TOTAL FOR MONTH: [illegible].6[illegible]
DPTR FM NORMAL: [illegible].98
GRTST 24HR [illegible] ON [illegible]- 6

SNOW, ICE PELLETS, HAIL
TOTAL MONTH: [illegible] INCH
GRTST 24HR [illegible]
GRTST DEPTH:

SYMBOLS USED IN COLUMN 16

1 = FOG OR MIST
2 = FOG REDUCING VISIBILITY TO 1/4 MILE OR LESS
3 = THUNDER
4 = ICE PELLETS
5 = HAIL
6 = FREEZING RAIN OR DRIZZLE
[illegible] = DUSTSTORM OR SANDSTORM: VSBY 1/2 MILE OR LESS
8 = SMOKE OR HAZE
9 = BLOWING SNOW
[illegible] = TORNADO

[NO. OF DAYS WITH]

MAX 32 OR BELOW: 0
MAX 90 OR ABOVE: 0
MIN 32 OR BELOW: 0
MIN 0 OR BELOW: [illegible]

WEATHER - DAYS WITH]

0.01 INCH OR MORE: 14
0.10 INCH OR MORE: 9
0.50 INCH OR MORE: 4
1.00 INCH OR MORE: [illegible]

[HDD (BASE 65)]
TOTAL THIS MO. 66
DPTR FM NORMAL -9
TOTAL SN JUL 1 4063
DPTR FM NORMAL -195

CLEAR (SCALE 0-3) 1[illegible]
PTCLDY (SCALE 4-7) 11
CLOUDY (SCALE 8-10) [illegible]

[CDD (BASE 65)]
TOTAL THIS MO. 93
DPTR FM NORMAL -36
TOTAL SN JAN 1 1[illegible]
DPTR FM NORMAL -5[illegible]

PRESSURE DATA
HIGHEST SLP 3[illegible].13 ON [illegible]
LOWEST SLP [illegible]9.[illegible] ON [illegible]

[REMARKS]

Attachment 'L'
Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

Explanation of the Preliminary Climate Data (F6) Product

Please note this information is preliminary and subject to revision. Official and certified climatic data can be accessed at the National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

WFO Monthly/Daily Climate Data

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[illegible]
[illegible]
PRELIMINARY [illegible]

STATION: PADUCAH ASOS
MONTH: JUNE
YEAR: [illegible]
LATITUDE: [illegible]
LONGITUDE: [illegible]

DY	TEMPERATURE (DEG F): MAX	MIN	AVG	DEP	HDD	CDD	WTR	SNOW	DEPTH	PRECIPITATION: SPD	SPD	DIR	MIN	PSBL	T-S	WX	SNOW: SPD	DR	WIND: AVG SPD	MX SPD	DIR	SUNSHINE: MIN	PSBL	SKY	PK WND SPD	DR
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	84	67	76	5	[illegible]	11	0.02	0.0	[illegible]	[illegible]	12	260	568	[illegible]	[illegible]	13	[illegible]	[illegible]	16	230
2	87	63	76	5	[illegible]	11	0.00	[illegible]	[illegible]	[illegible]	3	190	631	[illegible]	[illegible]	28	[illegible]	[illegible]	[illegible]	190
3	90	63	82	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	[illegible]
4	[illegible]	[illegible]	83	11	[illegible]	18	[illegible]	[illegible]	[illegible]	11.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	230
5	88	77	83	11	[illegible]	[illegible]	.00	[illegible]	[illegible]	[illegible]	18	[illegible]	6	[illegible]	[illegible]	7	[illegible]	[illegible]	9	220
SM	437	358			[illegible]	75	0.02	[illegible]		39.				3847		10				
AV	87.4	71.6												7.6	FASTST		PSBL			MAX(MPH)
													MISC ---->	# 2[illegible]	220				# 39	220

NOTES:
LAST OF SEVERAL OCCURRENCES

COLUMN 1: PEAK WIND IN M.P.H.

PRELIMINARY LOCAL CLIMATOLOGICAL DATA (WS FORM: F-6) , PAGE [illegible]

STATION: PADUCAH ASOS
MONTH: JUNE
YEAR: 2008
LATITUDE: 37 4 N
LONGITUDE: 88 46 W

(TEMPERATURE DATA) (PRECIPITATION DATA) SYMBOLS USED IN COLUMN 16

AVERAGE MONTHLY: [illegible] TOTAL FOR MONTH: [illegible] 1 = FOG OR MIST

Attachment 'L'

Paducah Remediation Services

Originator **J. Keith Thorn** Date **July 08, 2008** Calc. No. **CAC-PH746U-P001** Rev. No. **1**
Project **Material Disposition** Job No. **N/A** Checked **N/A** Date **N/A**

National Weather Service - Climate Data


```
DPTR FM NORMAL:     9.0     DPTR FM NORMAL:     -0.73      2 = FOG REDUCING VISIBILITY
HIGHEST:     99 ON  3       GRTST 24HR  0.17 ON 31- 1        TO 1/4 MILE OR LESS
LOWEST:      6- ON                                          3 = THUNDER
                            SNOW, ICE PELLETS, HAIL        4 = ICE PELLETS
                            TOTAL MONTH:     .  INCH       5 = HAIL
                            GRTST 24HR       ...           6 = FREEZING RAIN OR DRIZZLE
                            GRTST DEPTH:                   7 = DUSTSTORM OR SANDSTORM:
                                                               VSBY 1/2  MILE OR LESS
                                                           8 = SMOKE OR HAZE
(NO. OF DAYS WITH)          (WEATHER - DAYS WITH)          9 = BLOWING SNOW
                                                           X = TORNADO

MAX 32 OR BELOW:            0.01 INCH OR MORE:     1
MAX 90 OR ABOVE:     1      0.10 INCH OR MORE:
MIN 32 OR BELOW:            0.50 INCH OR MORE:
MIN  0 OR BELOW:            1.00 INCH OR MORE:

(HDD (BASE 65))
TOTAL THIS MO.       0      CLEAR  (SCALE 0-3)     4
DPTR FM NORMAL      -5      PTCLDY (SCALE 4-7)     1
TOTAL FM JAN 1   +365       CLOUDY (SCALE 8-10)
DPTR FM NORMAL    -

(CDD (BASE 65))
TOTAL THIS MO.      75
DPTR FM NORMAL       -      (PRESSURE DATA)
TOTAL FM JAN 1    1 8      HIGHEST SLP 30.40 ON 1
DPTR FM NORMAL    -20      LOWEST  SLP 29.60 ON 3

(REMARKS)
```

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APPENDIX C
TO REVISED ATTACHMENT 16

Leachate Log

PADUCAH
Remediation Services
A Portage Shaw Joint Venture Company

Permit No. 073-00045 PGDP SOLID WASTE LANDFILL – LEACHATE LOG McCracken County, Kentuck

Appendix C

Month _____ Year_____

DATE	PHASE	COLLECTION TANK NUMBER	MOBILE TANKER	VOLUME (gallons)	DISPOSAL METHOD*

WSD-F-0004

* R – Re-circulated to Working Phase
W – Transported to Wastewater Treatment Facility
L – Disposed at on-site Leachate Treatment Facility

ATTACHMENT 1

PART 4B

REVISED TECHNICAL APPLICATION ATTACHMENT 16, *LEACHATE COLLECTION SYSTEM*

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ATTACHMENT 16

LEACHATE STORAGE TANKS
REPLACEMENT OF HELP MODEL

(REPLACEMENT PAGES ONLY)

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CALCULATION COVERSHEET

Project Title Material Disposition **Job No.** N/A

Area/Building/Location C-746-U

Discipline Civil ***Calc. No.** CAC-PH746U-P001

Subject C-746-U Landfill HELP Model Revision and Required Leachate Storage

Computer Program Hydrological Evaluation of Landfill Performance (HELP) **Program No.** Ver. 3.07

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	1-9	J.K. Thorn	Mary M. Hensley	N/A	Lance Fleming	06/12/08
1	1-9	J.K. Thorn	Kendall L. Holt	N/A	Kendall L. Holt	07/08/08
2	1-9	J.K. Thorn	Kendall L. Holt	N/A	Randall E. Scott	02/23/11

SUMMARY OF REVISION

0	Initial Issue for Submission to Kentucky Division of Waste Management
1	Revised to clarify interpretation of maximum leachate head in Scenario 1 page 4 of 9
2	Revised to show LATA Environmental Services of Kentucky in lieu of Paducah Remediation Services. Revised to show 60-mil HDPE in final cap in lieu of 40-mil VLDPE pages 4 and 8 of Attachment 'F', 8 pages. Revised the average annual leachate collected for Scenario 1 on page 8 of 9 from 96252 ft^3 to 102415 ft^3. Changes have no effect of conclusions of this Calculation. Attachments 'A', 1 page; 'B', 20 pages; 'C', 18 pages; 'D', 18 pages; 'E', 33 pages; 'G', 8 pages; 'H' 2 pages; 'J', 7 pages; 'K', 7 pages; and 'L', 16 pages are unrevised.

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

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Originator J. Keith Thorn | Date Feb. 23, 2011 | Calc. No. CAC-PH746U-P001 | Rev. No. 2

Project Material Disposition | Job No. N/A | Checked Kendall L. Holt | Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

1.0 PURPOSE:

The purpose of this calculation is to revise the Hydrological Evaluation of Landfill Performance (HELP) Model analysis for the PGDP C-746-U Solid Waste Landfill, last revised in October 2007. The output from the revised HELP Model analysis will be used to calcuate the required storage to contain the 15 day Peak Leachate Production required by State regulations.

2.0 INPUT DATA:

The data to be used for this calculation shall be taken from the sources below.

2.1 The weather information for the city of Evansville, IN is used as the basis to generate synthetic data for Precipitation, Temperature, Solar Radiation, and Evapotranspiration. The Normal Mean Monthly Precipitation Values, The Normal Mean Monthly Temperature Values, and the Station Latitude were adjusted in accordance with the data given in Reference 4.3 for Paducah, KY. The synthetic daily precipitation values generated by the HELP Model were manually overwritten during a specific 15 day period to ensure that both the 25 year - 24 hour and 25 year - 15 day precipitation events were captured.

2.2 The 25 year - 24 hour (with a 90% probability not to be exceeded) precipitation value of 6.53 inches was obtained from Reference 4.2.

2.3 The 25 year - 15 day (with a 90% probability not to be exceeded) precipitation value of 12.69 inches was obtained by interpolation from the table in Reference 4.2.

3.0 ASSUMPTIONS:

In this calculation the following assumptions were made:

3.1 The Landfill Cross Section Schematics shown on Pages 1 - 4 of Attachment 'F' is valid.

3.2 The Soil Types used in HELP Modeling as shown on Pages 5 - 8 of Attachment 'F' is valid.

4.0 REFERENCES:

4.1 Hydrological Evaluation of Landfill Performance Modeling for the Paducah C-746-U Landfill, Shaw Environmental, Inc., October 2007.

4.2 Point Precipitation Frequency Estimates from National Oceanic and Atmospheric Administration (NOAA) Atlas 14, NOAA, 2004.(Attachment 'G')

4.3 United States Climate Normals 1971-2000, Climatology of the United States No. 81, Kentucky, NOAA. (Attachment 'H')

4.4 Hydrological Evaluation of Landfill Performance (HELP) Model Engineering Document foı Version 3.

4.5 The PGDP Solid Waste Landfill Leachate Log Oct. 31, 2007 thru June 3, 2008 (as modified to calculated daily leachate generated). (Attachment 'K')

4.6 National Weather Service Preliminary Local Climate Data Form F-6 for Paducah, Kentucky Station ASOS, Nov. 2007 thru June 2008. (Attachment 'L')

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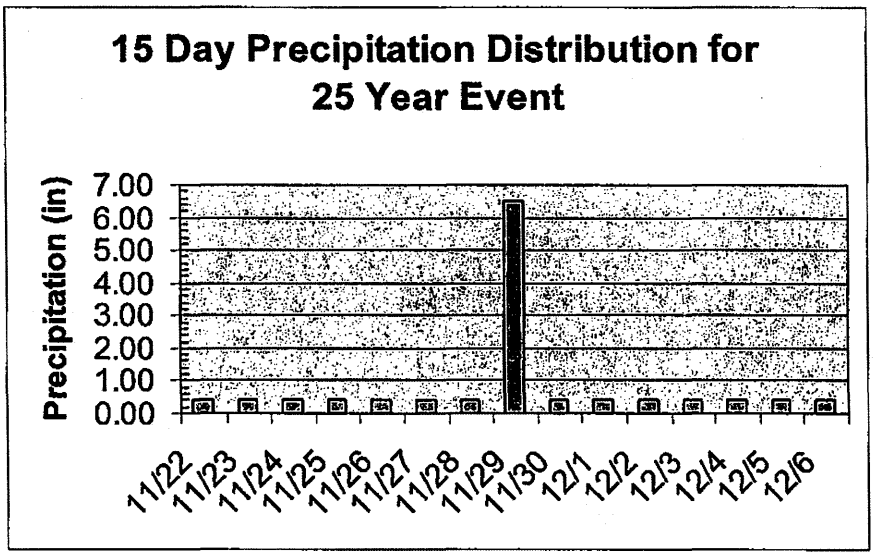
Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.0 CALCULATIONS:

5.1 Distribution of Precipitation During the 25 Year - 15 Day Event



In determining a "worst case" plausable scenario for decribing a 25 Year - 15 Day event which includes the 25 Year - 24 Hour event as well, the approach taken is shown in the graphic above. The 25 Year - 24 Hour event was assumed to have occured on the 8th day. One half of the balance of the 15 day precipitation is placed on each of the preceeding days. The result is a 15 day period that begins with the first seven days being 0.44 inches, the 8th day being 6.53 inches, and the last seven days being 0.44 inches. These prescipitation values were manually superimposed over the syntheticly generated values during Novemeber 22 to December 6 of the 9th year.

5.2 HELP Model Scenario 1 - Daily/Intermediate Cover Conditions

The daily cover operations were modeled as a series of 2 ft thicklayers of waste covered by 6 inches of daily cover material with a maximum thickness of 10 feet as shown on Page 1 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Bare ground condition was used. The Maximum Leaf Index is 1.0. The Evaporative Zone Depth is 18 inches. 70% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (assumed bare ground, slope of 50%, and slope length of 50 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

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Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

As a permit requirement, PGDP has committed to maintain a maximum head of leachate on the HDPE liner of no greater than 12 inches. The results of the HELP Model Peak Daily Values shown on Page 19 of 20 indicate that the modeled scenario (2.73 acres) would result in a MAXIMUM HEAD ON LAYER 11 of 1.394 feet. However, in practice the landfill will never have the entire area of any given phase or pair of phases configured with daily/intermediate cover (limited in this analysis to 0.5 acres), the leachate head will dissipate into the adjacent areas of the drainage layer which underlie more impervious cover material. These adjacent layers all have maximum heads of well under 12 inches. Therefore, the maximum head in a composite analysis would be no greater than 12 inches.

5.3 HELP Model Scenario 1 - Daily/Intermediate Cover Results

Attachment 'B' is the HELP Model run which calculates the peak daily leachate production rate of 910 ft^3 for Phases 2&3 (2.73 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 10 and can be found on Page 19 of 20.

To change the units of this value from ft^3 / day for Phases 2&3 to gallons/acre/day

$$\frac{910ft^3}{1.0day}\cdot\frac{7.48gal}{1.0ft^3}\cdot\frac{1}{2.73acre} = 2493.33\frac{gal}{acre\cdot day}$$

5.4 HELP Model Scenario 2 - Long Term Cover Conditions

The long term cover operations were modeled as a 15 ft thick layer of waste covered by 30 inches of long term cover material as shown on Page 2 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Poor vegetative condition was used. The corresponding Maximum Leaf Index is 1.05. The Evaporative Zone Depth is 18 inches. 80% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (slope of 10%, and slope length of 50 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

5.5 HELP Model Scenario 2 - Long Term Cover Results

Attachment 'C' is the HELP Model run which calculates the peak daily leachate production rate of 422 ft^3 for Phases 1, 2&3 (3.94 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 4 and can be found on Page 17 of 18.

To change the units of this value from ft^3 / day for Phases 1, 2&3 to gallons/acre/day

$$\frac{422ft^3}{1.0day}\cdot\frac{7.48gal}{1.0ft^3}\cdot\frac{1}{3.94acre} = 801.16\frac{gal}{acre\cdot day}$$

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Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.6 HELP Model Scenario 3 - Operational Cover Conditions

The operation cover conditions were modeled as a 48 in thick layer of soil cover installed over the 18 inch protection layer with no waste in between as shown on Page 3 of Attachment 'F'. This scenario was modeled for a 15 year elapsed time. Fair vegetative condition was used. The corresponding Maximum Leaf Index is 2.0. The Evaporative Zone Depth is 18 inches. 98% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (slope of 20%, and slope length of 12 feet.) The initial water content of the leachate collection system and operational cover material were set at the field capacity of the respective materials.

5.7 HELP Model Scenario 3 - Operational Cover Results

Attachment 'D' is the HELP Model run which calculates the peak daily leachate production rate of 294 ft^3 for Phases 4/5 (1.53 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 4 and can be found on Page 17 of 18.

To change the units of this value from ft^3 / acre/day to gallons/acre/day

$$\frac{294ft^3}{1.0day \cdot 1.53acre} \cdot \frac{7.48gal}{1.0ft^3} = 1437.33 \frac{gal}{acre \cdot day}$$

5.8 HELP Model Scenario 4 - Final Cover Conditions

The final cover conditions were modeled as a 60 ft thick layer of waste covered by a final cap system as shown in Exhibit 1 of Attachment 'F'. This scenario was modeled for a 30 year elapsed time. Good vegetative condition was used. The corresponding Maximum Leaf Index is 3.5 The Evaporative Zone Depth is 24 inches. 100% of the runoff was allowed. The SCS number was computed by HELP based on surface slope, slope length, soil texture and quantity of vegetative cover (assumed bare ground, slope of 11%, and slope length of 145 feet.) The initial water content of the leachate collection system and daily/intermediate cover material were set at the field capacity of the respective materials. The intial water content of the waste was set at the wilting point.

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Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.9 HELP Model Scenario 4 - Final Cover Results

Attachment 'E' is the HELP Model run which calculates the peak daily leachate production rate of 2.33 ft^3 for a Unit Area (1.0 acres). This value is shown as the DRAINAGE COLLECTED FROM LAYER 9 and can be found on Page 32 of 33.

To change the units of this value from ft^3 / acre/day to gallons/acre/day

$$\frac{2.80ft^3}{1.0day \cdot 1.0acre} \cdot \frac{7.48gal}{1.0ft^3} = 20.94 \frac{gal}{acre \cdot day}$$

5.10 Calculate Required Leachate Storage Throughout the Life of the Landfill

The values calculated in Sections 5.3, 5.5, 5.7 and 5.9 above are intended to be representative of the leachate production to be expected for the Daily/Intermediate, Long Term, Operational and Final Cover conditions respectively. With that as a basis, the spreadsheet shown in Attachment 'A' calculates the volume of leachate to be generated by the landfill under the criteria listed at the top of the spreadsheet.

5.11 Demonstrate the Correlation between the Model and the Actual Data

To establish the correlation between the HELP Model results and the actual rainfall and leachate data being collected for the current landfill operation we shall compare the ratio of actual leachate collected vs. gross rainfall over the landfill area. There were several improvements to correct grading that was inconsistent with the physical data in the HELP Model. These improvements were made at the beginning of April and have dramatically reduced leachate production. The Rain to Leachate Ratio ($Ratio_{Actual}$) calulated below will be for the months of April and May 2008 since the landfill configuration during that period is more accurately represented in the current HELP Model.

The total rainfall received by the landfill during April and May 2008 (See Attachment 'J') is

$$Rain_{AprilMay08Depth} := 12.42in$$

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MAR 3 0 2012

Originator J. Keith Thorn JKT Date Feb. 23, 2011 Calc. No. CAC-PH746U-P001 Rev. No. 2

Project Material Disposition Job No. N/A Checked Kendall L. Holt Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.11 (Continued)

We will convert that depth into a volume received by the landfill area Phases 1-3 (3.94 acres)

$$Rain_{AprilMay08Volume} := \left(\frac{Rain_{AprilMay08Depth}}{12\frac{in}{ft}}\right)\cdot\left(43560\cdot\frac{ft^2}{acre}\right)\cdot(3.94acre)\cdot\left(7.48\frac{gal}{ft^3}\right)$$

$$Rain_{AprilMay08Volume} = 1328697.26\,gal$$

The total leachate collected by the landfill during April and May 2008 (See Attachment 'J') is

$$Leachate_{AprilMay08Actual} := 138780.00\,gal$$

The ratio of leachate collected to rainfall received is

$$Ratio_{Actual} := \frac{Leachate_{AprilMay08Actual}}{Rain_{AprilMay08Volume}} \qquad Ratio_{Actual} = 10.44\%$$

The Long Term Cover Scenario 2 is based on the HELP Model run included as Attachment 'C'. In that model 3.94 acres is the area being modeled. The average annual precipitation for the 15 year period being modeled is 684561 ft^3, and can be found on Page 16 of 18 . We will now calculate a value of precipitation per acre for the Long Term Cover condition analyzed in the HELP Model..

$$Area_{LTC} := 3.94acre$$

$$Rain_{HELP\_LTC} := \frac{684561ft^3}{Area_{LTC}} \qquad Rain_{HELP\_LTC} = 173746.45\frac{ft^3}{acre}$$

The Daily/Interim Cover Scenario 1 is based on the HELP Model run included as Attachment 'B'. In that model 2.73 acres is the area being modeled. The average annual precipitation for the 15 year period being modeled is 474327 ft^3, and can be found on Page 18 of 20 . We will now calculate a value of precipitation per acre for the Daily/Interim Cover condition analyzed in the HELP Model..

$$Area_{DC} := 2.73acre$$

$$Rain_{HELP\_DC} := \frac{474327ft^3}{Area_{DC}} \qquad Rain_{HELP\_DC} = 173746.15\frac{ft^3}{acre}$$

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Project Material Disposition Job No. N/A Checked Kendall L. Holt KLH Date Feb. 23, 2011

C-746-U Landfill HELP Model Revision and Required Leachate Storage

5.11 (Continued)

Current landfill configuration is comprised of Phases 1-3 with a total area of 3.94 acres. Of that total approximately 3.44 acres is under Long Term Cover and approximately 0.50 acres is under Daily/Interim Cover. We will now calculate the average total amount of rainfall received by both the Long Term Cover area and Daily/Interim Cover area combined.

$$Rain_{HELP\_DC} \cdot 0.5acre + Rain_{HELP\_LTC} \cdot 3.44acre = 684560.85\ ft^3$$

Recall Attachment 'C', In the Scenario 2 model, 3.94 acres is the area being modeled. The average annual leachate collected for the 15 year period being modeled is 8322 ft^3 , and can be found on Page 16 of 18. We will now calculate a value of leachate collected per acre for the Long Term Cover condition analyzed in the HELP Model..

$$Leachate_{HELP\_LTC} := \frac{8322ft^3}{Area_{LTC}} \qquad Leachate_{HELP\_LTC} = 2112.18\frac{ft^3}{acre}$$

Recall Attachment 'B', In the Scenario 1 model, 2.73 acres is the area being modeled. The average annual leachate collected for the 15 year period being modeled is 102415 ft^3 , and can be found on Page 18 of 20. We will now calculate a value of leachate collected per acre for the Daily/Interim Cover condition analyzed in the HELP Model..

$$Leachate_{HELP\_DC} := \frac{102415ft^3}{Area_{DC}} \qquad Leachate_{HELP\_DC} = 37514.65\frac{ft^3}{acre}$$

As previously stated, current landfill configuration is comprised of Phases 1-3 with a total area of 3.94 acres. Of that total approximately 3.44 acres is under Long Term Cover and approximately 0.50 acres is under Daily/Interim Cover. Since the HELP Model is not capable of modeling muliple cover conditions at the same time, we will take the per acre values calculated above and apply them to the areas which represent the current landfill configuration to generate a composite calculation of the average annual leachate production predicted by the HELP Model.

$$Leachate_{HELP\_DC} \cdot 0.5acre + Leachate_{HELP\_LTC} \cdot 3.44acre = 194667.3\ gal$$

The ratio of Leachate predicted to rainfall applied in the HELP Model is

$$Ratio_{HELP} := \frac{Leachate_{HELP\_DC} + Leachate_{HELP\_LTC}}{Rain_{HELP\_DC} + Rain_{HELP\_LTC}}$$

$$Ratio_{HELP} = 11.4\%$$

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C-746-U Landfill HELP Model Revision and Required Leachate Storage

6.0 CONCLUSION:

This calculation utilizes the HELP Model to calculate Peak Daily leachate production values for four different cover conditions (Daily/Intermediate, Long Term, Operational, Final). Those values are then applied using a rational approach to calculate leachate storage requirements for the spectrum of landfill configurations anticipated (See Attachment 'A').

Of particular near-term interest are the values of approximately 60,000 gallons for the present landfill configuration of Phases 1-3 and approximately 88,000 gallons for the operation of Phases 1-5, as well as, approximately 154,000 gallons for operation of Phases 1-11.

To establish the correlation between the HELP Model results and the actual rainfall and leachate data being collected for the current landfill operation, we compared the ratio of actual leachate collected to gross rainfall over the landfill area ($Ratio_{Actual}$) with the ratio of Leachate predicted to rainfall applied in the HELP Model ($Ratio_{HELP}$).

$$Ratio_{Actual} = 10.44\%$$

$$Ratio_{HELP} = 11.4\%$$

This comparison seems to support a good correlation of the HELP Model to actual conditions.

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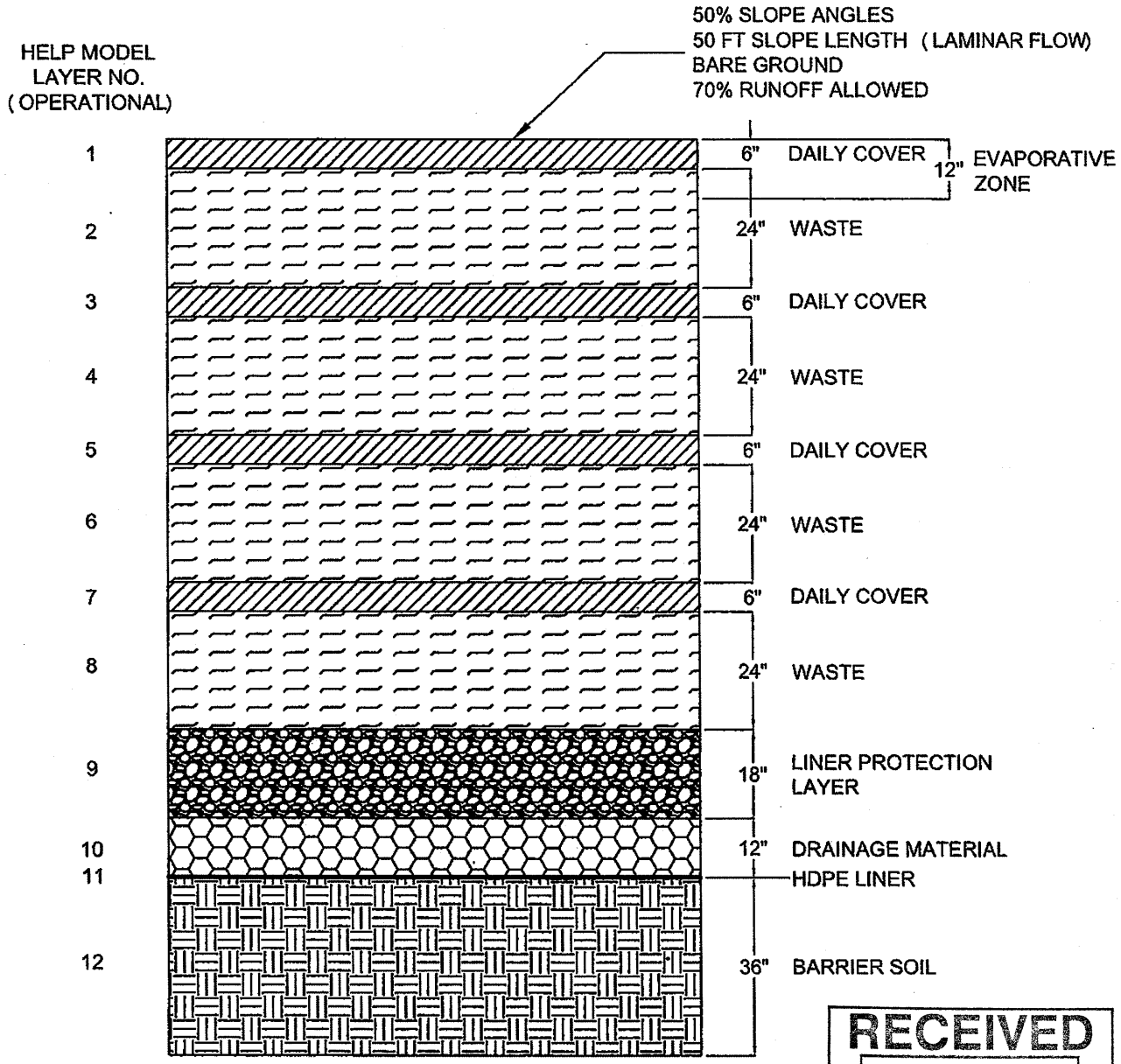

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PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
DAILY COVER

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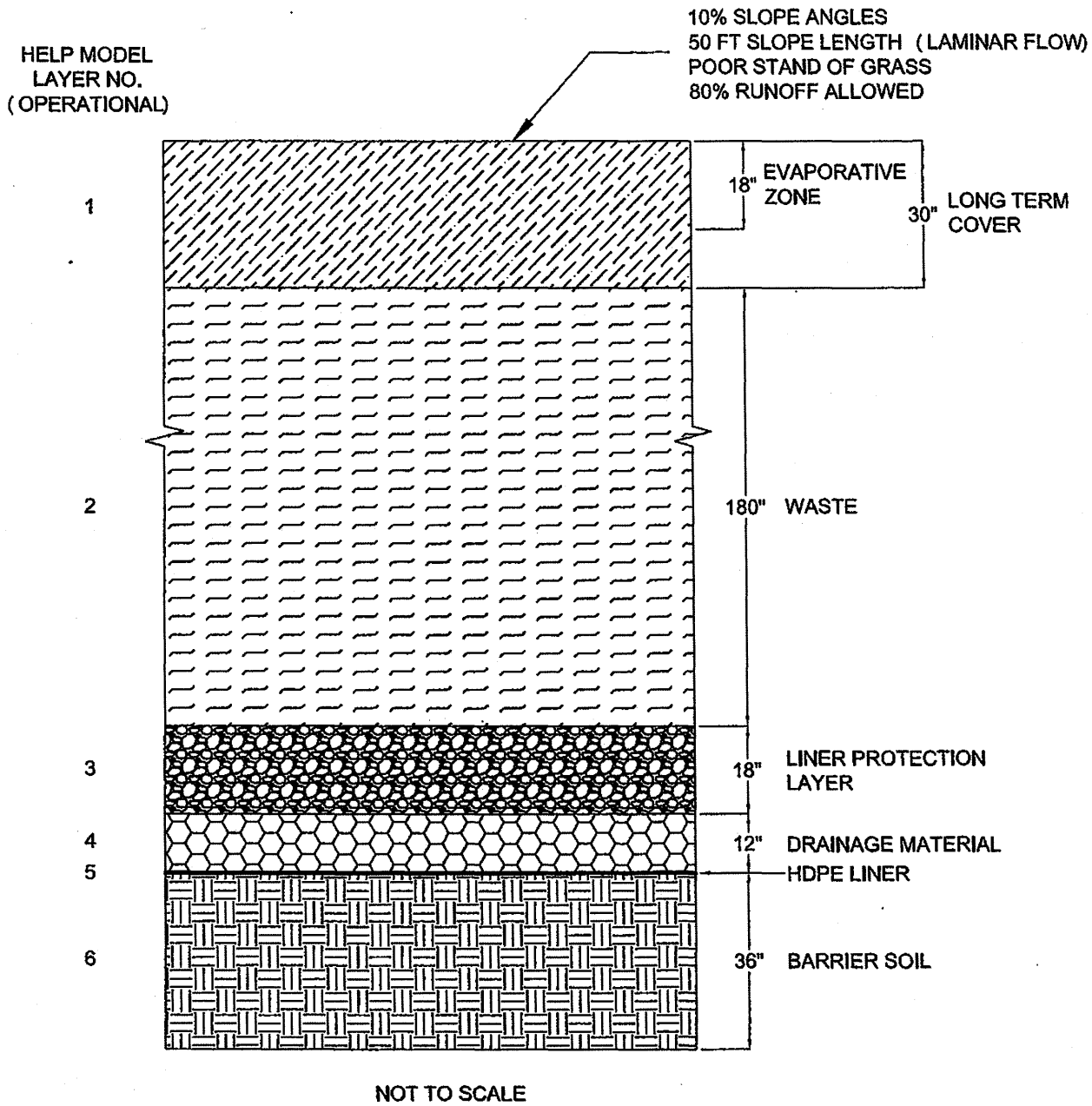

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PADUCAH C-746-U LANDFILL
PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
LONG TERM COVER

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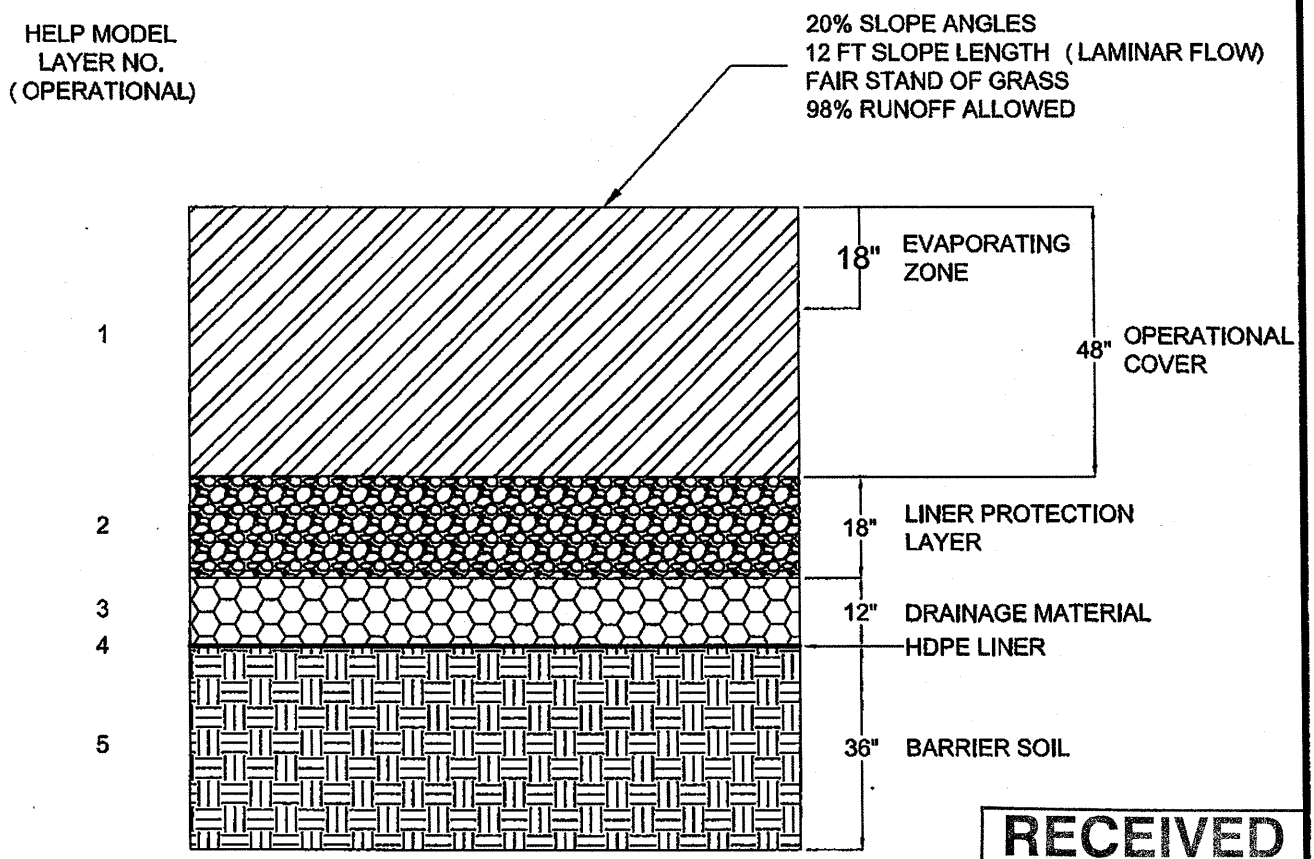

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LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
OPERATIONAL COVER

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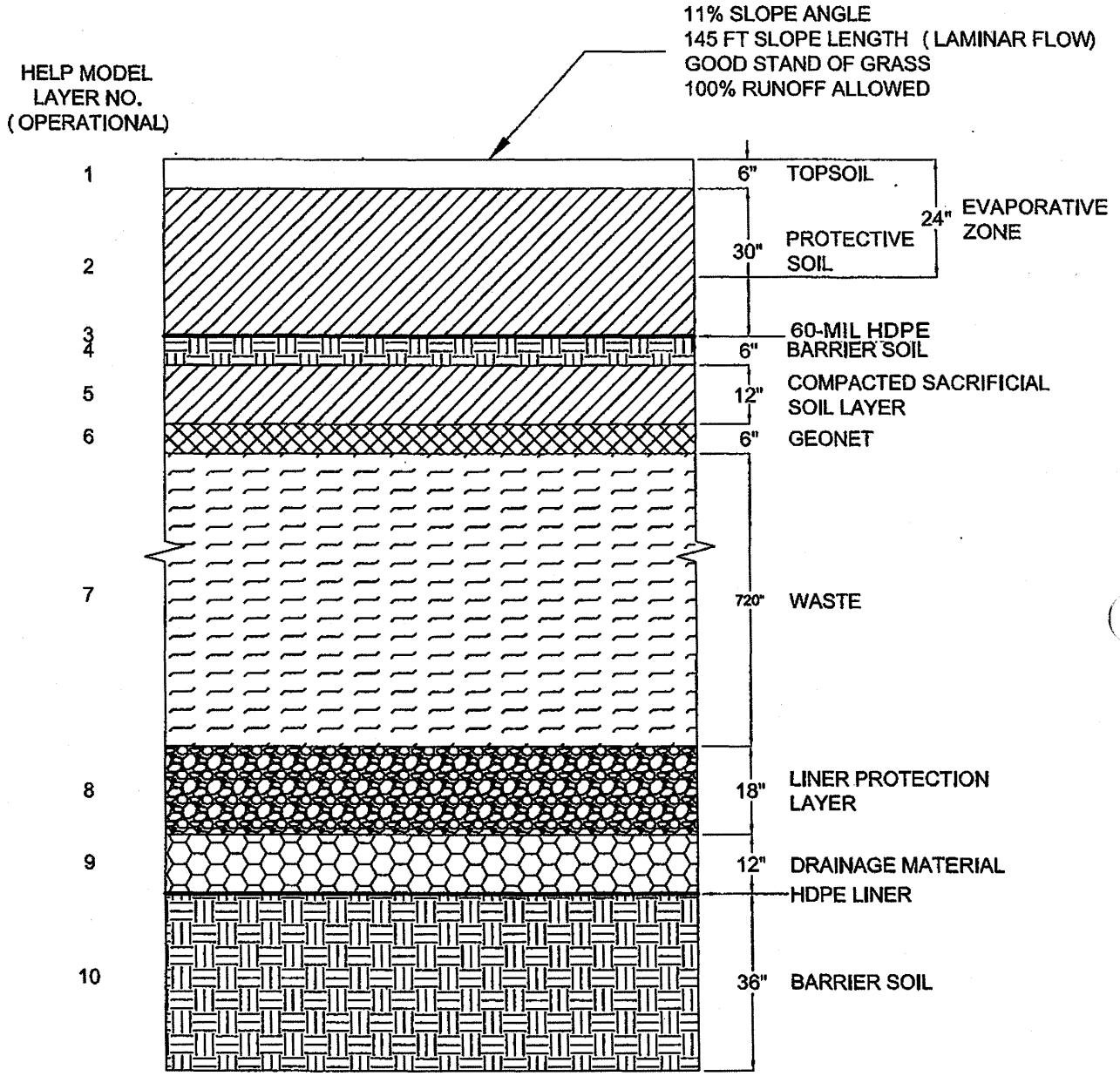

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PADUCAH, KENTUCKY

LANDFILL CROSS SECTION
SCHEMATIC OPERATIONAL PERIOD
FINAL COVER

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TITLE: LAYER TYPES AND DEFAULT TEXTURES FOR HELP MODELING

Purpose:

Select the appropriate HELP model default textures / soil properties for model input.

Scenario No. 1: Daily/Intermediate Cover Conditions

1. Page 1 of this Attachment shows the landfill layers for the daily/intermediate cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 1 – Daily/Intermediate Cover Conditions
Phases 2 – 3 (2.73 acres)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Daily Cover	SC	10
2	Waste	Municipal Solid Waste (channeling and dead zones)	19
3	Daily Cover	SC	10
4	Waste	Municipal Solid Waste (channeling and dead zones)	19
5	Daily Cover	SC	10
6	Waste	Municipal Solid Waste (channeling and dead zones)	19
7	Daily Cover	SC	10
8	Waste	Municipal Solid Waste (channeling and dead zones)	19
9	Liner Protection Layer	SC	24
10	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
11	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
12	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Scenario No. 2: Long Term Cover Conditions

1. Page 2 of this Attachment shows the landfill layers for long term cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 2 – Long Term Cover Conditions
Phases 1 – 3 (3.94 acres)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Long Term Cover	SC	24
2	Waste	Municipal Solid Waste (channeling and dead zones)	19
3	Liner Protection Layer	SC	24
4	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
5	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
6	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Project Materials Disposition Job No. N/A Checked Kendall L. Holt Date February 23, 2011

Scenario No. 3: Operational Cover Conditions:

1. Page 3 of this Attachment shows the landfill layers for final cover conditions.

2. This Table shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 3 – Operational Cover Conditions

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Operational Cover		
2	Liner Protection Layer	SC	24
3	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
4	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
5	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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Scenario No. 4: Final Cover Conditions:

1. Page 4 of this Attachment shows the landfill layers for final cover conditions.

2. This Tablet shows the HELP default soil, waste, and geomembrane characteristics. The following table summarizes the appropriate HELP default textures for the various layers:

Table 4 – Final Cover Conditions (Landfill Unit Acre)

Layer No.	Layer Description	Classification Description*	HELP Default Texture No.*
1	Vegetative Layer	SC	10
2	Protective Layer	SC	24
3	Final Cover Geomembrane (High Density Polyethylene)	High Density Polyethylene	36
4	Final Cover Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16
5	Sacrificial Soil Layer	SC	24
6	Drainage Net (0.5 cm / 0.2 in) (k = 0.1 cm/s)	Drainage Net	0
7	Waste	Municipal Solid Waste (channeling and dead zones)	19
8	Liner Protection Layer	SC	24
9	Drainage Layer ($k \geq 1.0 \times 10^{-2}$ cm/sec)	SP	1
10	Bottom Liner Geomembrane (High Density Polyethylene)	High Density Polyethylene (HDPE)	35
11	Bottom Liner Soil Barrier ($k \leq 1 \times 10^{-7}$ cm/sec)	Barrier Soil	16

*See Reference 4.4, Pages 19-25.

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ATTACHMENT 1

PART 5A

REVISED TECHNICAL APPLICATION ATTACHMENT 22,
CONSTRUCTION QUALITY CONTROL PLAN,
REPLACEMENT PAGE A-22-8

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ATTACHMENT 22

CONSTRUCTION QUALITY CONTROL PLAN
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3.2 Construction Inspection Activities for Contained Landfill Cap

Construction of the landfill cap will provide a barrier against interaction with surface water. Construction activities are detailed below in approximate order of construction. All components of the cap will be constructed and tested, as previously mentioned in "Construction Inspection Activities for a Contained Landfill Liner" (Section 3.1). Listed below are cap components and associated activities in order from bottom to top.

A. Cap Subgrade Preparation

Subgrade preparation will consist of minimal fine grading, as necessary, for establishing proper slopes. The cap will be placed in direct contact with the waste to the extent possible.

B. Gas Vent Layer Construction

Construction of the gas vent layer will include the installation of the following:

1. Crushed stone gas vent pockets excavated into the cap subgrade surface,
2. A double composite geonet in direct contact with the waste to the extent possible, and
3. Gas vent pipes augered back through the in-place clay and sacrificial soil layers into the pockets.

C. Sacrificial Soil and Clay Layer Construction

Construction of the sacrificial soil and clay layers will include placement of 6 inch (compacted thickness) of soil as a sacrificial layer. The sacrificial layer will be placed over the double composite geonet to serve as a construction buffer prior to the installation of a low permeability clay layer 6 inch in compacted thickness.

D. Cap Geomembrane Installation and Anchor Trench

Panels of textured high-density polyethylene (HDPE) will be laid out and welded together to form a continuous geomembrane barrier against infiltration of rainfall into the waste. Prior to beginning the panel deployment, excavation of an anchor trench will begin. The geomembrane ends and sides will be placed in the anchor trench and the trench will be backfilled. Density testing on HDPE shall be in accordance with ASTM 1505 Condition A.

E. Geotextile Filter Fabric Installation

Panels of geotextile will be rolled out and sewn together to form a continuous layer that will serve as a cushion, an infiltration filter, and a drainage layer.

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ATTACHMENT 1

PART 5B

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***CONSTRUCTION QUALITY CONTROL PLAN*,**
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CONSTRUCTION QUALITY CONTROL PLAN
REPLACEMENT PAGE A-22-8

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Construction of the landfill cap will provide a barrier against interaction with surface water. Construction activities are detailed below in approximate order of construction. All components of the cap will be constructed and tested, as previously mentioned in "Construction Inspection Activities for a Contained Landfill Liner" (Section 3.1). Listed below are cap components and associated activities in order from bottom to top.

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A. Cap Subgrade Preparation

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Subgrade preparation will consist of minimal fine grading, as necessary, for establishing proper slopes. The cap will be placed in direct contact with the waste to the extent possible.

B. Gas Vent Layer Construction

Construction of the gas vent layer will include the installation of the following:

1. Crushed stone gas vent pockets excavated into the cap subgrade surface,
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C. Sacrificial Soil and Clay Layer Construction

Construction of the sacrificial soil and clay layers will include placement of 6 inch (compacted thickness) of soil as a sacrificial layer. The sacrificial layer will be placed over the double composite geonet to serve as a construction buffer prior to the installation of a low permeability clay layer 6 inch in compacted thickness.

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D. Cap Geomembrane Installation and Anchor Trench

Panels of textured high-density polyethylene (HDPE) will be laid out and welded together to form a continuous geomembrane barrier against infiltration of rainfall into the waste. Prior to beginning the panel deployment, excavation of an anchor trench will begin. The geomembrane ends and sides will be placed in the anchor trench and the trench will be backfilled. Density testing on HDPE shall be in accordance with ASTM 1505 Condition A.

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E. Geotextile Filter Fabric Installation

Panels of geotextile will be rolled out and sewn together to form a continuous layer that will serve as a cushion, an infiltration filter, and a drainage layer.

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ATTACHMENT 1

PART 6A

REVISED TECHNICAL APPLICATION ATTACHMENT 26, *CLOSURE CAP SPECIFICATIONS*

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SOLID WASTE LANDFILL
TECHNICAL APPLICATION
ATTACHMENT 26—CLOSURE CAP SPECIFICATIONS

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ATTACHMENT 26

CLOSURE CAP SPECIFICATIONS

The proposed closure cap for the Paducah Gaseous Diffusion Plant Solid Waste Landfill consists of, in ascending order, a double composite geonet gas vent layer equivalent to a 12-inch sand layer with a minimum permeability of $1x10^{-3}$ cm/sec; a compacted sacrificial soil layer; a clay cap with a maximum permeability of $1x10^{-7}$ cm/sec and minimum thickness of 6 inches; a 60-mil, textured on both sides, high-density polyethylene (HDPE) geomembrane; a layer of filter fabric; and a minimum of 36 inches of revegetative soil. A detail of the cap system for the landfill is shown in the engineering drawings.

The structural integrity of the cap exceeds the minimum factor of safety as specified in 401 *KAR* 48:080 § 10. The calculations may be found in Attachment 5.

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ATTACHMENT 1

PART 6B

REVISED TECHNICAL APPLICATION ATTACHMENT 26, *CLOSURE CAP SPECIFICATIONS*

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ATTACHMENT 26

CLOSURE CAP SPECIFICATIONS

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SOLID WASTE LANDFILL
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ATTACHMENT 26—CLOSURE CAP SPECIFICATIONS

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ATTACHMENT 26

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The structural integrity of the cap exceeds the minimum factor of safety as specified in 401 *KAR* 48:080 § 10. The calculations may be found in Attachment 5.

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ATTACHMENT 2 TO FORM DEP 7017

APPROPRIATE DRAWINGS, CALCULATIONS, MAPS, CROSS-SECTIONS, ETC.

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ATTACHMENT 2

PART 1

EVALUATION OF SEISMIC DESIGN ADEQUACY FOR C-746-U LANDFILL AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

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PAD-ENG-1003

Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Merlin Johnson 2-23-12

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Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Issued—February 2012

Prepared by
Geosyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, CA 92648
under subcontract LKY-10S005

Prepared for the
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Office of Environmental Management

LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
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ACRONYMS

a_{avg}	average acceleration (of sliding mass; calculated)
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
D_s	significant duration (of strong ground shaking)
DSHA	deterministic seismic hazard analysis
EPA	U.S. Environmental Protection Agency
FEM	Finite Element Method
F-F	Free-Field
FMSM	Fuller Mossbarger, Scott, and May Engineers, Inc.
FS_{static}	static factor of safety
HDPE	high density polyethylene (geomembrane)
JEBc	James E. Beavers Consultants
KDWM	Kentucky Division of Waste Management
k_y	yield acceleration (of sliding mass)
LATA Kentucky	LATA Environmental Services of Kentucky, LLC
LCRS	leachate collection and removal system
MSW	municipal solid waste
NOD	Technical Notice of Deficiency
PGA	peak ground acceleration (free-field ground surface acceleration)
PGDP	Paducah Gaseous Diffusion Plant
PHGA	peak horizontal ground acceleration (in bedrock)
S1E	Scenario 1 Event
S2E	Scenario 2 Event
S3E	Scenario 3 Event
S4E	Scenario 4 Event
SSI	soil-structure interaction
u_{max}	maximum calculated permanent sliding displacement
VLDPE	very low density polyethylene
V_s	shear wave velocity
WLA	William Lettis & Associates, Inc.
ε	axial strain (in HDPE geomembrane)

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EXECUTIVE SUMMARY

This report documents results of seismic evaluations, in accordance with the requirements of 401 *KAR* Chapters 47 and 48, that were required to demonstrate the adequacy of the design of the C-746-U Landfill at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This report further addresses the "Requirements of Seismic Design for C-746-U Landfill," as presented in notes from the April 6, 2010, meeting with the Kentucky Division of Waste Management (KDWM) (Ashburn 2010), and Technical Notice of Deficiency No. 1 issued by KDWM October 27, 2010. In particular, this report does the following:

- Establishes, by reference, the largest local scenario earthquake that could reasonably be expected beneath the site.
- Evaluates whether a displacement associated with local scenario earthquake can be propagated from the seismogenic depth to the surface assuming normal, dip-slip faulting.
- Demonstrates that displacement from local scenario earthquake cannot propagate to the surface.
- Demonstrates that the present landfill design can withstand the type and magnitude of displacement that can be expected from the largest local scenario earthquake.
- Provides recommended design modifications necessary to enable the landfill containment systems to withstand the predicted ground motions from the largest scenario earthquake.

The recommended design modification calls for replacement of the composite landfill cover system's smooth geomembrane with a double-textured geomembrane.

The results of other seismic evaluations documented herein indicate that seismically induced deformations of the composite landfill base liner and cover systems will be acceptable and that the potential for soil liquefaction at the C-746-U Landfill is low. The results further indicate that the impact of design earthquake motions and fault movement on ancillary facilities, such as the leachate collection and removal system and surface water diversion systems, will be acceptable.

This report concludes that future construction activities of the C-746-U Landfill may proceed in accordance with the original 1994 Ebasco/Parsons design and the recommended modifications to the final landfill composite cover system.

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1. INTRODUCTION

1.1 GENERAL

Geosyntec Consultants (Geosyntec) has prepared this report for LATA Environmental Services of Kentucky, LLC (LATA Kentucky). This report evaluates, in accordance with the requirements of 401 *KAR* Chapters 47 and 48, the adequacy of the existing design of the C-746-U Landfill and future landfill expansions at the Paducah Gaseous Diffusion Plant (PGDP). Specifically, this report addresses "Requirements of Seismic Design for C-746-U Landfill," as presented in notes from the April 6, 2010, meeting with Kentucky Division of Waste Management (KDWM) (Ashburn 2010) and the Technical Notice of Deficiency (NOD) No. 1 issued by the Kentucky Department for Environmental Protection October 27, 2010 (KDEP 2010).

1.2 PROJECT BACKGROUND

The C-746-U Landfill is just north of PGDP, as shown in Figure 1. The approximate limits of the C-746-U Landfill are shown in the inset of Figure 1. The C-746-U Landfill is a municipal solid waste (MSW) disposal facility with a permit boundary encompassing approximately 72 acres. The C-746-U Landfill is underlain by approximately 400 ft of alluvium. Groundwater is approximately 33 ft to 40 ft below the existing, slightly sloping ground surface. The site-specific geophysical and Holocene (past 11,000 years) faulting studies by William Lettis & Associates (WLA 2006) postulate that it is possible that local faults exist in the bedrock beneath PGDP. The same study reveals that, if existing, these local faults were inactive during the Holocene period.

The C-746-U Landfill, including the landfill expansion, originally was designed in 1994 by the Ebasco/Parsons team (Ebasco/Parsons 1994). The design basis was 401 *KAR* Chapters 47 and 48. Consistent with these requirements, this design includes composite landfill liner and cover systems; a groundwater monitoring network; a leachate collection and removal system (LCRS); and a landfill gas detection, monitoring and extraction system. This design was approved by KDWM in 1994.

Figure 2 shows a representative cross section through the landfill. The location of this cross section is indicated in Figure 1. As indicated in Figure 2, the design waste fill thickness ranges from 5 ft to approximately 80 ft, and the design (average) landfill side slope inclination is 4H: 1V (Horizontal: Vertical). Insets in Figure 2 provide additional relevant information about the components of composite landfill liner and cover systems.

The 1994 construction sequencing plan calls for the C-746-U Landfill to be constructed in 23 phases. To date, 5 phases have been constructed and approved by KDWM. LATA Kentucky is the remediation prime contractor to the U.S. Department of Energy (DOE) with responsibility to complete construction of the C-746-U Landfill, including construction of the composite liner and cover systems for the remaining 18 phases (Phases 6 to 23) of the C-746-U Landfill development and additional LCRSs.

During the April 6, 2010, meeting (Ashburn 2010), KDWM expressed concerns about the seismic stability of the C-746-U Landfill and outlined the scope of work required for the final approval of the project. LATA Kentucky retained James E. Beavers Consultants (JEBc) to update seismic hazard parameters using a deterministic seismic hazard analysis (DSHA) for the PGDP (JEBc 2010) and Geosyntec to address the remaining scope items, as explained below.

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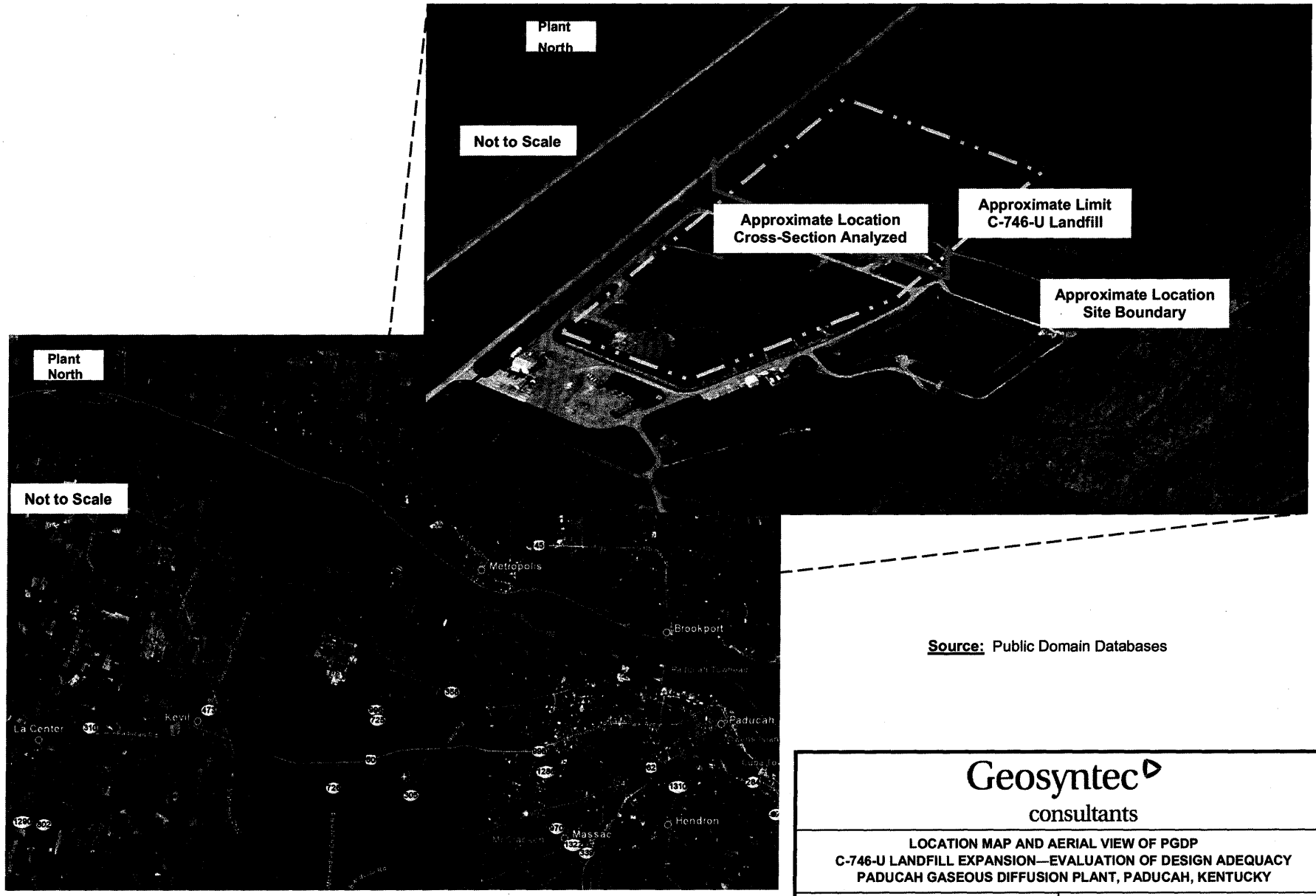

Source: Public Domain Databases

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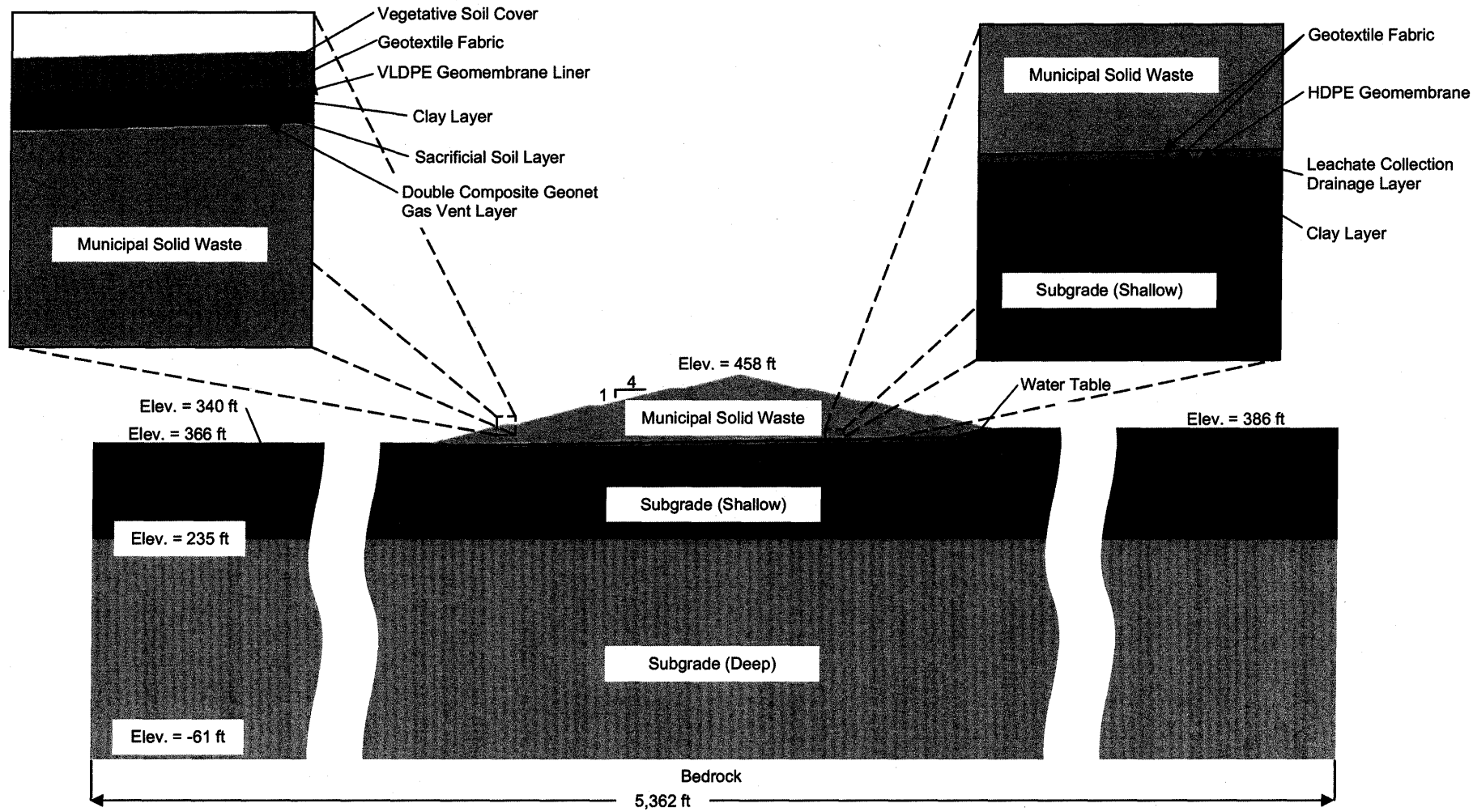
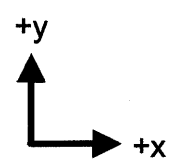
LOCATION MAP AND AERIAL VIEW OF PGDP
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.	
PROJECT NO.	GJ4658	FIGURE NO.	1

Figure 1. Location Map and Aerial View of PGDP





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STABILITY ANALYSIS CROSS-SECTION
C-746-U LANDFILL EXPANSION – EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 2

Figure 2. Stability Analysis Cross Section

1.3 SCOPE OF WORK AND REPORT ORGANIZATION

Geosyntec's scope for this study consisted of the following tasks:

- Review and summarize the seismic hazard update study by JEBc and evaluate significant duration of strong ground shaking that is required for evaluation of design ground motions (i.e., acceleration time histories in bedrock that are required for dynamic PGDP response analyses).

- Develop design ground motions based upon (1) the results of seismic hazard study by JEBc and (2) additional evaluations of significant duration of strong ground shaking performed by Geosyntec.

- Develop a representative model of the PGDP (400 ft of alluvium underlying the PGDP and 80 ft of waste fill) for use in pseudostatic evaluations, site response analyses, seismic deformation analyses, and a fault rupture propagation simulation.

- Perform site response analysis to evaluate how alluvium and waste fill modify design (i.e., bedrock) ground motions. The results of this site response analysis are an essential first step in the evaluation of the seismic stability of landfill mass, landfill composite liner and cover systems, and ancillary facilities, including the LCRS and the surface water collection system.

- Perform static and pseudostatic stability evaluations of the final C-746-U Landfill configuration. This evaluation is the second essential step in evaluation of seismic stability of the landfill mass, landfill composite liner and cover systems, and ancillary facilities, including the LCRS and surface water collection system.

- Perform a seismic deformation analysis of C-746-U Landfill waste mass, and composite landfill liner and cover systems, combining the results of the previous two steps of the analysis (i.e., of site response analysis and pseudostatic evaluation of yield acceleration).

- Demonstrate that soil liquefaction potential at PGDP is low based upon the site characterization information (depth to groundwater, material composition, and density) and results of site response analysis (calculated shear strain profile).

- Demonstrate that the landfill LCRS and the surface water collection system can sustain the design seismic loading based upon the results of site response analysis (calculated peak shear strain profile) and seismic deformation analysis (calculated maximum permanent displacement of landfill mass).

- Perform an engineering study that demonstrates that the impact of a postulated fault movement directly below the C-746-U Landfill on the landfill liner and cover systems can be tolerated by the current design. As a part of this study, demonstrate that the landfill surface water and leachate collection systems can sustain impact of fault movement.

- Evaluate if the existing leachate tank foundation and wet well designs conform to the newly evaluated seismic loading.

- Develop conclusions and recommendations.

This report is organized in accordance with the scope of work outlined above.

2. OVERVIEW OF REGULATORY REQUIREMENTS AND BASIS FOR STABILITY EVALUATIONS

2.1 DESIGN EARTHQUAKE

Subtitle D mandates the minimum standard for seismic design of landfills as a probabilistically evaluated seismic event with 2% probability of being exceeded (PE) in 50 years (2% PE in 50 years). The return period of this seismic event is 2,475 years.

A meeting was held on April 6, 2010, between DOE and KDWM (Ashburn 2010) in Frankfort, Kentucky, to establish KDWM requirements for updating the seismic hazard for C-746-U Landfill. KDWM stated at that meeting that the seismic hazard assessment for C-746-U Landfill should be conducted using a deterministic, rather than a Subtitle D-mandated probabilistic approach.

Consistent with the conclusions of the above-cited meeting, seismic hazard parameters were evaluated based upon a site-specific deterministic seismic hazard analysis.

2.2 DESIGN FAULT RUPTURE DISPLACEMENT

401 *KAR* 48:050 Section 5 requires that disposal facilities, such as the C-746-U Landfill, be located more than 200 ft from a fault that has surface displacement within Holocene time.

Based upon the results of site-specific geophysical measurements and a Holocene faulting study, WLA (2006) postulated that local faults were inactive during the Holocene period. To provide a conservative basis for design, a parametric study with simulated fault displacements beneath the C-746-U landfill has been conducted and is documented herein.

2.3 REPRESENTATIVE SLOPE CONFIGURATIONS

The representative slope configuration is the final configuration of the C-746-U Landfill as it will exist for an extended period of time and, hence, can be exposed to strong earthquake shaking. Furthermore, this final configuration has the highest and steepest waste fill slopes and will be overlain by the landfill final cover.

2.4 SLOPE STABILITY—STATIC AND SEISMIC STABILITY CRITERIA

The static stability of the representative slope configuration was evaluated using the limit equilibrium approach with a static factor of safety (FS_{static}) of 1.5 as the stability criterion. The seismic stability was evaluated in accordance with the same regulations using the Newmark (1965) method, with a maximum calculated permanent seismic displacement of 12 inch (liner) and 36 inch (cover) as the seismic stability criteria. The particular value of limiting seismic displacement for landfill liner is based upon a study by Seed and Bonaparte (1992) and has been adopted by the U.S. Environmental Protection Agency (EPA), as explained in Richardson et al. (1995). The 36-inch criterion for the landfill composite cover is justified by ease of access after the earthquake to perform necessary repairs. The relevant static and seismic slope stability criteria are summarized in Table 1.

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Table 1. Summary of Slope Stability Design Basis for C-746-U Landfill

Slope Type	Shear Strength Parameters(1)	Static Stability Criterion	Design Earthquake	Max. Allowable Seismic Displacement
Permanent Waste Fill Slope and Liner	Large Displacement	$FS_{static} \geq 1.5$	Deterministic Event	12 inch
Permanent Landfill Cover	Large Displacement	$FS_{static} \geq 1.5$	Deterministic Event	36 inch

Note: (1) Refers to the shear strength parameters evaluated by the interface shear testing and used in conjunction with stability criteria listed in this table.
FS = factor of safety

Included in Table 1 is relevant information for the static and seismic stability evaluations, including an acknowledgement that the large displacement (nearly residual) shear strength parameters are used in conjunction with the listed stability criteria.

2.5 ALLOWABLE STATIC AND SEISMIC SETTLEMENT

There are no specific limits imposed on the intensity (i.e., amount) of static and seismically induced settlement in the C-746-U Landfill; however, ancillary structures placed over waste—such as temporary berms, drainage swales, the gas extraction system piping—should, whenever possible, be designed and constructed to accommodate relatively large waste fill settlements.

2.6 ALLOWABLE TENSION IN LANDFILL COMPOSITE LINER

Large fault rupture displacement can induce large strains in overlying alluvium. Depending on alluvium thickness and composition, these strains could propagate towards surface and strain surface improvements such as the composite landfill liner. Numerous test results have shown (e.g., Yazdani et al. 1995), that the high density polyethylene (HDPE) component of the landfill liner can be strained up to 4% in axial direction without jeopardizing its integrity; therefore, Geosyntec established axial strain (ε) in the HDPE geomembrane of $\varepsilon \leq 4\%$ as a stability criterion for this type of application.

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3. SEISMIC HAZARD ANALYSIS

3.1 PREVIOUS STUDIES

The seismic hazard for the C-746-U Landfill was evaluated by JEBc (2010) and its subconsultant, Dr. Chris Cramer (Dr. Cramer's study is incorporated in JEBc and is not separately referred to herein). Consistent with decisions made during the April 6, 2010, meeting with KDWM (Ashburn 2010), a deterministic seismic hazard analysis was performed by JEBc.

Three deterministic earthquake scenarios were evaluated to establish the design earthquake and, hence, seismic hazard parameters for the development of design ground motions. The scenarios chosen were based on both actual events from nearby fault systems and postulated events.

Seismic scenario events evaluated were identified as Scenario 1 Event (S1E), Scenario 2 Event (S2E), and Scenario 3 Event (S3E). These scenario events are shown schematically in Figure 3, where red bars represent postulated significant seismic sources. S1E assumes a moment magnitude of Mw 7.6, just west of the confluence of the Mississippi and Ohio Rivers, to replicate the February 7, 1812, New Madrid earthquake (NM in Figure 3). S2E assumes a Mw 7 at the confluence of the Wabash and Ohio Rivers for the Wabash Valley Fault System (WV in Figure 3). S3E assumes an Mw 5.5 at a distance of 22 km (13.67 miles)[1] from PGDP to simulate a local event. Epicenters of recent (past 30 years) earthquakes in the vicinity of PGDP (sizes of green dots are proportional to the magnitude of recorded event) also are shown in Figure 3.

The results of the JEBc deterministic seismic hazard study indicate that S1E induces both the highest bedrock peak horizontal ground acceleration (PHGA) and the highest spectral ordinates in the bedrock at the site. In particular, the S1E scenario PHGA evaluated for bedrock at the geometric center of PGDP is 0.36 g. The corresponding spectral ordinates (5% viscous damping) are equal to 0.54 g at 0.2 seconds and to 0.19 g at 1.0 second.

We note that this S1E PHGA of 0.36 g is significantly higher than PHGAs evaluated for the original S2E and S3E scenarios and for the supplemental S4E scenario corresponding to the M_w 5.5 event at a distance of 2.5 km that was evaluated as a part of the parametric studies conducted for PGDP.

The JEBc (2010) seismic hazard study that served as a basis for evaluations documented herein is included as Appendix A.

3.2 EVALUATION OF SIGNIFICANT DURATION OF STRONG GROUND SHAKING

Geosyntec evaluated the significant duration of strong ground shaking (D_s) to establish a target duration value for development of design ground motions. As duration increases with both earthquake magnitude and distance, the S1E scenario was established as the controlling event. A bedrock D_s was established for this S1E event using deterministic principles and the Kempton and Stewart (2006) duration model. The D_s evaluated for bedrock at the geometric center of PGDP is between 26 and 29 seconds, significantly longer than for the other two scenarios evaluated. Calculation sheets are included as Appendix B.

---

[1] The S3E Scenario, per regulatory comment, was not representative of a local event; therefore, an additional scenario, S4E, has been evaluated. This S4E scenario differs from the S3E scenario, as M_w 5.5 event was placed at a distance of 2.5 km in lieu of the 22 km used in Scenario S3E. The relevant calculations with this shortened distance are provided in Appendix F.

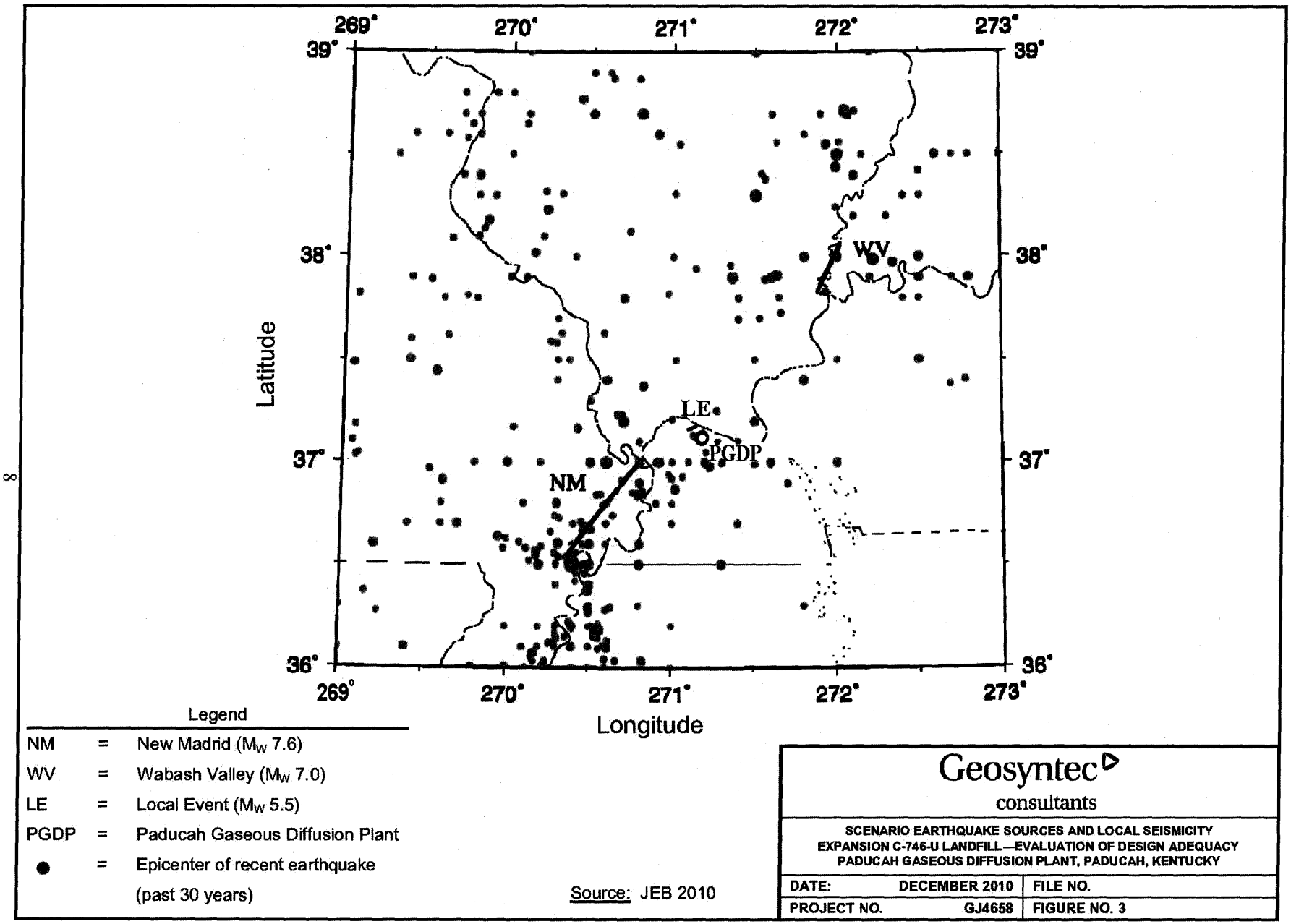

Figure 3. Scenario Earthquake Sources and Local Seismicity

3.3 DESIGN GROUND MOTION PARAMETERS

Based upon the results of the seismic hazard study by JEBc (2010), the results of our internal study with the supplemental S4E scenario provided in Attachment F, and our evaluation of design bedrock D_s, Geosyntec identified and established S1E as the controlling (i.e., design) seismic event for site response and seismic deformation analyses at PGDP, including development of design ground motions.

Below is a summary of key S1E seismic hazard parameters used for development of design ground motions:

- Design Earthquake Magnitude/Distance Pair: M_w 7.6/36.5 km (3.11 miles) (1812 New Madrid Event, S1E);
- Design Bedrock PHGA: 0.36 g;
- Design Bedrock Spectral Ordinates: 0.54 g at 0.2 seconds; 0.19 g at 1.0 second; and
- Design Bedrock D_s: 29 seconds.

The design spectral ordinates explained above are plotted in the form of a target acceleration response spectral ordinates (i.e., at periods of 0.01, 0.2, and 1 seconds) in Figure 4.

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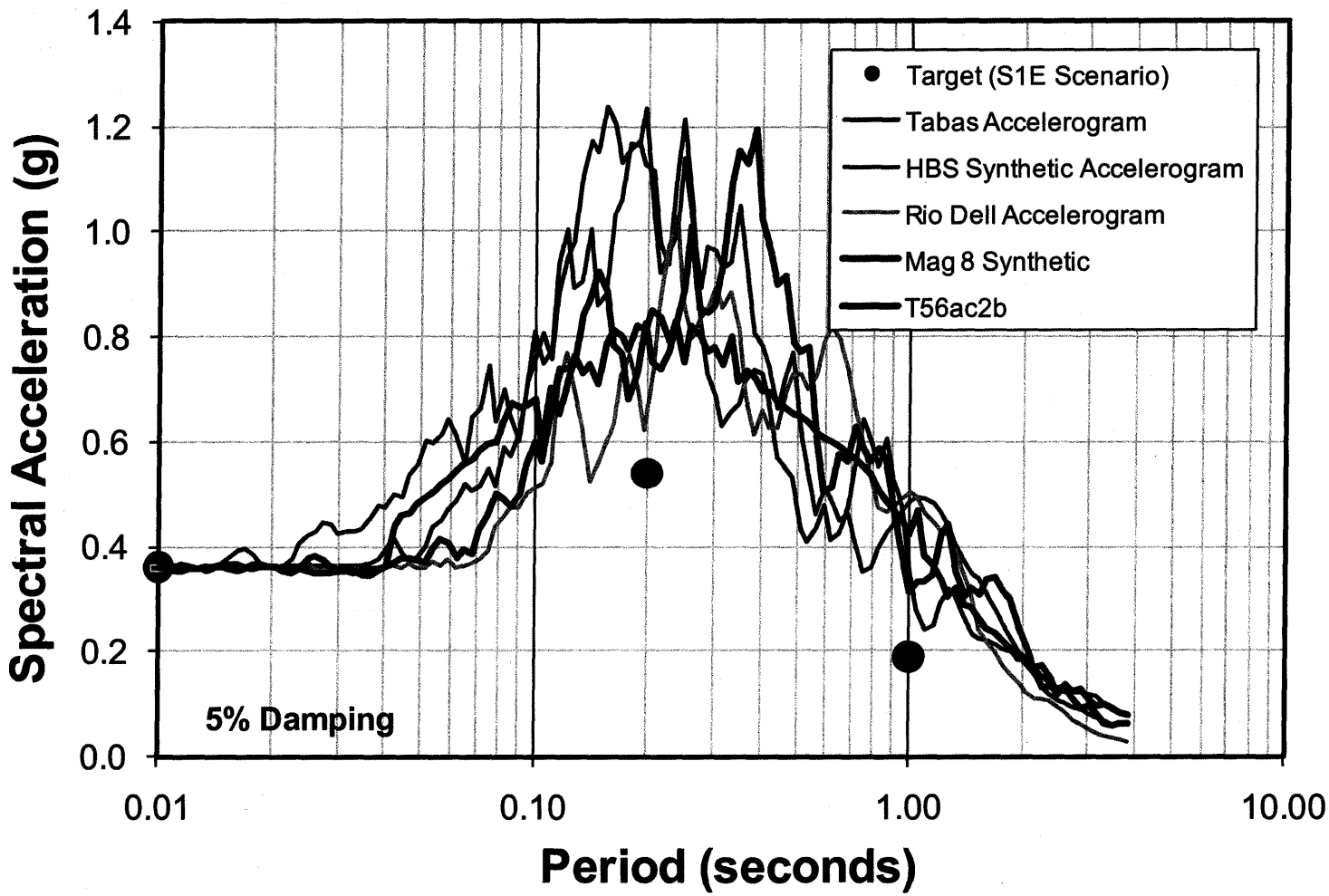

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ACCELERATION RESPONSE SPECTRA FOR FREE FIELD
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 4

Figure 4. Acceleration Response Spectra for Free Field

4. DESIGN GROUND MOTIONS

Design ground motions (design accelerograms) are an essential input for the seismic site response analysis. The processed motions (i.e., the results of site response analyses) are an essential input into the seismic deformation analysis.

The design ground motions were selected to conform, as a suite of motions, to the design ground motion parameters explained above. This suite includes the following accelerograms:

- The 270-degree component of the Rio Dell accelerogram from the 1992 M_w 7.0 Cape Mendocino, California, earthquake, scaled to 0.36 g;
- The HBS synthetic accelerogram generated to simulate bedrock motions from a large-magnitude event, scaled to 0.36 g;
- The M_w 8^+ synthetic accelerogram developed to simulate a bedrock ground motions generated by a distant (110 km or 70 miles) large-magnitude (M_w 8^+) event on the San Andreas fault, scaled to 0.36 g;
- The T56ac2b spectrum-compatible synthetic record developed by to represent bedrock strong ground motions generated by a local (up to 15 miles) large-magnitude (M_w 8^+) event on the San Andreas fault, scaled to 0.36 g; and
- The north-south (N-S) component of the Tabas accelerogram from the 1978 M_w 7.4 Tabas-e-Golshan, Iran, earthquake, scaled to 0.36 g.

To demonstrate that the selected suite of design ground motions conforms to the target spectral ordinates, the acceleration response spectra of individual design ground motions are plotted against the target acceleration response spectrum ordinates (periods of 0.01, 0.2, and 1 seconds) in Figure 4.

Figure 4 demonstrates that the acceleration response spectra of design accelerograms not only conform, but significantly exceed the target spectrum ordinates at 0.01, 0.2, and 1 seconds, thus providing a conservative basis for design. The significant duration of selected motions conforms to the target significant duration of 29 seconds.

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5. REPRESENTATIVE MODEL OF THE SITE

The representative model of the PGDP soil column and waste mass (site) was developed based upon the C-746-U Landfill design drawings developed by the Ebasco/Parsons team (1994), the results of geotechnical, geological, and geophysical investigations, as documented and interpreted in Risk Engineering, Inc. (REI 1999), and information on depth to groundwater from miscellaneous groundwater monitoring well logs provided by LATA Kentucky.

A graphical depiction of the representative model of PGDP is shown in Figure 2 (the location of the particular cross section is shown in Figure 1). A representative soil column, with more detailed information on soil stratification, classification, stiffness (shear wave velocity), and unit weight distribution, is shown in Figure 5.

Figure 5 shows that PGDP is underlain with an alluvial soil profile with alternating layers of silty clay, silty sand, sand and gravel, silt, and clay. The shear wave velocity distribution across the profile is relatively uniform with an average value of approximately 1,300 ft/s, with exception of the top 30 ft where it rapidly increases from approximately 650 ft/s to 1,100 ft/s.

The approximate elevation of groundwater at the site is at elevation 340 ft above mean sea level (approximately 33 ft to 40 ft below the existing, slightly sloping ground surface).

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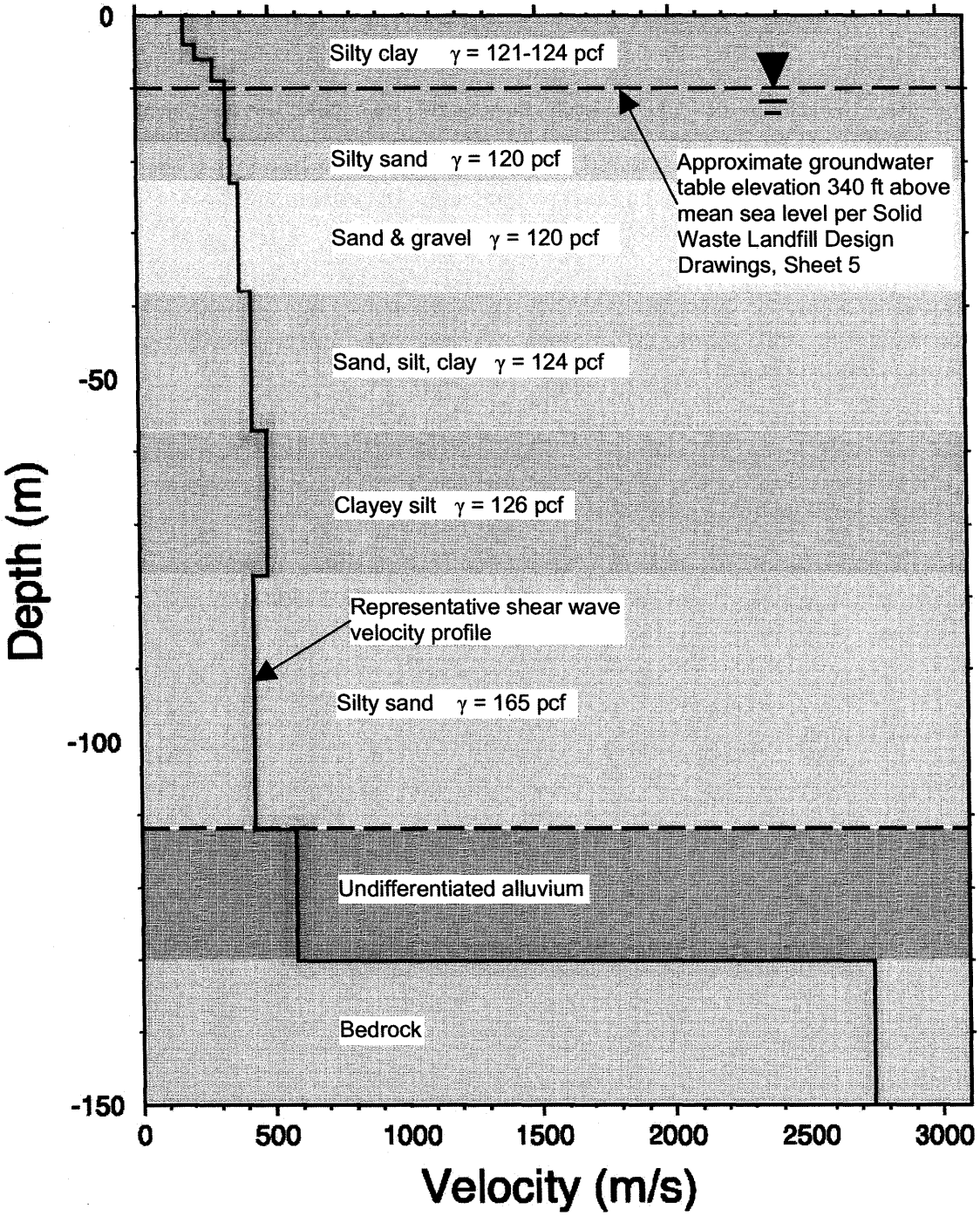

Source: Risk 1999

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REPRESENTATIVE SOIL COLUMN AND SHEAR WAVE VELOCITY PROFILE
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.	
PROJECT NO.	GJ4658	FIGURE NO.	5

Figure 5. Representative Soil Column and Shear Wave Velocity Profile

6. ENGINEERING EVALUATIONS

6.1 STATIC AND PSEUDOSTATIC STABILITY EVALUATION OF LANDFILL BASE LINER

6.1.1 Approach, Model, and Representative Cross Section

Geosyntec evaluated the stability of the C-746-U Landfill under static loading conditions. Geosyntec also conducted a pseudostatic evaluation to calculate yield acceleration of sliding mass (k_y). Yield acceleration of sliding mass is an essential input for seismic deformation analysis. Both static and pseudostatic evaluations are based upon limit equilibrium principles (rigid body mechanics). Geosyntec used SLOPE/W (GSI 2010) to perform the calculations. The program automatically evaluates a number of failure surfaces and reports the lowest value calculated by several limit equilibrium methods.

Both the static and pseudostatic evaluations were performed using the representative cross section shown in Figure 2. This representative cross section is the same cross section that was evaluated during the design stage of the project and, more recently, during the slope stability reassessment by Fuller Mossbarger, Scott, and May Engineers, Inc. (FMSM) (2001).

6.1.2 Material Properties

Table 2 provides the material properties used for the evaluations documented herein.

The shear strength parameters of MSW (cohesion and friction angle) are based upon generic (lower-bound) values reported by Kavazanjian et al. (1995). The unit weight of MSW (γ_{MSW}) is based on Matasovic and Kavazanjian (1998); it represents the upper bound value of recommendations by Zekkos et al. (2006). This assumed unit weight value is significantly higher than γ_{MSW} of 59 pcf that was evaluated by TetraTech, Inc., based upon the 2008-2009 survey records (reported in "Annual Survey Summary Sheet for Solid Waste Landfills," March 2009, attachment to the Annual Survey Report for the site). We further note that the upper-bound value of MSW unit weight employed (85 pcf) is conservative for seismic evaluations documented herein, as seismically-induced forces are proportional to the mass of waste deposit (i.e., the intensity of seismic force is proportional to γ_{MSW}/g, where g is acceleration of gravity). Properties for the compacted clay component of the composite liner system under static loading conditions are based on the values for residual shear strength of an interface between cohesive soil and textured HDPE geomembrane (Koerner and Narejo 2005). Properties for other materials used in the stability analyses were selected to correspond to those evaluated and used by FMSM 2001.

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Table 2. Estimate of Material Parameters for Slope Stability Analyses

Material	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Municipal Solid Waste (confining stress < 770 psf)	85	0	500
Municipal Solid Waste (confining stress > 770 psf)	85	33	0
Drainage Layer (Gravel)	135	35	0
Compacted Clay (Static)	116.5	16	0
Compacted Clay (Pseudostatic)	116.5	18.1	180
Engineered Fill	120	28	0
Subgrade (Shallow)	107.4	33	0
Subgrade (Deep)	107.4	33	0

The shear strength parameters of MSW (cohesion and friction angle) are based upon generic (lower-bound) values reported by Kavazanjian et al. (1995). The unit weight of MSW is based on Matasovic and Kavazanjian (1998) and represents the upper bound value of recommendations by Zekkos et al. (2006). Properties for the compacted clay component of the composite liner system under static loading conditions are based on the values for residual shear strength of an interface between cohesive soil and textured HDPE geomembrane (Koerner and Narejo 2005). Properties for other materials used in the stability analyses were selected to correspond to those evaluated and used by FMSM (2001).

6.1.3 Results

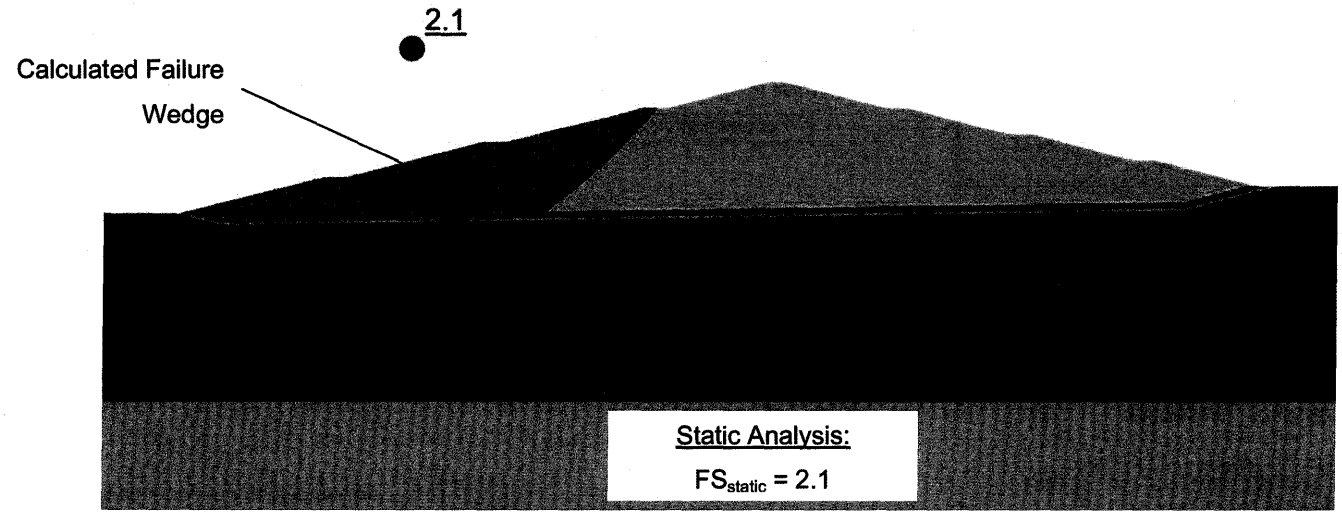
The results of the waste fill and landfill liner stability evaluations are presented in Figure 6. The lowest calculated $FS_{static} = 2.1$; hence, the static stability criterion of $FS_{static} \geq 1.5$ is met. The lowest calculated yield acceleration of sliding mass is $k_y = 0.26$. This yield acceleration, if lower than the average acceleration of sliding mass calculated in site response analysis, serves as an input into the seismic deformation analyses.

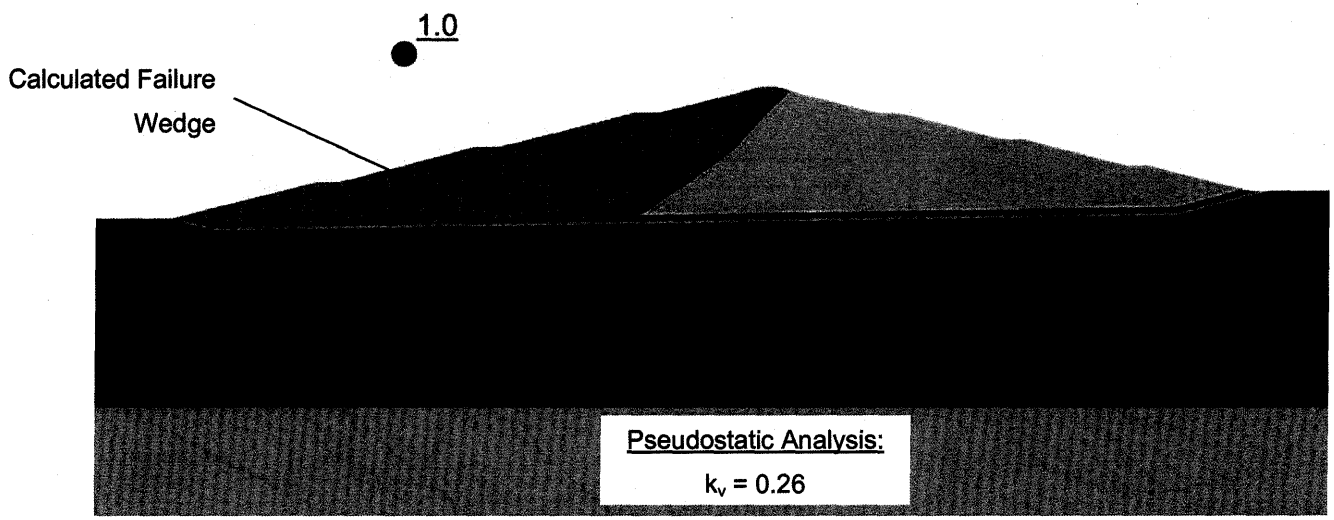
Figure 6 further shows the shapes of evaluated sliding mass for static and pseudostatic evaluations also required for the seismic deformation analyses.

6.2 STATIC AND PSEUDOSTATIC STABILITY EVALUATION OF LANDFILL COVER

The configuration of the final cover was established based on the approved design cross section and final cover detail developed by FMSM (2001). Detailed configuration of the C-746-U Landfill final cover, as analyzed herein, is shown in an inset of Figure 7.

The slope of the final cover is approximately 4H: 1V across the site. The critical interface was assumed to be that between the filter fabric (assumed to be non-woven needle-punched geotextile) and the 40-mil very low density polyethylene (VLDPE) smooth on both sides. Based on the average of typical testing data reported by Koerner and Narejo (2005), this interface was characterized with adhesion of zero and residual friction angle of 9 degrees. The stability of the final cover was evaluated using the limit





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STATIC AND PSEUDOSTATIC STABILITY EVALUATIONS—RESULTS
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

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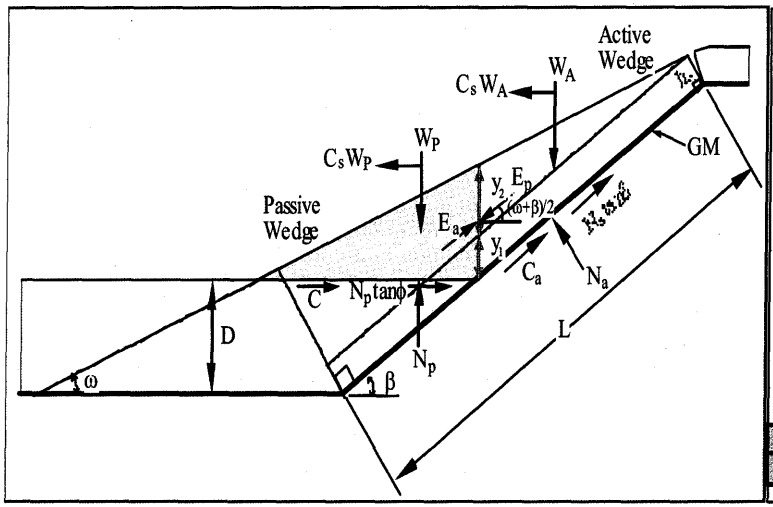
PROJECT NO.	GJ4658	FIGURE NO.	6

Figure 6. Static and Pseudostatic Stability Evaluations—Results

Uniform and/or Tapered Cover Soil with Consideration of Seismic Forces



Calculation of FS

Active Wedge:

Wa= 454.5 kN
Na= 439.8 kN
Ca= 132.4 kN

Passive Wedge:

Wp= 32.3 kN
C= 0.0 kN

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= 107.3
b= -289
c= 35.7

k_y= 0.36 g
FS_{static}= 2.57

(Note: for uniform cover soil thickness the input value of $\omega = \beta$)

thickness of cover soil at top (crest) of the slope = hc =	0.91	m	
thickness of cover soil along the bottom of the site = D =	0.91	m	
soil slope angle beneath the geomembrane = β =	14.6	°	= 0.25 (rad.)
finished cover soil slope angle = ω =	14.6	°	= 0.25 (rad.)
length of slope measured along the geomembrane = L =	30.1	m	

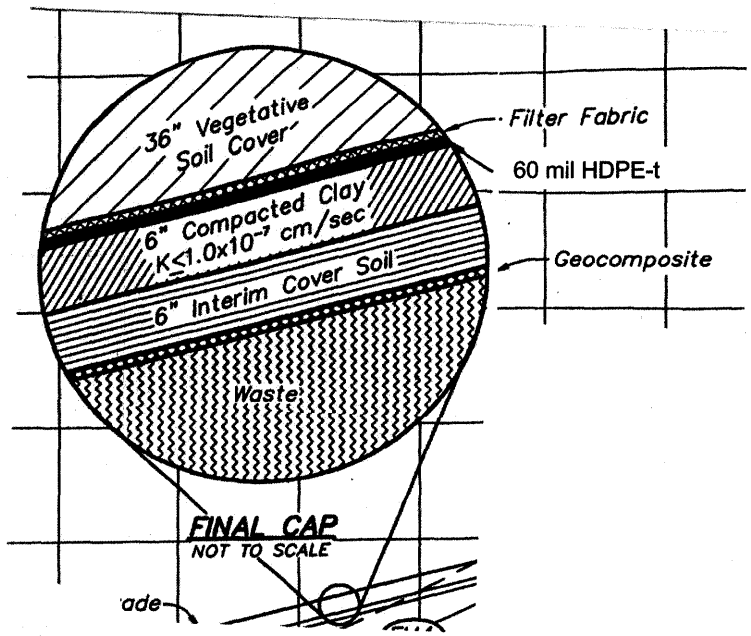
y2= 0.00 (m)
y1= 0.94 (m)
$(\omega+\beta)/2$= 0.255 (rad.)
(= 14.6 °)

unit weight of the cover soil = γ =	18.9	kN/m^3	
friction angle of the cover soil = ϕ =	28.0	°	= 0.49 (rad.)
cohesion of the cover soil = c =	0.0	kN/m^2	
interface friction angle between cover soil and geomembrane = δ =	18.0	°	= 0.31 (rad.)
adhesion between cover soil and geomembrane = ca =	5.0	kN/m^2	

seismic coefficient = Cs = 0.00 g

Note: numbers in boxes are input values

numbers in Italics are calculated values



Source: FMSM [2001] (modified)

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FINAL COVER VENEER STABILITY ANALYSIS
C-746-U LANDFILL EXPANSION – EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.	
PROJECT NO.	GJ4658	FIGURE NO.	7

Figure 7. Final Cover Veneer Stability Analysis

equilibrium-based method developed by Koerner and Soong (1998) specifically for this type of application. The force-equilibrium polygon of this method is shown in Figure 7.

Initial results of this stability analysis indicated that the original cover design with smooth VLDPE cannot sustain the static loading (i.e., calculated $FS_{static} < 1.0$); therefore, a design modification is recommended (see Section 9.2). The recommended revision calls for replacement of the 40-mil smooth VLDPE with a 60-mil, textured on both sides, HDPE geomembrane. Based on the average of typical testing data reported by Koerner and Narejo (2005), this "new" interface was characterized with adhesion of 100 psf and residual friction angle of 18 degrees.

Summary calculations for the recommended configuration (i.e., configuration with 60-mil double textured HDPE) are presented in Figure 7. The result of these calculations indicate that the lowest calculated static $FS_{static} = 2.57$. The corresponding calculated yield acceleration of sliding mass equals $k_y = 0.36$ g.

6.3 SITE RESPONSE AND SEISMIC DEFORMATION ANALYSES

6.3.1 Site Response Analysis

The JEBc (2010) report includes a simplified site response study by Dr. Chris Cramer. That study was based upon the 2006 edition of the International Building Code site amplification factors and, as such, does not account for the effects of nonlinear soil behavior on input (i.e., bedrock) ground motions.

Geosyntec developed two dynamic site response models that account for soil nonlinearity. The first model represents free-field (F-F) site condition (i.e., waste fill is not included in this model). The second model is a soil-structure interaction (SSI) model, with waste fill treated as a structure. Hence, this SSI model incorporates both the soil profile and the C-746-U Landfill. Both site response models considered are schematically depicted at their representative locations in Figure 8.

Both dynamic models shown in Figure 8 incorporate an approximately 400-ft thick layer of alluvium that is characterized in Figure 5. The SSI model also incorporates waste fill at the location of the critical failure surface as established by the pseudostatic analysis. The waste fill was characterized by a generic shear wave velocity (V_s) profile of MSW, as developed by Matasovic and Kavazanjian (1998) and shown in Figure 9. Other relevant information required to characterize the waste fill is shown in Figure 10 (the conservative, upper-bound unit weight profile of MSW) and in Figure 11 (modulus reduction and damping curves of MSW). All three sets of these material properties have been developed as a part of a comprehensive study on dynamic MSW properties at the same MSW landfill and are widely used in landfill design. For convenience, the Matasovic and Kavazanjian (1998) paper is reproduced as Appendix C.

The site response analyses were performed using the SHAKE2000 (www.geomotions.com) computer program. SHAKE2000 incorporates the equivalent linear soil (and MSW) model to account for nonlinear behavior of these materials. The design accelerograms were scaled to design bedrock PHGA of 0.36g and applied as outcrop motions in SHAKE2000 analysis. The computer program outputs are enclosed in Appendix D (F-F analysis) and Appendix E (SSI analysis). Summary results are presented below and in Figures 12 through 14.

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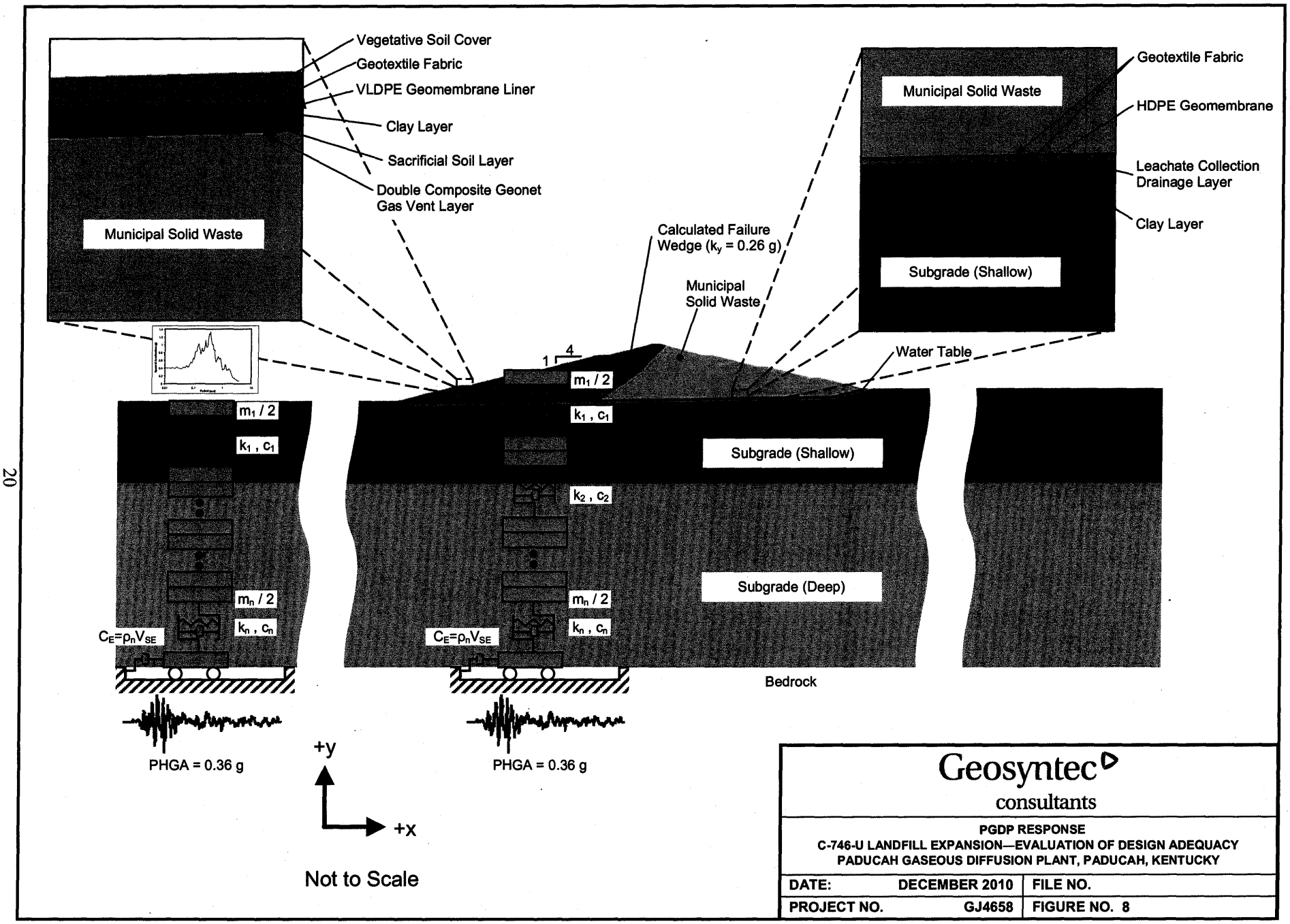
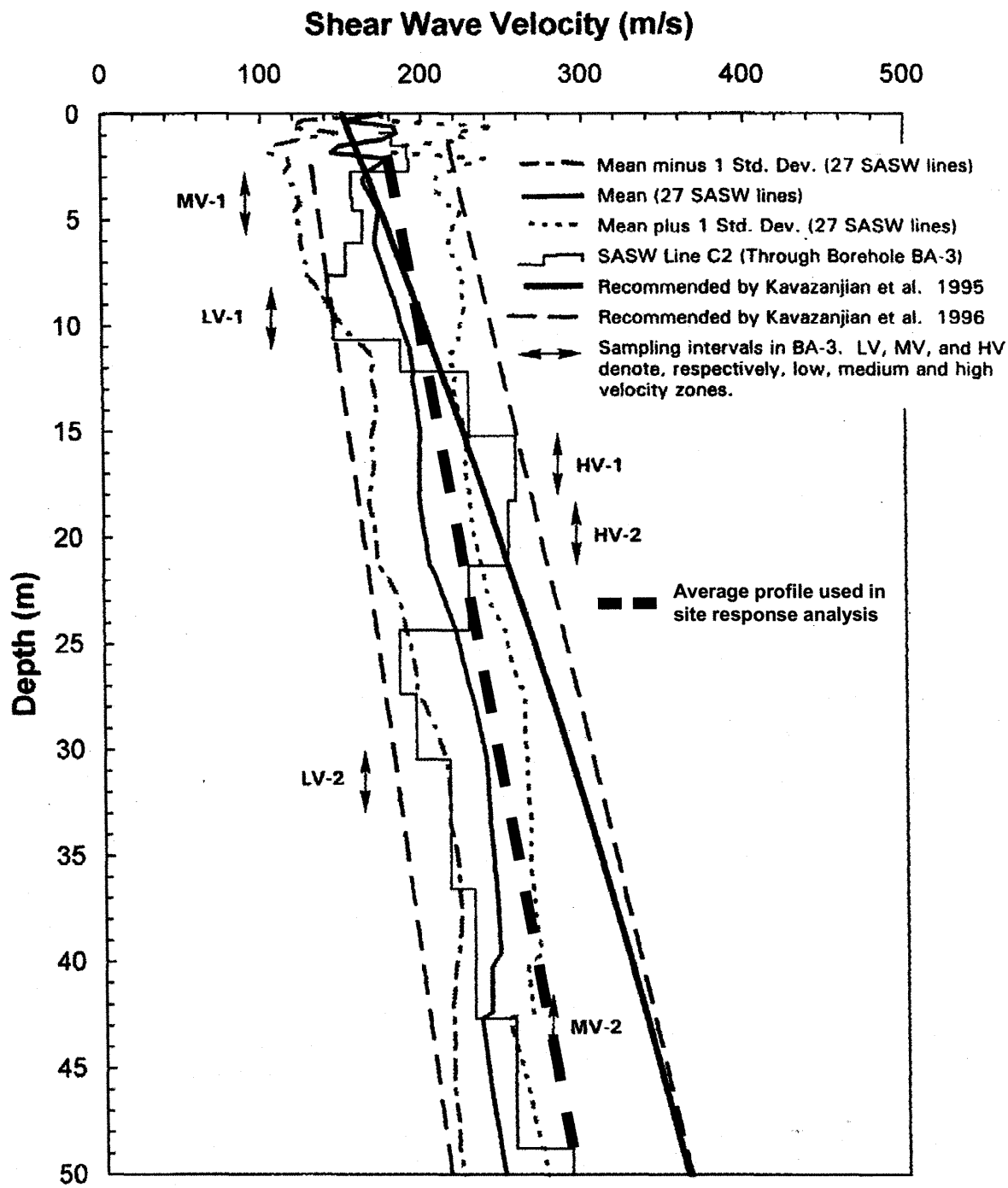


Figure 8. PGDP Response



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Reference: Matasovic and Kavazanjian 1998

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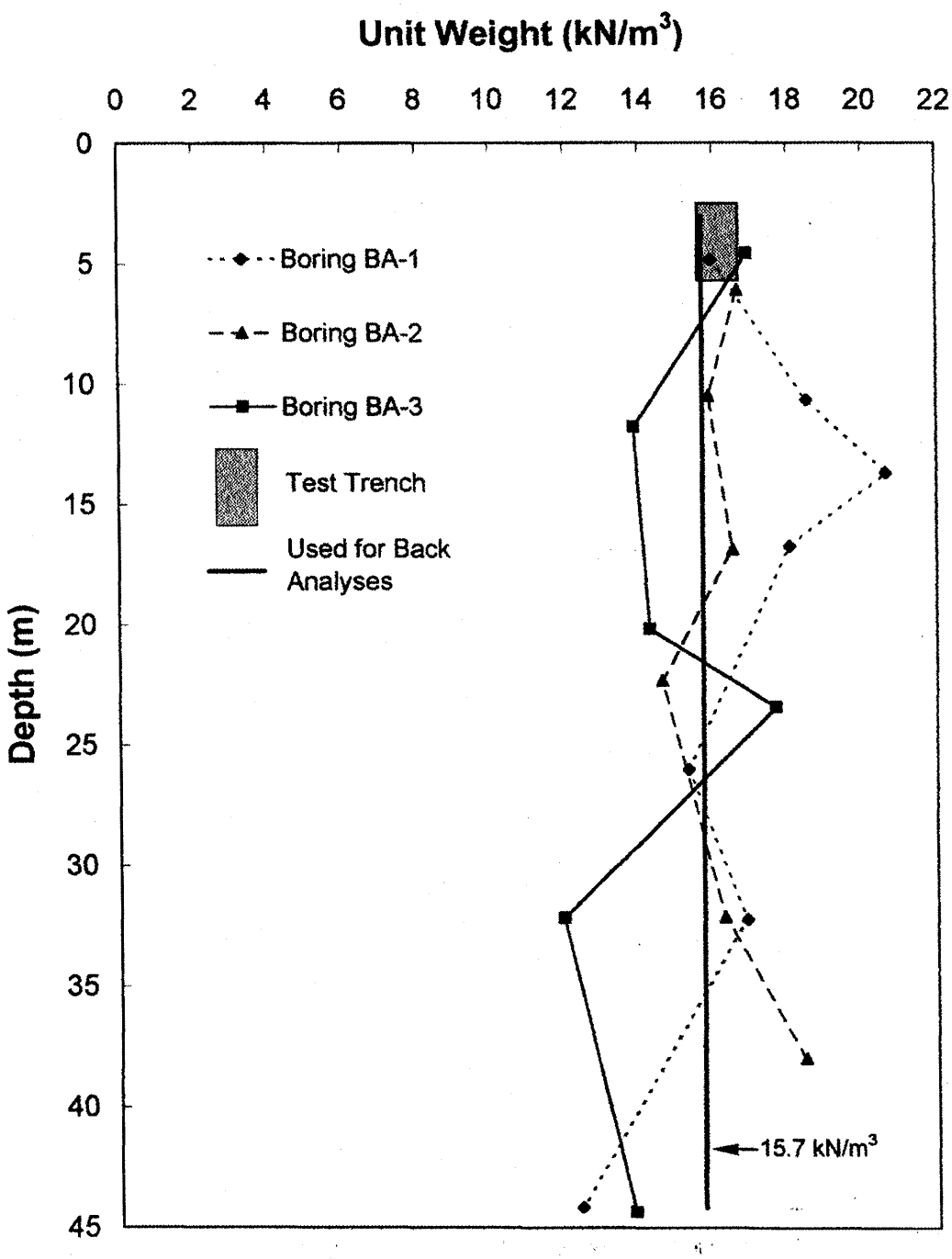
SHEAR WAVE VELOCITY PROFILE OF MSW
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 9

Figure 9. Shear Wave Velocity Profile of MSW



Reference: Matasovic and Kavazanjian 1998

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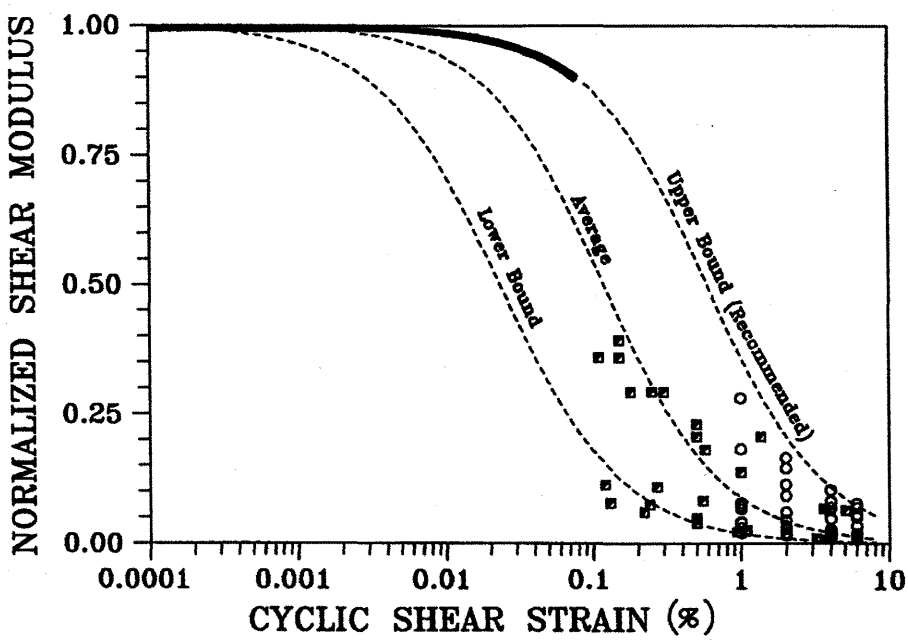
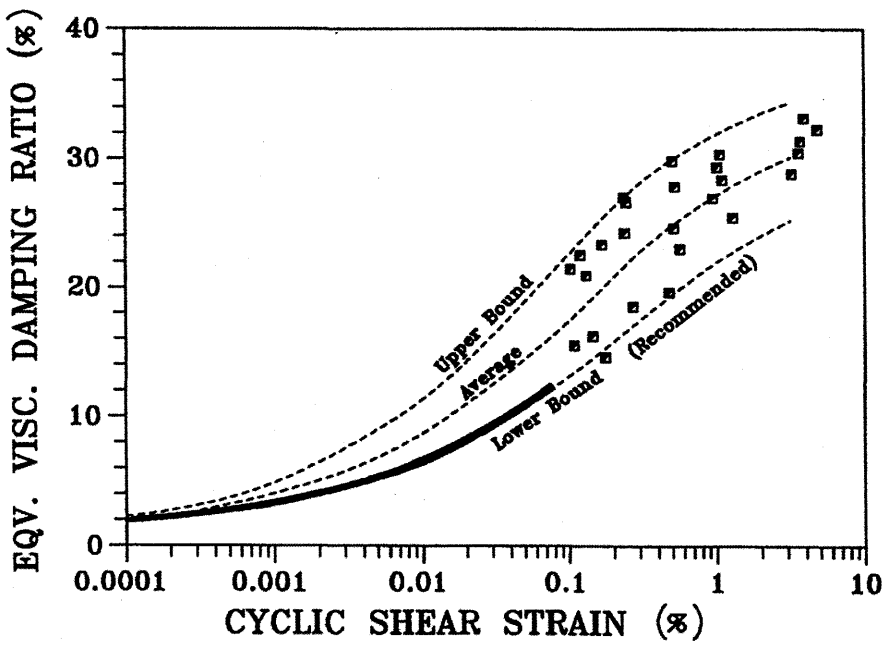
UNIT WEIGHT PROFILE OF MSW
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 10

Figure 10. Unit Weight Profile of MSW





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Back Calculated
Evaluated from Monotonic DSS Testing of OII Solid Waste
Evaluated from Cyclic DSS Testing of OII Solid Waste

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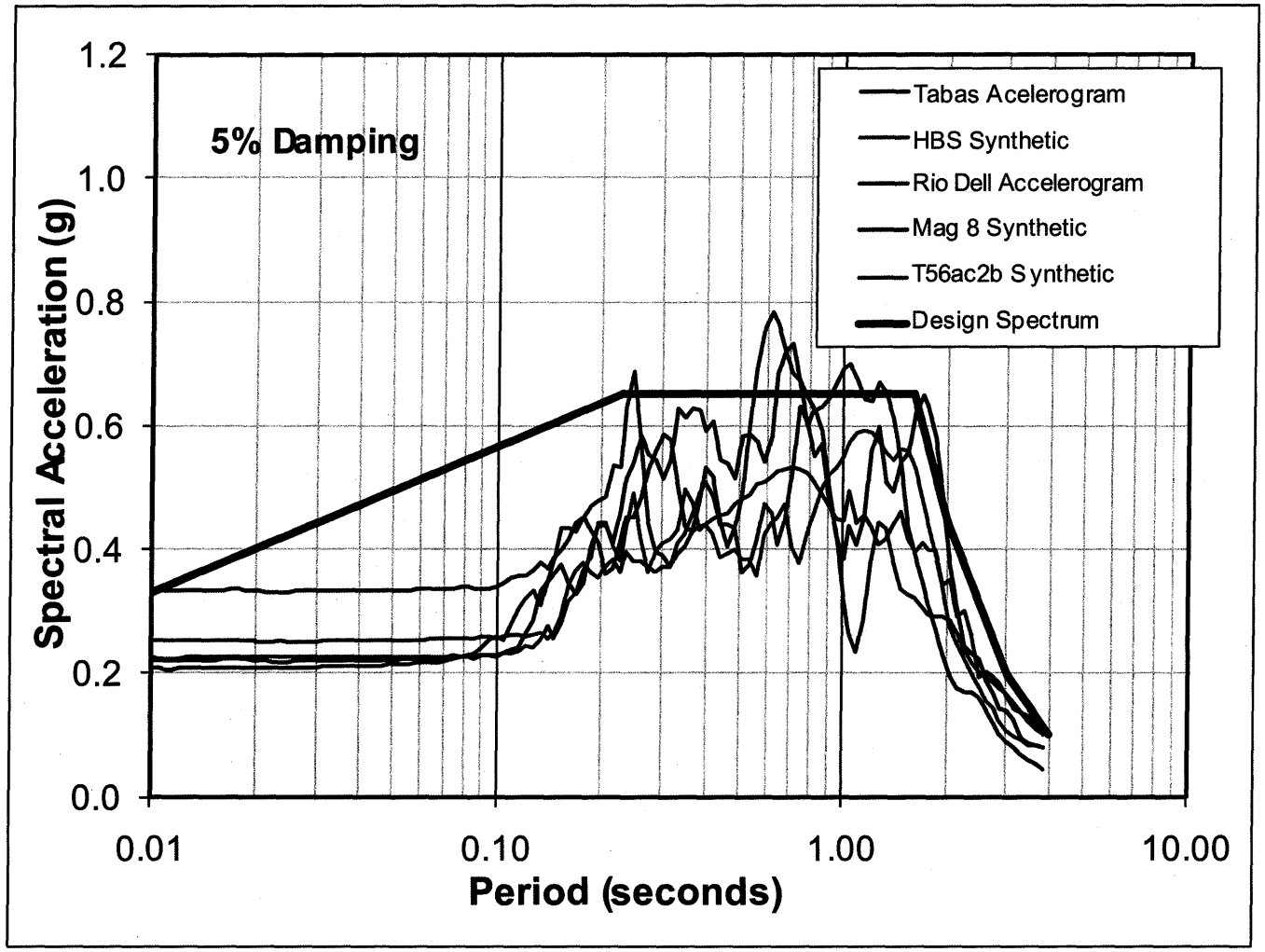
MODULUS REDUCTION AND DAMPING CURVES OF MSW
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 11

Reference: Matasovic and Kavazanjian 1998

Figure 11. Modulus Reduction and Damping Curves of MSW



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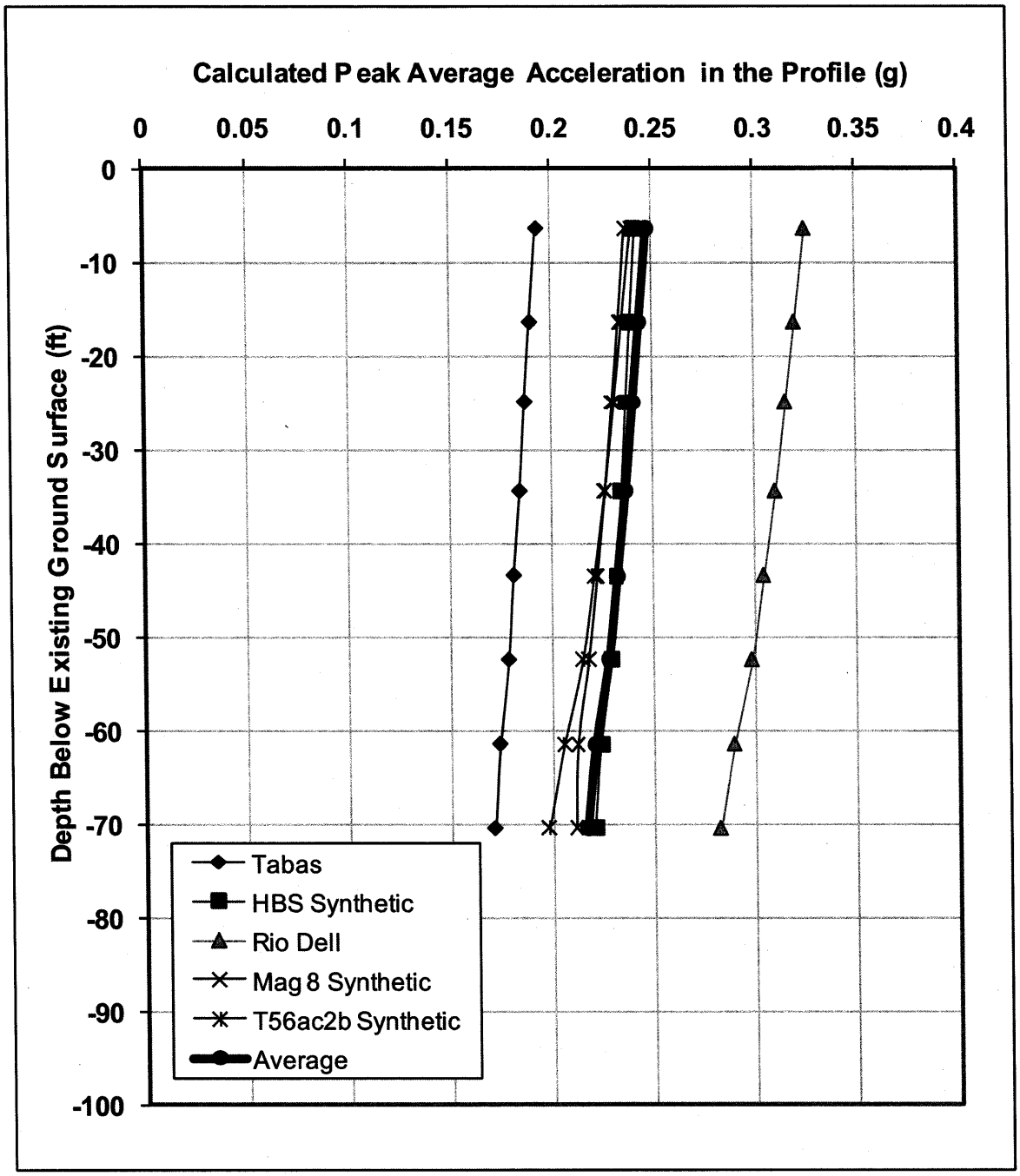
DESIGN ACCELERATION RESPONSE SPECTRUM FOR FREE FIELD
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 12

Figure 12. Design Acceleration Response Spectrum for Free Field



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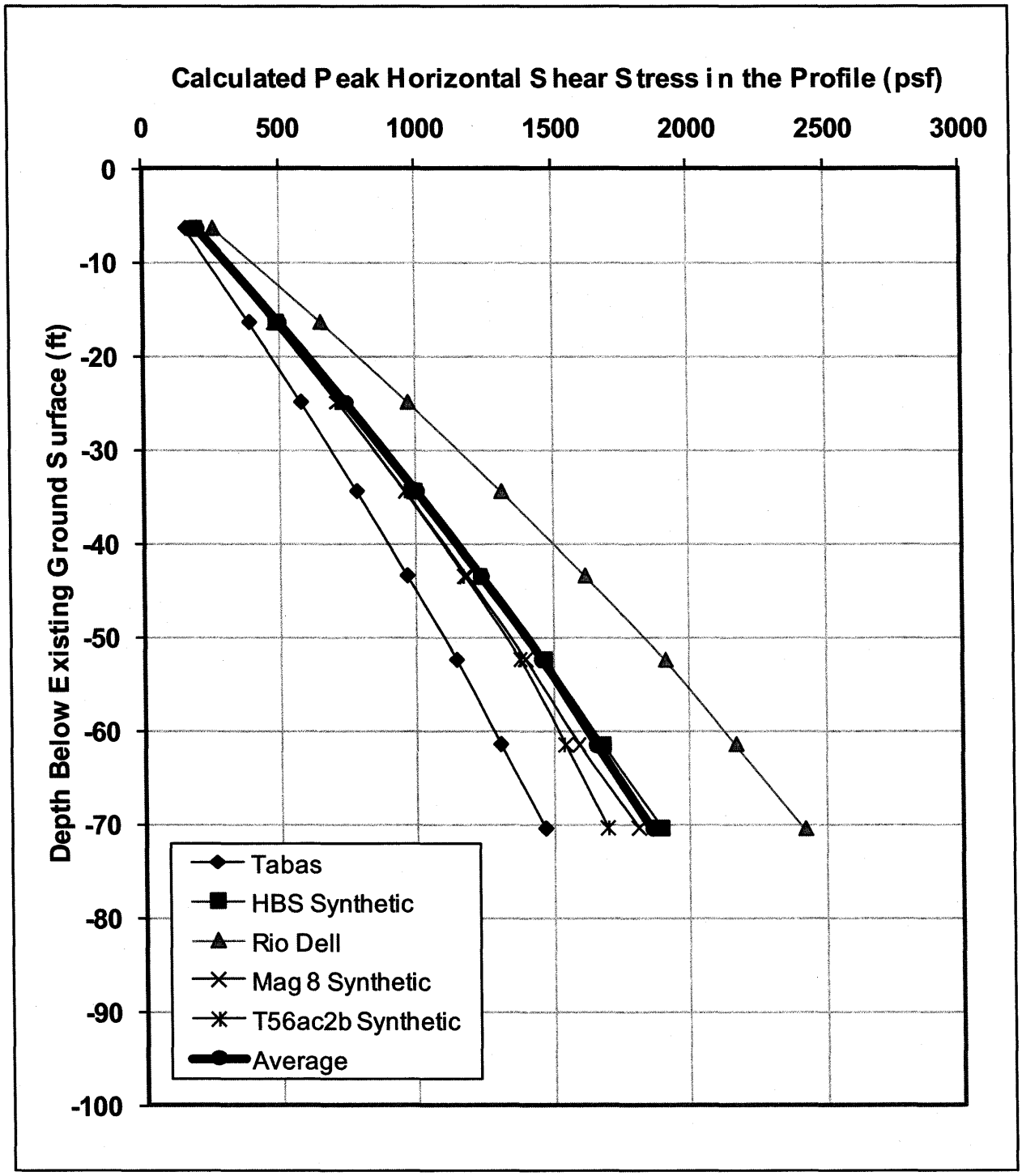
PEAK AVERAGE ACCELERATION PROFILE FOR FREE FIELD
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 13

Figure 13. Peak Average Acceleration Profile for Free Field



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PEAK SEISMIC SHEAR STRESS PROFILE FOR FREE FIELD
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 14

Figure 14. Peak Seismic Shear Stress Profile for Free Field

The summary results presented in Table 3 show that the approximately 400-ft thick alluvial deposit with and without waste fill attenuates bedrock (i.e., input, design) ground motions. This response is typical of deep (over 300 ft) soil deposits as the one analyzed herein.

Table 3. Summary of Site Response Analysis

Accelerogram	Bedrock PHGA (1)	Free-Field PGA(2)	a_{avg}(3) in Landfill Cover	a_{avg}(3) in Landfill Liner
T56ac2b Synthetic	0.36 g	0.25 g	0.30 g	0.22 g
HBS Synthetic	0.36 g	0.23 g	0.22 g	0.19 g
Rio Dell	0.36 g	0.33 g	0.32 g	0.255 g
Mag. 8^+ Synthetic	0.36 g	0.22 g	0.27 g	0.19 g
Tabas	0.36 g	0.21 g	0.26 g	0.15 g

Notes: (1) PHGA = peak horizontal acceleration in bedrock. Accelerograms were scaled to this deterministically evaluated PHGA.
(2) PGA = calculated peak ground acceleration at ground surface.
(3) a_{avg} = peak average acceleration of sliding mass.

Figure 7 presents the design acceleration response spectrum (5% viscous damping), as evaluated using SHAKE2000, design ground motions as shown in Figure 4, and representative soils profile as shown in Figure 4. This design acceleration response spectrum represents the free-field conditions at the PGDP and, therefore, may be used for structural design.

Figure 13 presents the peak average acceleration (a_{avg}) profile at the PGDP. This profile was developed for the F-F PGDP conditions and may be used for structural design of underground facilities such as wet wells.

Figure 14 presents the peak shear stress profile at the PGDP. This profile was developed for the F-F site conditions and may be used for structural design of underground structures such as wet wells.

Figure 15 presents the peak shear strain profile at the PGDP. As was done for the shear stress and the acceleration profiles, this profile was developed for the F-F site conditions. It may be used for evaluation of the impact of design earthquake on buried and near-ground ancillary facilities at the site, such as piping, drainage facilities, and paving.

6.3.2 Seismic Deformation Analysis—Landfill Liner

The lowest calculated yield acceleration of landfill mass is k_y = 0.26 g (see Section 6.1 and Figure 6). The lowest calculated average acceleration of sliding mass is a_{avg} = 0.255 g. As the highest calculated average acceleration of sliding mass is lower than its average acceleration counterpart, the design seismic event is not likely to induce permanent seismic displacements of sliding mass, and very likely not seismic displacements that approach the stability criterion of $u_{max} \leq 12$ inch.

6.3.3 Seismic Deformation Analysis—Landfill Cover

The lowest calculated yield acceleration of the landfill composite cover system (Note: VLDPE replaced with double textured HDPE geomembrane) is k_y = 0.36 g (see Section 6.2 and Figure 7). The highest calculated average acceleration of sliding mass is a_{avg} = 0.32 g. As the lowest calculated average acceleration of sliding mass is lower than its highest calculated average acceleration counterpart, the

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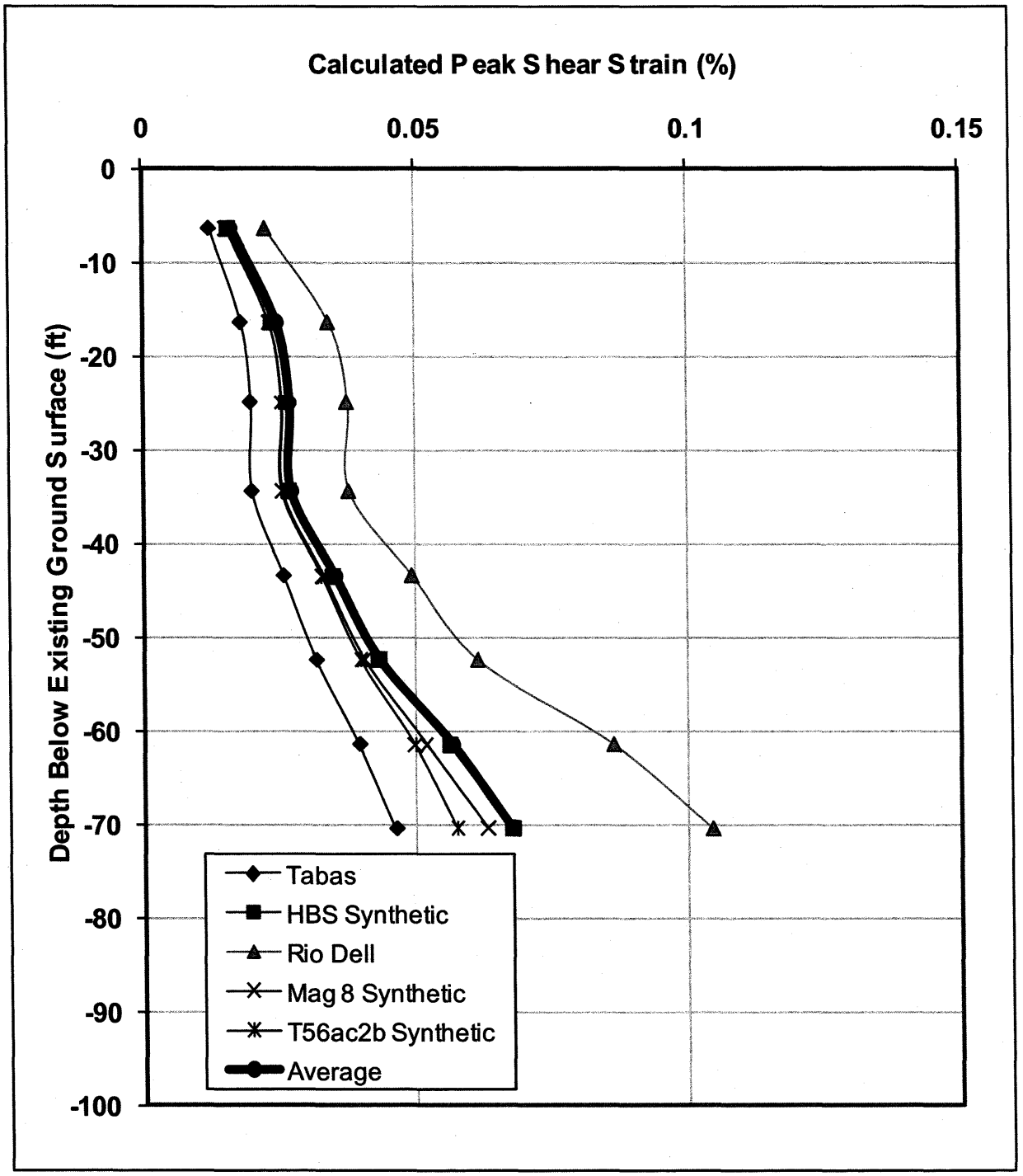

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PEAK SEISMIC SHEAR STRAIN PROFILE FOR FREE FIELD
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
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Figure 15. Peak Seismic Shear Strain Profile for Free Field

design seismic event is not likely to induce permanent seismic displacements of sliding mass, and very likely not seismic displacements that approach the stability criterion of $u_{max} \leq 36$ inch.

6.4 EVALUATION OF SOIL LIQUEFACTION POTENTIAL

Soil liquefaction is a phenomenon in which saturated cohesionless soils undergo a temporary loss of strength during severe ground shaking and acquire a degree of mobility sufficient to permit ground deformation. In extreme cases, the soil particles can become suspended in groundwater, resulting in the soil deposit becoming mobile and fluid-like. Liquefaction is generally considered to occur primarily in loose to medium dense deposits of saturated soils. Thus, three conditions are required for liquefaction to occur: (1) a cohesionless soil of loose to medium density; (2) a saturated condition; and (3) rapidly changing, high intensity shear strain induced by cyclic loading during strong ground shaking.

The soil classification, shear wave velocity and density information on the C-746-U Landfill subgrade soils indicate that these soils do not contain cohesionless soils that are in a loose to medium density. Moreover, the cohesionless soils below the water table, extending from a depth of approximately 22 ft to the depth of bedrock, are very stiff with measured shear wave velocities exceeding 1,310 ft per second and, as such, might be categorized as weak rock. The stiffness of these soils rules out the potential for liquefaction.

The calculated shear strains in the profile, as shown in Figure 15, are very low and do not exceed 0.1% (very low shear strain) at depths less than 70 ft below the existing, F-F ground surface; therefore, even in the presence of strong earthquake motions, the probability of soil liquefaction occurring at PGDP is very low.

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7. EVALUATION OF THE IMPACT OF FAULT MOVEMENT

7.1 APPROACH

Geosyntec performed an engineering study to evaluate the impact of fault movement along a postulated local fault below PGDP on the C-746-U Landfill composite landfill liner system. The evaluation was performed by the means of the Finite Element Method (FEM), as coded in SIGMA/W (GSI 2010, www.geo-slope.com).

The numerical modeling approach consisted of the following steps:

(1) Development of the FEM model;
(2) Simulation of geostatic loading conditions;
(3) Simulation of fault displacement; and
(4) Evaluation of the strains in the geomembrane due to fault displacement.

7.2 ESTIMATED MAGNITUDE OF FAULT DISPLACEMENT

7.2.1 Key Assumptions

Studies by WLA (2006) and JEBc (2010) suggest that magnitudes of local earthquakes (i.e., S3E local events) do not exceed M_w 6.0; however, to provide a very conservative basis for this type of evaluation, Geosyntec simulated a rupture induced by a M_w 7.0 event directly beneath the C-746-U Landfill. This earthquake magnitude corresponds to a S2E design event (Wabash Valley, WV, in Figure 2). Faults capable of generating such an event are not known to exist within a 32-k (20-mile) radius of PGDP.

7.2.2 Fault Displacement Estimate

The magnitude of fault displacement was estimated using empirical relationships developed by Wells and Coppersmith (1994). These relationships (i.e., design charts) are reproduced in Figure 16. The first chart shown in Figure 16 relates earthquake magnitude to maximum surface displacement. The second chart relates maximum surface displacement to average subsurface displacement.

Based on the earthquake magnitude/maximum surface displacement relationship shown in Figure 16, Geosyntec estimates that an event with M_w 7.0 may induce fault rupture (induced displacement) on the order of 11 ft. It should be noted that an event with M_w 6.0 would induce less than 1 ft of displacement, regardless of the style of faulting. The initial evaluation results indicate that induced displacement of 1 ft has no impact on the ground surface. To demonstrate the case in point, the evaluations are based on the extreme value of 11 ft.

7.3 GEOMETRY, BOUNDARY CONDITIONS, AND MODELING DETAILS

The FEM model was developed based upon the representative cross section through PGDP shown in Figure 2 and the representative soil column shown in Figure 5. This FEM model with noted boundary conditions is shown in Figure 17. Bedrock underlying alluvium was assumed to be infinitely rigid.

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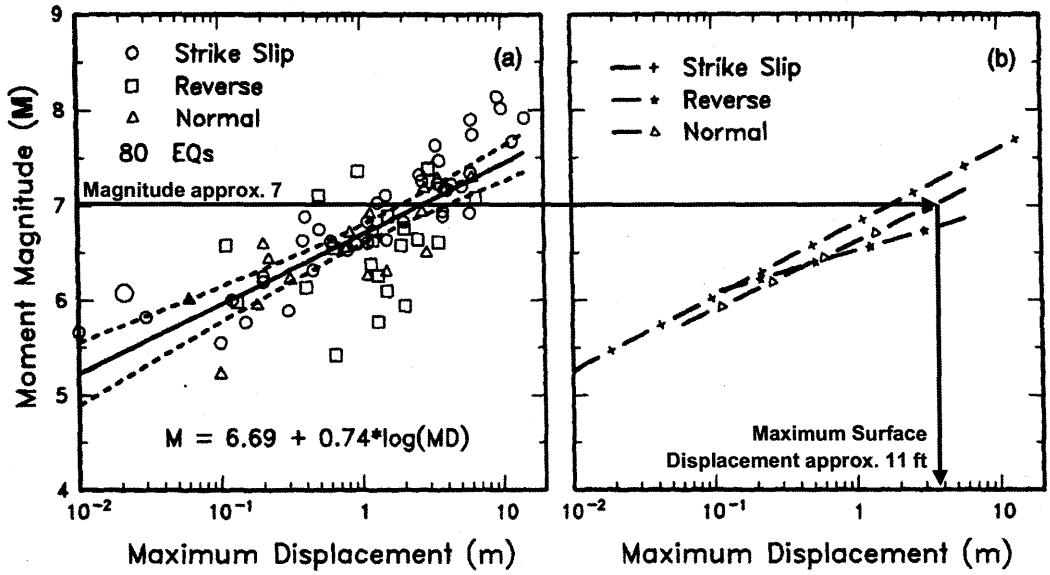

Figure 10. (a) Regression of maximum surface displacement on magnitude (M). Regression line shown for all-slip-type relationship. Short dashed line indicates 95% confidence interval. (b) Regression lines for strike-slip, reverse, and normal-slip relationships. See Table 2 for regression coefficients. Length of regression lines shows the range of data for each relationship.

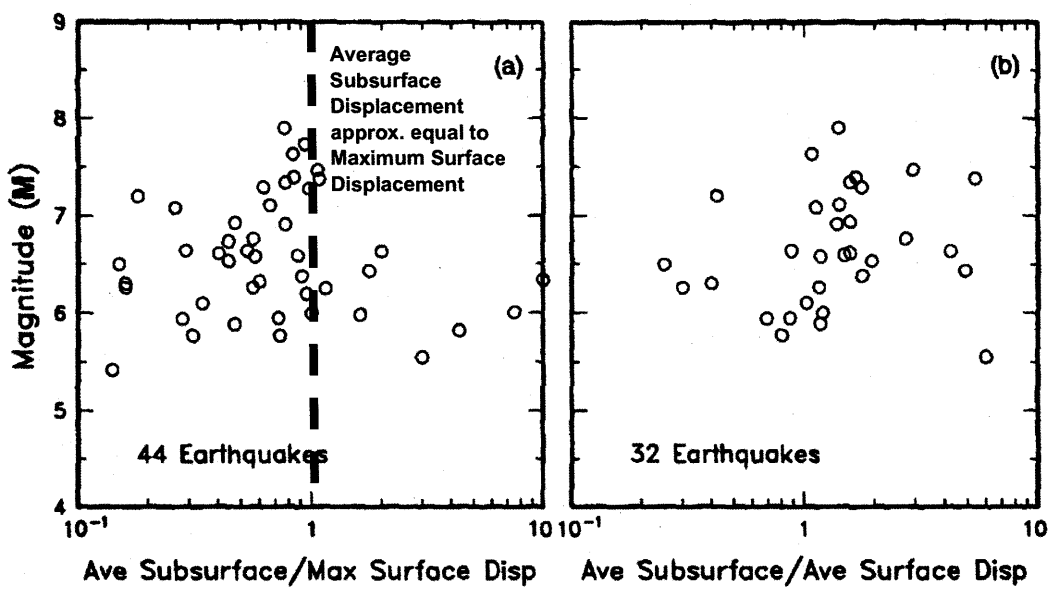

Figure 6. (a) Ratio of average subsurface to maximum surface displacement versus magnitude. (b) Ratio of average subsurface to average surface displacement versus magnitude. Average subsurface displacement is calculated from the seismic moment and the rupture area.

Source: Wells & Coppersmith 1994

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EVALUATION OF FAULT DISPLACEMENT
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

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Figure 16. Evaluation of Fault Displacement

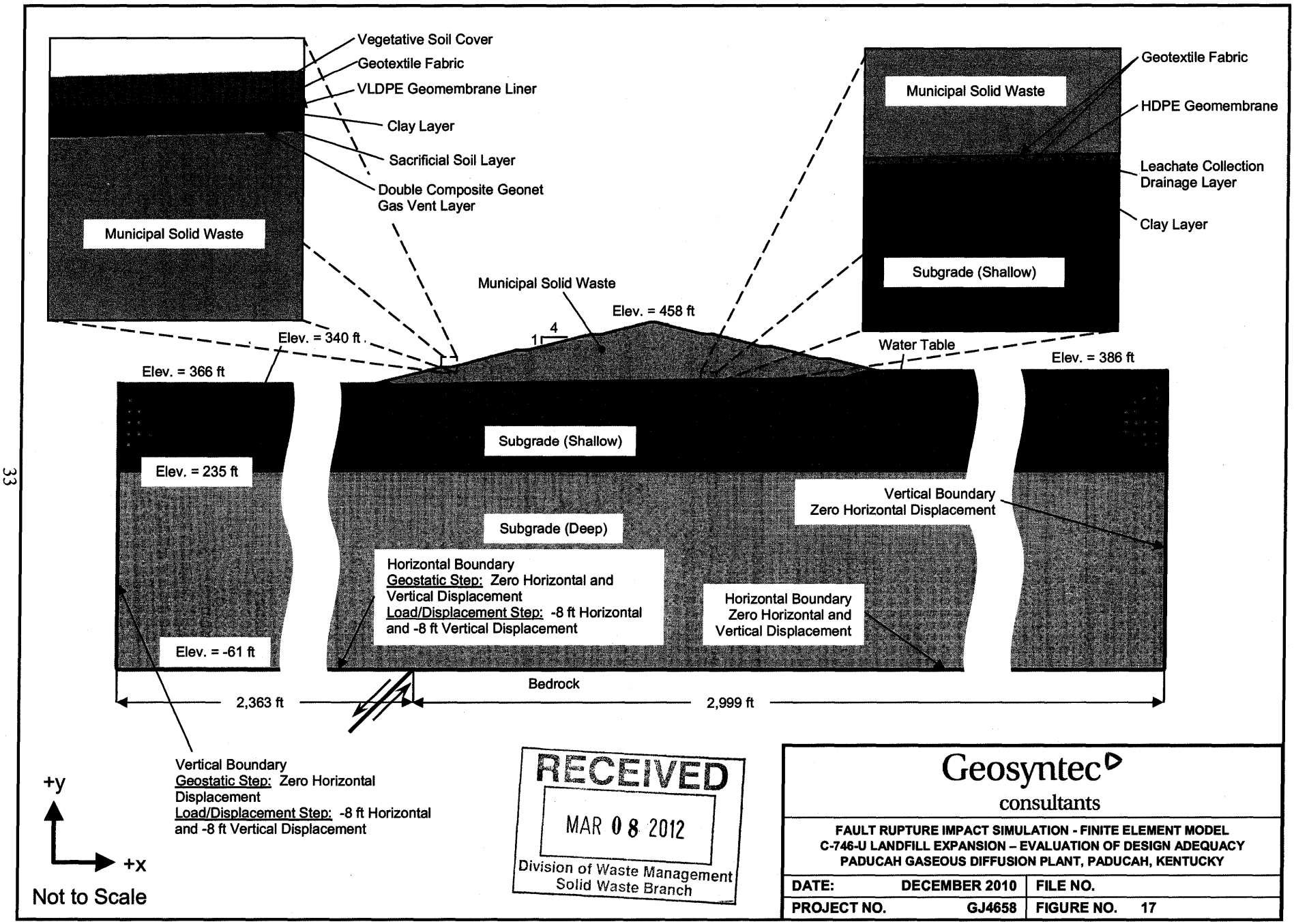

Figure 17. Fault Rupture Impact Simulation-Finite Element Model

Two modeling steps were used in the analysis: (1) a geostatic step and (2) a load/deformation step. During the geostatic step, displacement boundary conditions were applied, as shown in Figure 17, and stresses and groundwater conditions were allowed to reach equilibrium. The output values from this first step were assigned as initial conditions for the load/deformation step. During this second step, boundary conditions were changed in order to simulate fault displacement of 8 ft horizontally and 8 ft vertically (for a total displacement of approximately 11 ft) occurring at the bedrock below the landfill.

With the exception of the HDPE geomembrane, all of the materials in the model were modeled as "plane strain" continuum elements. The geomembrane was modeled using "beam" (i.e., structural) elements. These structural elements were attached to the nodes of the FEM model mesh, thus allowing for direct calculation of strain in the HDPE geomembrane of the landfill composite liner system.

7.4 MATERIAL PROPERTIES

The following materials are included in the FEM model of fault rupture propagation: (1) MSW, (2) drainage layer at the base of the landfill, (3) HDPE component of the composite landfill liner system, (4) compacted clay liner of the composite landfill liner system, (5) engineered fill, and (6) shallow and deep subgrade soils, as identified in Figure 5.

All materials except the HDPE geomembrane of landfill liner were assumed to be linear elastic/Mohr-Coulomb materials. The HDPE geomembrane was assumed to be linear elastic, with negligible shear stiffness, to act only in tension, and to be rigidly bonded to the materials directly above and below it (i.e., to drainage layer and compacted clay, respectively). A detailed list of assumed material properties is presented in Table 4.

Table 4. Estimate of Material Parameters for Fault Rupture Propagation Analysis

Material	Unit Weight (pcf)	Young's Modulus (psf)	Poisson's Ratio	Friction Angle (degrees)	Cohesion (psf)
Municipal Solid Waste (FEM)	85	$3{,}120 \times 10^3$	0.3	33	0
Drainage Layer (Gravel)	135	$9{,}360 \times 10^3$	0.3	35	0
Compacted Clay	116.5	$3{,}120 \times 10^3$	0.3	18.1	180
Engineered Fill	120	$9{,}360 \times 10^3$	0.3	28	0
Subgrade (Shallow)	107.4	$9{,}360 \times 10^3$	0.3	33	0
Subgrade (Deep)	107.4	$16{,}640 \times 10^3$	0.3	33	0
Geomembrane	Not Applicable	1	Not Applicable	Not Applicable	Not Applicable

As in site response analysis, estimated properties of the MSW are based upon generic values developed by Kavazanjian et al. (1995) (shear strength) and Matasovic and Kavazanjian (1998) (stiffness and unit weight). The shear strength parameters of MSW also are consistent with their counterparts used in static and pseudostatic (i.e., yield acceleration) evaluations.

Shear strength properties and unit weights of soil (i.e., alluvium) were estimated based on the values reported by FMSM (2001). Stiffness of soil materials was estimated based on the representative shear wave velocity profile that is included in Figure 5 and unit weights (i.e., mass density) reported by FMSM (2001).

7.5 RESULTS

The results of the finite element method modeling of fault rupture propagation are presented in Figure 18. Figure 18 shows a contour plot of induced horizontal displacement within model boundaries. This displacement was induced by an 11-ft vertical offset that simulates conservatively evaluated fault movement in a M_w 7.0 Wabash Valley S2E event.

The contour plot in Figure 18 indicates that the largest calculated displacement is at or near the location of the simulated fault movement of 11 ft. Figure 18 further shows that the induced displacement gets evenly distributed across the profile and diminishes laterally. As there are no abrupt changes in the calculated contour plot, the calculated axial strains in the HDPE geomembrane component of the C-746-U Landfill composite liner system are likely to be small. This is demonstrated by calculations in the inset of Figure 18 that show the calculated distribution of axial strain (ε) in the HDPE geomembrane. The largest calculated axial strain is relatively small (less than 1.1%), and does not exceed the stability criterion of $\varepsilon \leq 4\%$ established in this report.

The calculated peak axial strain induced by a local seismic event (i.e., S4E local events with M_w 5.5 or M_w 6.0) is negligible.

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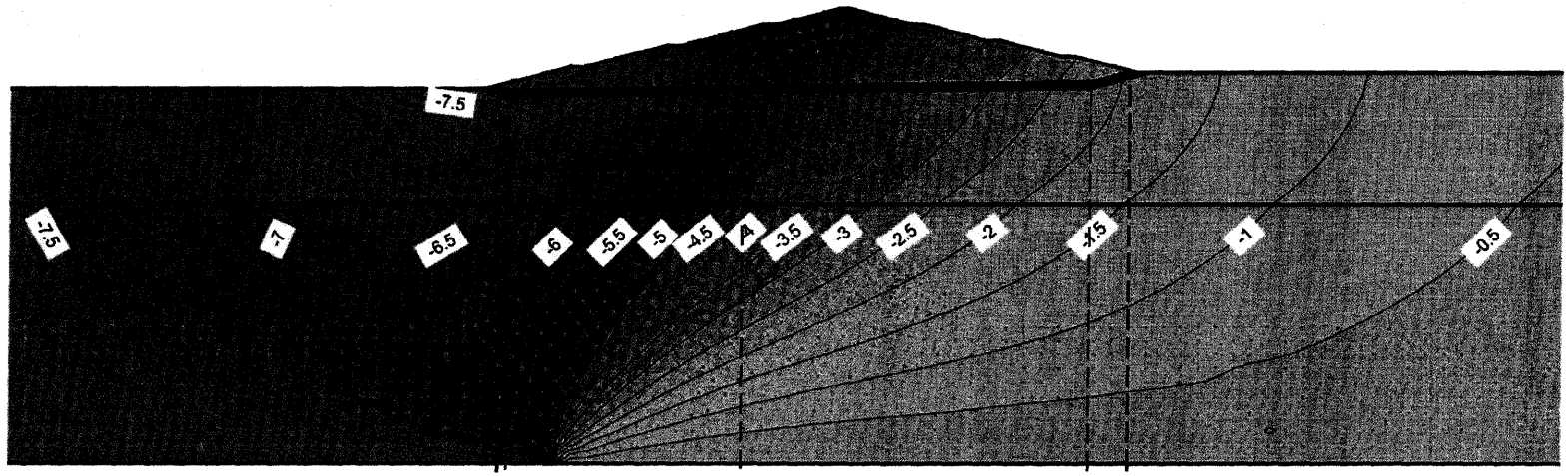
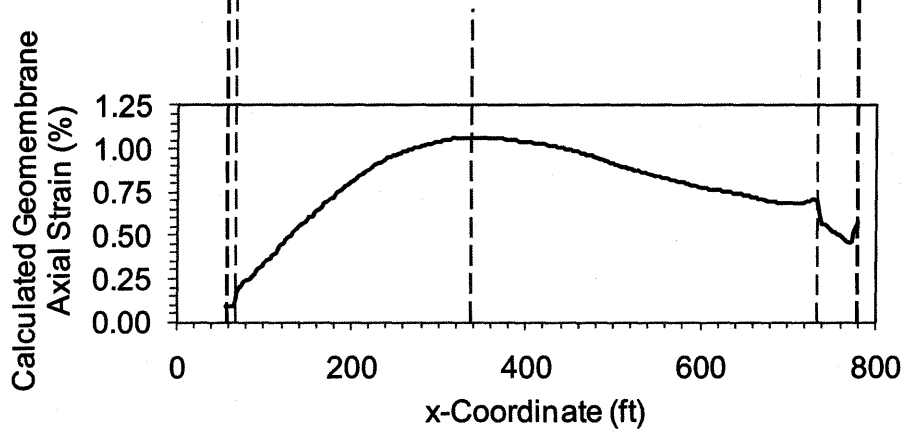


Contours of Horizontal Displacement (ft)



Plot of Calculated Axial Strain in Geomembrane

Geosyntec consultants

FAULT RUPTURE IMPACT SIMULATION RESULTS
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 18

Figure 18. Fault Rupture Simulation Results

8. ANCILLARY STRUCTURES—SEISMIC IMPACT AND DESIGN CONSIDERATIONS

8.1 LEACHATE STORAGE TANK SYSTEM—EXISTING TANK

A series of engineering drawings and drawing revisions prepared by Shaw (2009; 2010) and Tetra Tech (2008; 2009; 2010) present the C-746-U Landfill LCRS design, including the existing leachate storage design. In particular, the design and anchorage details of the existing 20,000-gal leachate tank are shown in drawing S7DC746OUA001 prepared by Tetra Tech (2008; 2009; 2010). This drawing shows that the existing leachate storage tank is anchored into a reinforced concrete slab by a 7/8-inch diameter, 10-inch long (min.) galvanized rock bolts.

The results of the Geosyntec evaluations indicate that the existing 20,000-gal leachate storage tank anchorage is designed in accordance with the standards of engineering practice and, therefore, adequate. This anchorage can resist design seismic loading as evaluated herein and presented in Figure 12 in a form of design acceleration response spectrum (5% viscous damping).

8.2 LEACHATE STORAGE TANK SYSTEM—FUTURE ADDITIONS

Figure 19 shows several leachate storage tank foundation options that may be considered for future developments at the C-746-U Landfill. We note, however, that it is ultimately incumbent upon the project structural engineer to select the appropriate foundation option for a given tank. It is also incumbent on the project structural engineer to evaluate appropriate seismic loading for design of tank anchorage based upon the leachate tank diameter to height ratio (i.e., estimated period of oscillation) and the design acceleration response spectrum shown in Figure 12 (5% viscous damping).

8.3 SURFACE WATER AND OTHER ANCILLARY FACILITIES

The results of site response analysis documented herein and presented in a form of calculated peak shear strain profile in Figure 15 indicate that seismically induced shear strains in the profile are very small. Within the top 10 ft of the profile, these shear strains are on the order 0.03%. This is a very low shear strain and, therefore, it is unlikely that buried utilities and surface improvements will be severely damaged by strong ground shaking.

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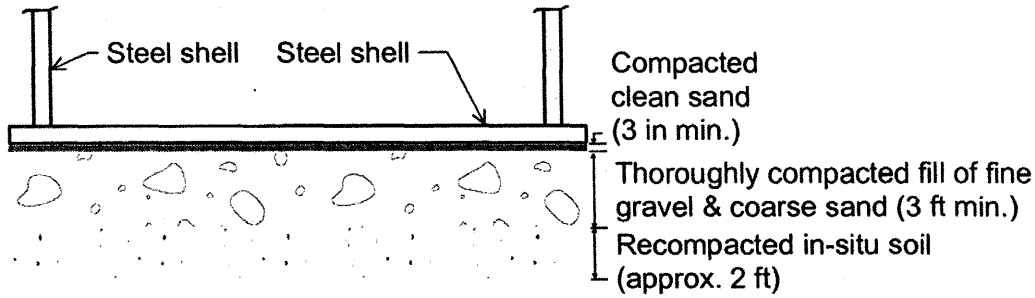
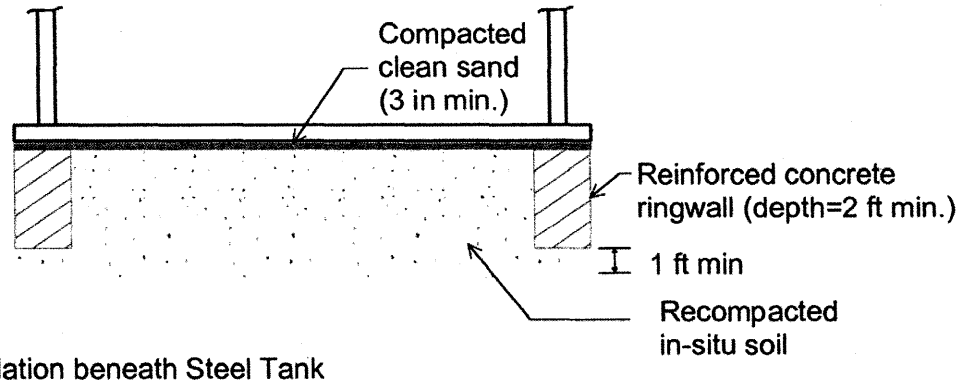
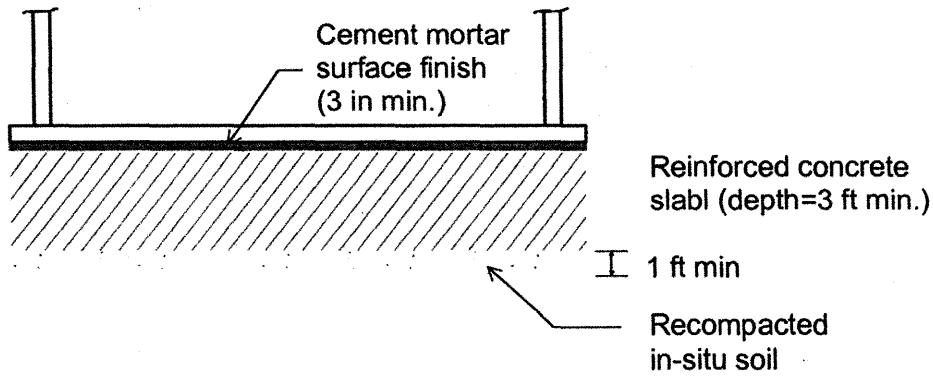
(a) Engineered Fill beneath Steel Tank



(b) Reinforced Concrete Ring beneath Steel Tank



(c) Slab Foundation beneath Steel Tank



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LEACHATE TANK FOUNDATION OPTIONS
C-746-U LANDFILL EXPANSION—EVALUATION OF DESIGN ADEQUACY
PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

DATE:	DECEMBER 2010	FILE NO.
PROJECT NO.	GJ4658	FIGURE NO. 19

Figure 19. Leachate Tank Foundation Options

9. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

9.1 SUMMARY AND CONCLUSIONS

This report documents results of the seismic evaluations that were required to demonstrate the adequacy of the design of the C-746-U Landfill at PGDP in Paducah, Kentucky. In particular, this report addresses "Requirements of Seismic Design for C-746-U Landfill," as presented in notes from the April 6, 2010, meeting with KDWM (Ashburn 2010), and NOD No. 1 issued by KDWM October 27, 2010, and concludes that future construction of C-746-U Landfill may proceed in accordance with the original 1994 Ebasco/Parsons design with recommended modifications to the final landfill composite cover system as proposed herein.

The results of seismic evaluations documented herein indicate that, with the exception of the C-746-U Landfill composite final cover system, the landfill, as presently designed, will perform in an acceptable manner during a deterministically determined design earthquake. The composite cover system, if modified in accordance with the recommendations below, will perform in acceptable manner as well. In particular, the results of seismic evaluations indicate that seismically induced deformations of the composite landfill base liner and cover systems will be small, that the potential for soil liquefaction at the C-746-U Landfill is low, and that even an extreme fault movement directly below the C-746-U Landfill will be absorbed by an approximately 400-ft thick layer of alluvium. The results of seismic evaluations further indicate that the impact of design earthquake motions and fault movement on ancillary facilities, including leachate and surface water collection systems, will be small, provided that the tanks are bolted properly into the foundations. This report also provides supplemental information for future structural design at the landfill, including F-F design acceleration response spectrum (5% viscous damping) and seismic loading for design of underground structures.

9.2 RECOMMENDATIONS

Based upon the results of the evaluations documented herein, it is recommended that future construction activities of the C-746-U Landfill proceed in accordance with the original 1994 Ebasco/Parsons design with specified modifications to the final landfill composite cover system as follows:

- The originally specified 40-mil VLDPE geomembrane of the composite landfill cover system should be replaced with a textured (both sides) 60-mil thick HDPE geomembrane.

- The assumed interface properties along the 60-mil double textured HDPE geomembrane/geotextile interface (residual friction angle = 18 degrees; apparent adhesion = 100 psf) requires confirmation during construction. This confirmation should be by interface testing of representative material samples in an accredited laboratory. If these interface residual shear strength parameters are not confirmed by testing, LATA Kentucky and Geosyntec should be notified immediately and should perform supplemental evaluations to assess if tested materials can be used in construction of the C-746-U Landfill.

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10. TERMS OF REFERENCE AND LIMITATIONS

10.1 TERMS OF REFERENCE

This report was prepared by Dr. Neven Matasovic, P.E., G.E. (California and Alaska) with assistance from Mr. Alan Witthoeft, E.I.T., and Christopher S. Conkle, P.E. (California), all of Geosyntec. In accordance with the peer review policy of the firm, this report was peer reviewed by Dr. Jay Beech, P.E. (Kentucky), also of Geosyntec.

10.2 LIMITATIONS

The conclusions and professional opinions presented in this report for the C-746-U Landfill at the PGDP in Paducah, Kentucky, were developed by Geosyntec based on limited investigation data. Our evaluations were performed using generally accepted engineering approaches and principles and the degree of care and skill ordinarily exercised under similar circumstances by reputable engineers practicing in this area.

It should be recognized that the data, conclusions, and recommendations contained in this report are partially based on information provided and work conducted by others. Geosyntec is not responsible for circumstances resulting from errors, omissions, or inaccuracies in the information and work performed by others. Should any items deviate from the assumptions presented herein, LATA Kentucky should be notified immediately so that the appropriate response can be determined in consultation with Geosyntec.

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APPENDIX A

SEISMIC HAZARD EVALUATION
(JEBc STUDY WITH DR. CRAMER'S LETTER REPORT APPENDED)

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James E. Beavers Consultants
Structural Engineering and Natural and Technological Hazards

U.S. DEPARTMENT OF ENERGY
PADUCAH GASEOUS DIFFUSION PLANT

SEISMIC HAZARD REEVALUATION FOR THE C-746-U CONTAINED LANDFILL: A DETERMINISTIC APPROACH

SUBMITTED TO
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC

STATE OF KENTUCKY
JAMES EARL BEAVERS
22084
LICENSED
PROFESSIONAL ENGINEER

BY

JAMES E. BEAVERS CONSULTANTS

November 1, 2010
(Revised September 15, 2011)

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ACRONYMS

CERI	Center for Earthquake Research and Information
DSHA	deterministic seismic hazard analysis
DOE	U.S. Department of Energy
g	gravity
JEBc	James E. Beavers Consultants
KDWM	Kentucky Division of Waste Management
k_s	seismic coefficient
MCE	maximum credible earthquake
M_s	surface wave magnitude
M_w	moment magnitude
NMSZ	New Madrid Seismic Zone
NRC	U.S. Nuclear Regulatory Commission
PGA	peak ground acceleration in hypothetical bedrock outcrop at the site
PGDP	Paducah Gaseous Diffusion Plant
PSHA	probabilistic seismic hazard analysis
REI	Risk Engineering, Inc.
S1E	Scenario 1 Event
S2E	Scenario 2 Event
S3E	Scenario 3 Event
SEI	Structural Engineering Institute
S_a	spectral acceleration ordinate
USEC	United States Enrichment Corporation
USGS	U.S. Geological Survey
yrp	year return period

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EXECUTIVE SUMMARY

This evaluation is presented to address Special Condition ACTV0006(5.) of the Solid Waste Landfill Permit for the C-746-U Contained Landfill (landfill) at Paducah Gaseous Diffusion Plant. The special condition requires approval by the Kentucky Division of Waste Management (KDWM) of a seismic hazard reevaluation prior to construction of phases 6 through 23 of the landfill. A meeting was held on April 6, 2010, between U.S. Department of Energy and KDWM in Frankfort, KY, to establish requirements for this seismic hazard reevaluation. The parties reached agreement at that meeting to conduct the site-specific seismic hazard assessment using a deterministic methodology. The design earthquake level is to be the maximum credible earthquake, with ground motion parameters evaluated at a median level.

Using the agreed methodology, three earthquake scenarios were established. The scenarios established are based on known faulting in the area and on postulated faulting that may exist in the relative vicinity of the site. The bedrock ground motions (i.e., accelerograms) evaluated using the results of this study will be used to assess the following: (1) the response of local alluvium and landfill mass to strong ground shaking; (2) the impact of fault rupture propagation (if any) on the landfill containment system; and (3) to evaluate the adequacy of the current design with regard to the expansion of phases 6 through 23 of the landfill.

The three seismic scenario events are referred to as Scenario 1 Event (S1E), Scenario 2 Event (S2E), and Scenario 3 Event (S3E). S1E represents a moment magnitude (M_w) 7.6 event on the New Madrid Fault, just west of the confluence of the Mississippi and Ohio Rivers. S2E represents an M_w 7 event on the Wabash Valley Fault at the confluence of the Wabash and Ohio Rivers. S3E represents an M_w 5.5 event in the vicinity of the site (22 km from the geometric center of the site).

The results of the deterministic seismic hazard study documented herein indicate that S1E induces the highest peak horizontal ground acceleration (PGA) in a hypothetic bedrock outcrop at the geometric center of the site (bedrock PGA = 0.36 g). The corresponding spectral acceleration ordinates are 0.54 g for 0.2-second period and 0.19 g for 1.0-second period.

To compensate for uncertainty associated with postulated existence of local faulting, recommendation is made that a local M_w 5.5 event at a distance of 2.5 km to the site be considered as a fault rupture hazard for the site.

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1. INTRODUCTION

A meeting was held on April 6, 2010, between the U.S. Department of Energy (DOE) and Kentucky Division of Waste Management (KDWM) to establish KDWM expectations related to seismic design of the upcoming C-746-U Contained Landfill (site) expansion at Paducah Gaseous Diffusion Plant (PGDP). A special condition in the landfill permit requires approval by KDWM of a seismic hazard reevaluation prior to construction of phases 6 through 23 of the landfill. As stated at the meeting, "KDWM expects the C-746-U Contained Landfill permittee to determine the design maximum credible earthquake from a scenario-based analysis that is consistent with geological evidence for the region." KDWM then cited specific examples [e.g., a projected magnitude 7.6 earthquake to the west of PGDP near Wickliffe, Kentucky, based on extent of the known New Madrid Seismic Zone (NMSZ) and documented maximum historical earthquakes at New Madrid and Charleston, Missouri]. KDWM also stated, "The selection of the maximum credible earthquake should not be constrained by the commonly used 2,500-year return period" (yrp) and "with documentation of the maximum credible earthquake, the permittee is expected to use a deterministic approach to assess the spectral response of the seismic event at the land surface and, more importantly, within the mass of the landfill waste cell" [1].

James E. Beavers Consultants (JEBc) was a participant at the April 6, 2010, meeting. While the principal of JEBc, James E. Beavers, is extremely familiar with the PGDP, having conducted seismic analyses on some of the facilities as far back as the early 1970s (e.g., an evaluation report on the C-746-U Contained Landfill in 2001) [2], JEBc has no seismological staff. As a result, JEBc contacted Dr. Arch Johnston, founding Director of the Center for Earthquake Research and Information (CERI) at the University of Memphis, Memphis, Tennessee. Dr. Johnson suggested that JEBc use the services of Dr. Chris Harold Cramer, a well-known seismologist at CERI, to assist in the seismic source evaluation and evaluation of seismic hazard parameters at the site. Dr. Cramer's vita is provided in Appendix A. Dr. Neven Matasovic, P.E., G.E. of Geosyntec Consultants also was consulted as a part of this study [3].

2. BACKGROUND

Numerous studies of the seismic hazard at PGDP have been conducted, dating back to the early 1970s. Beavers and several coauthors have addressed the issues between the various hazard studies up to the early 1990s [4 and 5]. As a result, there are several seismic hazard studies and seismic hazard analyses for PGDP. The subject of this report is to conduct a deterministic seismic hazard analysis (DSHA) to reevaluate the seismic hazard at the PGDP [1].

The seismic hazard at PGDP primarily is related to its proximity to the NMSZ area, as shown in Figure 1.[1] In addition to the NMSZ, the Wabash Valley Seismic Zone and local fault zones also should be considered. As a result, any new or existing facility must

[1] The NMSZ runs south out of the figure into the state of Tennessee.

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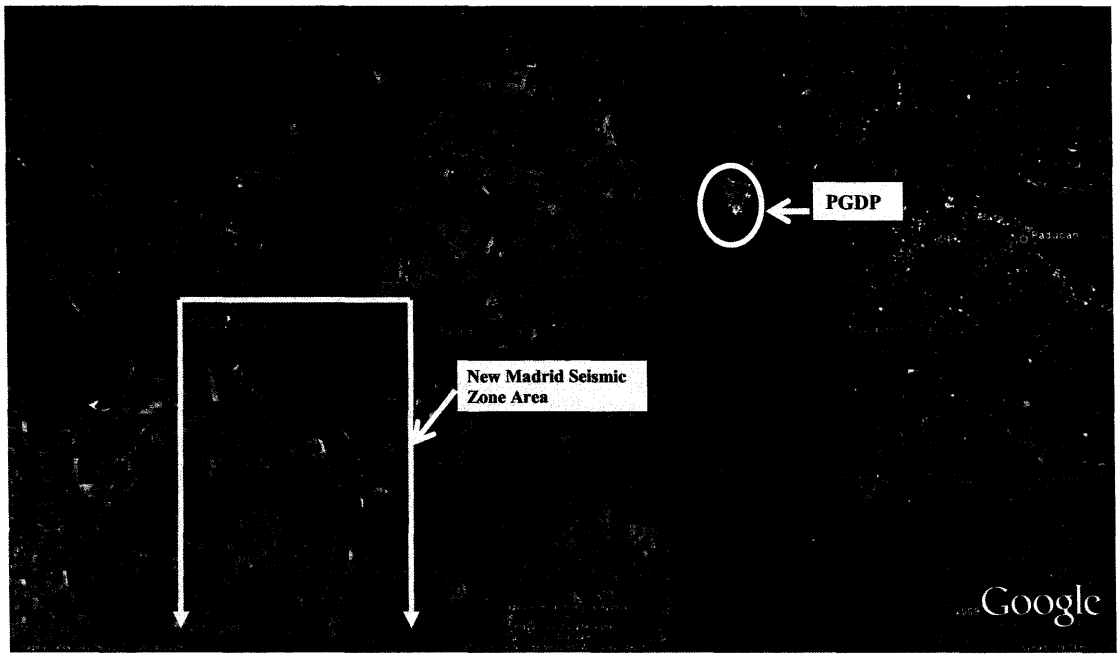

Figure 1. The Geographical Relationship between the NMSZ and the PGDP

consider the controlling seismic hazard at PGDP when evaluating and designing facilities.

During the life of the C-746-U Contained Landfill, numerous activities have occurred concerning the seismic capacity of the landfill [2 and 6]. The (probabilistically evaluated) bedrock peak horizontal ground acceleration (PGA) used in the original design of the landfill is 0.40 g. The containment structures, including liners, leachate collection system, and surface water control system, are designed to resist 0.40 g (the effect of local soil conditions and landfill itself were neglected in the original design). The PGA used in the seismic analysis corresponds to a bedrock acceleration, which has a 90 percent probability of not being exceeded in 250 years. This is equivalent to a 2,500-yrp earthquake. This value was obtained from a probabilistic seismic hazard analysis (PSHA) conducted in 1993 by Risk Engineering, Inc. (REI) [7]. Table 1 shows a chronology of events related to the history of the design and construction of the landfill in the late-1990s to the early-2000s time frame. Referencing Table 1, KDWM added the following permit condition for the C-746-U Contained Landfill on February 1, 2001:

> The permittee shall prepare and submit to the Division of Waste Management a complete reevaluation of the seismic hazards to the landfill liner, cap, leachate collection, and surface water collection systems by August 31, 2001. This study shall be coordinated with the Solid Waste Branch geological and engineering staff. The seismic reevaluation study shall completely reevaluate the ground motion potential, the potential for structural offset along local faults, and all other seismic risks associated with the New Madrid Seismic Zone, the Wabash Valley Seismic Zone, and local fault zones.

Table 1. Chronology of Seismic Evaluation and Study Events

	Activity	Comments	Date
A	Site-specific seismic hazard study conducted by REI, bedrock PGA of 0.40 g.	REI reported rock only ground motions in this study, 0.40 g at 2,500 yrp [7 (Fig 5.18)].	1993
B	Seismic Design of the C-746-U Contained Landfill was performed using bedrock PGA of 0.40 g (Solid Waste Landfill Technical Application) applied as seismic coefficient (k_s) equal to 0.2 g (k_s = bedrock PGA/2).	After applicant submitted the three-phase application process, regulators approved operation of the landfill in November 1996 via Permit No. 073-00045.	1994 through 1995
C	REI updated 1993 study and calculated PGA of 0.51 g.	Report revision performed for USEC and driven by NRC.	1999
D	White Paper by Dr. Beavers evaluated existing landfill design.	Determined that existing landfill design was adequate for PGA of 0.51 g.	2/20/2001
E	C-746-U Contained Landfill Permit reissued with new seismic requirement identified in permit condition.	Permit appeal filed by DOE; seismic technical submittals proposed following "Seismic Summit" conducted with DOE, KDWM, and USGS in Frankfort, KY.	New permit condition 2/1/2001 Seismic Summit held 5/29/2001
F	KDWM requested newly constructed cells to be designed to a PGA of 0.8 g.	DOE appeals request and KDWM agrees to consider a new study to determine the PGA value.	KDWM request 8/10/2001; accepts new study concept 10/31/2001
G	DOE conducted new evaluation study to fulfill the ground motion assessment requirements of permit condition.	New study completed and submitted to KDWM.	3/7/2002
H	DOE conducted reevaluation of the seismic capacity of the landfill and associated support facilities to fulfill the remaining items of permit condition.	KDWM response that the submitted information does not meet requirements of landfill permit.	9/27/2002
I	DOE submitted Holocene Fault Study for landfill to KDWM.	Notice of Deficiency received from KDWM.	10/27/2010

The issues related to this condition were addressed [2 and 6], and it was concluded that no evidence of Holocene faulting existed on or near the footprint of the C-746-U Landfill. Later, these three items were decided: (1) the planned fault study at C-746-U Landfill would not be implemented at that time, (2) a technical justification would be prepared and submitted to KDWM, and (3) the previously submitted ground motion study for the C-746-U Landfill [6] satisfied the permit condition of February 1, 2002, landfill permit. KDWM and DOE did not reach agreement that this permit condition was resolved.

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3. DETERMINISTIC SEISMIC HAZARD ASSESSMENT

3.1 Background

As stated previously, KDWM requires the design seismic event to be determined deterministically. The design deterministic earthquake level should be the maximum credible earthquake (MCE) level. The median ground motions should be develop.

The site-specific DSHA should consider local faults and fault zones [near-field and intermediate-field events; 8 and 9], but also a far-field event that corresponds to a major event in the NMSZ. The major event on the NMSZ should correspond, in the terms of earthquake magnitude, to the largest of the 1811–1812 series of events.

3.2 Introduction

The DSHA parameters documented herein were evaluated in the following sequence:

(1) Assign an MCE moment magnitude (M_w) 7.6 to NMSZ, measure distance from the confluence of the Mississippi and Ohio Rivers (shortest distance from the fault zone to the site; 36.5 km), and attenuate the ground motions to the site;

(2) Assign an M_w 7.0 earthquake in the Wabash Valley Seismic Zone northeast of the PGDP (site-to-source distance of 100 km) and attenuate its ground motions to the site;

(3) Select a local earthquake of M_w 5.5 at the distance of 22 km from the PGDP and attenuate those ground motions to the PGDP; and

(4) Compare the seismic hazard parameters (i.e., bedrock PGA) from the near-field [Scenario 1 Event (S1E)], intermediate-field [Scenario 2 Event (S2E)], and far-field [Scenario 3 Event (S3E)] events to establish the design seismic event for the C-746-U Landfill.

3.3 Previous Studies

As mentioned earlier, many seismic studies at PGDP have been conducted over the years. In 1993, REI conducted a PSHA at PGDP [7]. Later, the United States Enrichment Corporation (USEC) contracted REI to update the 1993 study. That revised study, requested by the U.S. Nuclear Regulatory (NRC), was completed in 1999 [11] and resulted in a 2,500 yrp PGA value at bedrock of 0.8 g as compared to the 1993 value of 0.4 g in bedrock. This higher PGA value was primarily a result of the consideration of a recurrence of an 1811–1812 New Madrid type earthquake occurring closer to the PGDP.

Based on preliminary estimates by JEBc of the DSHA approach [12], it appeared that the new DSHA ground motion numbers would result in lower values at bedrock, less than half of the 1999 REI study and nearer the results of the 1993 study [7]. If that is the case, these lower ground motion values in hard rock could result in amplification of soil surface ground motions to higher values than the results of REI [11] at the top of soil.

Earthquake investigations over the years have shown that low intensity rock motions (bedrock PGA less than approximately 0.4 g), local soft soil deposits may amplify the rock motions. Conversely, if the rock motions are above approximately 0.4 g, local soft soil deposits may deamplify the rock motions. This potential deamplification is well documented in numerous publications (e.g., references 13, 14, and 15).

3.4 Scenario 1 Event

3.4.1 Description

Scenario S1E represents an M_w 7.6 event in the NMSZ (this M_w approximately corresponds to surface wave magnitude M_s of 7.8). M_w 7.6 corresponds to the largest of the three infamous earthquake events that occurred in 1811 and 1812. At one time, it was rated as the second highest of the three New Madrid earthquakes having a M_s of 8.4 [16]. In 1999, however, Van Arsdale and Johnston [17] estimated these three events as having M_s 8.1 for the December 16, 1811, event; M_s 7.8 for the January 23, 1812, event; and M_s 8.0 for the February 7, 1812, event. More recently, Bakun and Hopper [18] estimated the M_s of these events as 7.6 for the December 16, 1811, event; M_s 7.5 for the January 23, 1812, event; and M_s 7.8 for the February 7, 1812, event. The later M_s estimate of 7.8 approximately corresponds to M_w 7.6.

The United States Geological Survey (USGS) Web site lists the following M_s estimates for the New Madrid earthquake sequence: $M_s \approx 7.7$ for the event occurring in northeast Arkansas on December 16, 1811; $M_s \approx 7.5$, for the event occurring in Missouri on January 23, 1812; and $M_s \approx 7.7$ for the event occurring on February 7, 1812, along the Reelfoot fault in Missouri and Tennessee.

There have been other large earthquake events in the NMSZ, such as the 1895 Charleston, Missouri, earthquake of M_w 6.7; however, this epicentral event was of a smaller magnitude than the 1811–1812 events, resulting in S1E being the controlling event.

Based on the above discussion, cited references, and a more recent understanding of the historical events, the authors have estimated that placing an M_w 7.6 earthquake just west of the confluence of the Mississippi and Ohio Rivers represents a realistic location and magnitude for S1E and is representative of an MCE for the NMSZ. The corresponding fault location is shown in Figure 2 and is based primarily on research by the USGS [19]. The closest approach of this event from the NMSZ to the site is approximately 36.5 km (Appendix B), which puts it on the northern end of the postulated fault line shown in Figure 2.

3.4.2 S1E Ground Motions

For S1E, the ground motions were attenuated to the PGDP site using the attenuation equations discussed in Appendix B. The attenuation equations used in this assessment are those used by USGS in its national mapping process for the International Building Code [20] and the Structural Engineers Institute (SEI) Standard [21]. These attenuation equations are considered to represent state-of-the-art methodology.

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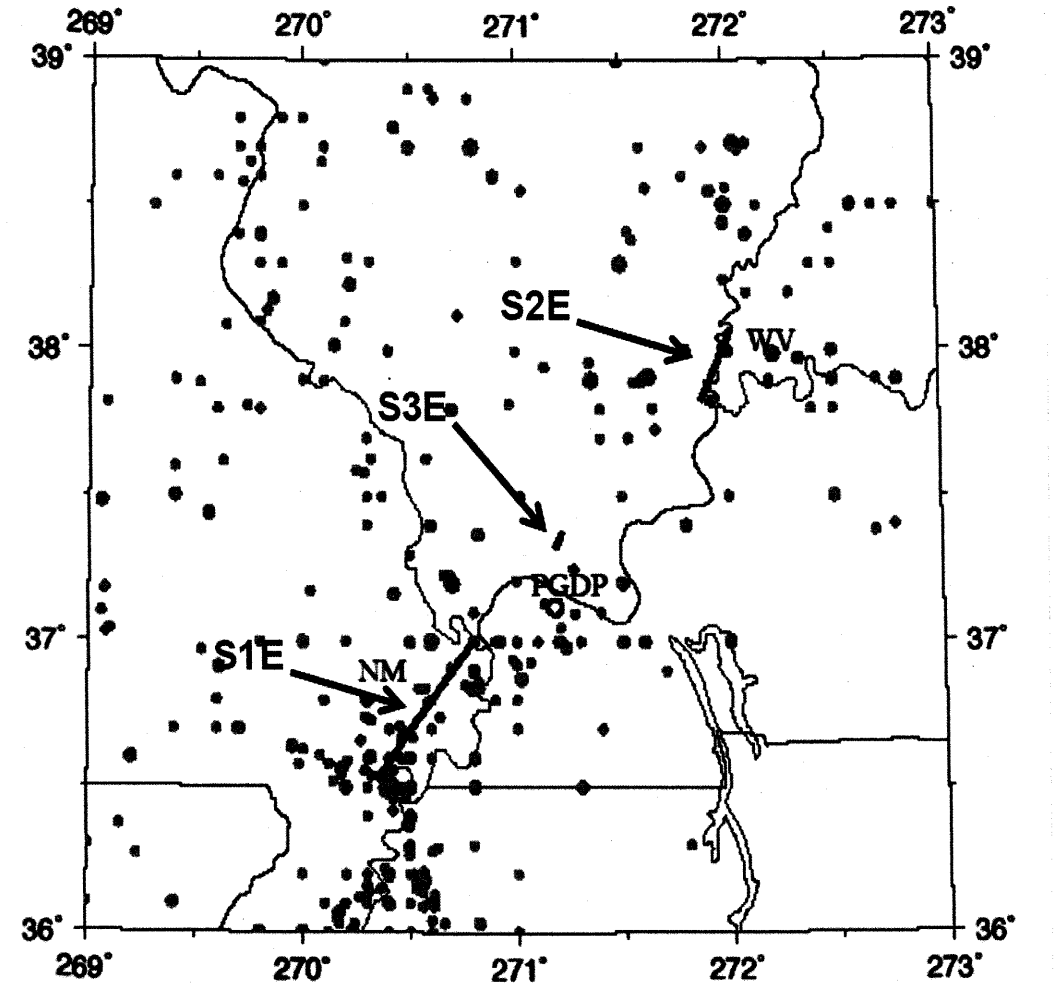

Figure 2. Seismic Scenario Sources in Relation to PGDP
(Red = Ruptures; Green = Earthquakes with $M_w \geq 3$)

Using the USGS attenuation equations, the ground motion values (PGA and spectral acceleration ordinates) were computed for S1E, as discussed in Appendix B. The median PGA value for S1E was computed for the hard rock foundation at PGDP to be 0.36 g. The corresponding spectral values are 0.54 g for 0.2-second period and 0.19 g for 1.0-second period.

The use of median values of seismic hazard parameters is consistent with DOE criteria [22] and is considered appropriate based on the hazard level of the landfill.

3.5 Scenario 2 Event

3.5.1 Description

In the case of S2E, not as much is known about the Wabash Valley Seismic Zone with respect to the occurrence of earthquakes or records of their past magnitudes. The Van Arsdale and Johnston study [17] addressed the potential seismic hazard at PGDP from the Wabash Valley Seismic Zone. This study considered paleoliquefaction constraints on magnitude, location, and time of occurrence of these events. Results were sufficiently compelling to be used in the 1999 REI PSHA [11] seismic source zoning. Thus, the authors included the Wabash Valley as the basis for the S2E earthquake.

Based on Van Arsdale and Johnston's work [17] and the corresponding referenced study [23], evidence was presented that two paleoearthquakes had occurred within the mapped extent of the Wabash Valley Fault System. These two earthquakes were estimated as having an M_s 7.6 and M_s 7.2 (magnitude scale not inferred). More recently, Olson et al. [24] assign an M_s of 7.1–7.3 and 6.7 for these two events. Others have cited M_w in the area ranging from M_w 6 to M_w 7 [25].

As result of the above studies and the locations of the paleoearthquakes, the authors chose an M_w 7 earthquake on the Illinois-Indiana border at the southern extent of the Wabash Valley near the city of Evansville, Indiana, or as stated in Appendix B and shown in Figure 2, at the confluence of the Wabash and Ohio Rivers. This location would give highest S2E ground motions at the PGDP site since this is the closest proximity of the Wabash Valley Seismic Zone to the PGDP and, thus, represents a conservative approach for S2E earthquake. A larger magnitude could have been used (e.g., an M_w 7.6), but the authors chose the lower magnitude and placed the epicenteral location at/near the closest location to the PGDP. The authors believe this is an appropriate magnitude and distance location representative of an earthquake from the Wabash Valley Seismic Zone. Choosing the largest earthquake and closest location to the PGDP would be overly conservative.

3.5.2 S2E Ground Motions

As was done for the S1E earthquake event, the ground motions were attenuated to PGDP, as discussed in Appendix B. As presented in Table B2 of Appendix B, the median bedrock PGA value for the S2E earthquake is 0.07 g. The corresponding spectral values are 0.12 g for 0.2-second period and 0.04 g for 1.0-second period. This bedrock PGA value is significantly lower than its S1E counterpart; therefore, S1E controls.

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3.6 Scenario 3 Event

3.6.1 Description

The S3E represents the impact of a local event occurring near the PGDP. A local event usually is considered a smaller earthquake, one that is considerably smaller than an M_w 6.5 and that still could do damage. Usually, a smaller earthquake is picked as an M_w 5.5 because M_w 5.0 is where damage to structures begins, and the M_w 5.5 is where significant damage begins to occur. In addition, the local event occurs more often than

the larger events at sites of interest. Smaller events often have higher frequencies of ground motion than larger events. The location for a close-in event usually is assumed around 20 km, which is a judgment call; in this case the authors use 22 km. There are no criteria developed for the establishment of a close-in event.

3.6.2 S3E Ground Motions

As was done for the S1E and S2E earthquake events, the ground motions for the S3E were attenuated to PGDP from the assumed distance of 22 km, resulting in bedrock ground motions computed in Appendix B. From Table B2 of Appendix B, the median bedrock PGA = 0.10 g. The corresponding acceleration spectral values are 0.14 g for 0.2-second period and 0.02 g for 1.0-second period. Therefore, S1E earthquake event still controls.

Review of historic seismicity in the vicinity of the site (see Figure 2) indicates that local $M_w \geq 3$ events have occurred at a relatively close approach to the site. Therefore, it is recommended that, for the fault rupture impact study, a postulated M_w 5.5 event be placed at a distance of 2.5 km from the site (the distance of 2.5 km approximately corresponds to the seismogenic distance for M_w 5.5 events).

4. DESIGN GROUND MOTION PARAMETERS FOR THE C-746-U CONTAINED LANDFILL DESIGN EVALUATION

In accordance with DOE Standard 1020-2002 [22], the ground motion parameter values evaluated herein correspond to MCE median values. For landfill design purposes, the controlling parameters are bedrock PGA and associated spectral acceleration ordinates (S_a). The highest evaluated bedrock PGA corresponds to the S1E scenario (M_w 7.6 on the closest approach of the New Madrid Fault to the site).

The design ground motion parameters evaluated for S1E are listed in Table 2. These parameters may be used to assess the adequacy of the existing design for expansion of the C-746-U Contained Landfill. For evaluation of fault rupture hazard, considerations also should be given to a local M_w 5.5 event at a distance of 2.5 km from the site.

Table 2. Design Ground Motion Parameters (S1E)*

Bedrock PGA	Bedrock S_a @ 0.2 Sec	Bedrock S_a @ 1.0 Sec
0.36g	0.54g	0.19g

*See Appendix B for results from all scenarios.

5. CONCLUSIONS AND RECOMMENDATIONS

This study documents the results of DSHA performed at MCE level, with seismic hazard parameters evaluated as median values. This DSHA was conducted to address Special Condition ACTV0006(5.) of the Solid Waste Landfill Permit for the C-746-U Contained

Landfill at PGDP, which requires approval by KDWM of a seismic hazard reevaluation prior to construction of phases 6 through 23 of the landfill.

The results of this DSHA indicate that design median bedrock PGA equals 0.36 g; the corresponding spectral acceleration ordinates are as follows: 0.54 g at 0.2 seconds and 0.19 g at 1.0 second. These ground motion parameters correspond to S1E (M_w 7.6 on the closest approach of the New Madrid Fault).

Review of historic seismicity in the vicinity of the site indicates that local events have occurred at a relatively close approach to the site. Therefore, it is recommended that, for the fault rupture study, a postulated M_w 5.5 event be placed at a distance of 2.5 km from the site.

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APPENDIX A

VITA OF CHRIS CRAMER

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Chris Cramer Vita

A.1 Education:

University of Puget Sound	B.S.	Physics/Math	1969
Stanford University	M.S.	Geophysics	1973
Stanford University	Ph.D.	Geophysics	1976

A.2 Teaching:
Probabilities and Seismic Hazard Analysis, Department of Earth Sciences, University of Memphis

A.3 Research Goals:
As a staff member of the Center for Earthquake Information and Research (CERI) my goal is to contribute to the improvement of our understanding of seismic hazard and loss in the central U.S., the nation, and the world, and to credibly communicate this understanding to earth science professionals, engineers, emergency response planners, private industry, and the general public.

A.4 Research Overview:

- Probabilistic and Scenario Seismic Hazard and Risk Analysis
- Earthquake Strong Ground Motion and Site Effects
- Uncertainty in Hazard and Loss Estimates
- Seismology, including Downhole Seismology
- Tectonics

A.5 Current and Recent Research Projects

- Strong- and Weak-Motion Comparisons at Turkey Flat Site Effects Array, Parkfield, CA
- Ground Motion Intensity Modeling for the 1811-1812 New Madrid Earthquakes
- Memphis, TN, St. Louis, MO, and Charleston, SC, Urban Seismic Hazard Mapping
- Effect of the Upper Mississippi Embayment on Seismic Hazard Modeling
- CEUS ground motion database for soil and rock (various soil conditions)

A.6 Graduate Students

- Allison Shumway, Masters Student – Focal Mechanisms for the Northeast New Madrid Seismic Zone
- Jerry Kutliroff, Masters and Ph.D. Student – Seismic Hazard of the Israel, Middle East
- Donny Dangkua, Ph.D. Student – Eastern North America intensity vs ground motion

A.7 Recent Publications

Cramer, C. H., J. S. Gomberg, E. S. Schweig, B.A. Waldron, and K. Tucker, 2006. First USGS urban seismic hazard maps predict the effects of soils, Seism. Res. Lett. 77, 23-29.

Cramer, C. H., 2006. An assessment of the impact of the EPRI (2003) ground motion prediction models on the USGS national seismic hazard maps, Bull. Seism. Soc. Am. 96, 1159-1169.

Cramer, C. H., 2006. Quantifying the uncertainty in site amplification modeling and its effects on site-specific seismic-hazard estimation in the Mississippi embayment and adjacent areas, Bull. Seism. Soc. Am. 96, 2008-2020.

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APPENDIX B

SCENARIO EVALUATION OF SEISMIC HAZARD AT PADUCAH GASEOUS DIFFUSION PLANT

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B.1 SUMMARY

Scenario ground motions have been calculated for the Paducah Gaseous Diffusion Plant (PGDP) site for three earthquake scenarios: a moment magnitude (M_w) 7.6 on the New Madrid North Fault [northeast (NE) segment], an M_w 7.0 in the southern Wabash Valley near the confluence of the Wabash River with the Ohio River, and a local M_w 5.5 and M_w 6.0, both at 22 km from the PGDP site (to the north, arbitrarily). The suite of U.S. Geological Survey (USGS) national seismic hazard mapping project Eastern North America (ENA) ground motion prediction (attenuation) relations and weights were used to calculate hard rock ground motions at the PGDP site for each scenario [1]. Clearly, the New Madrid M_w 7.6 scenario provides the greatest ground motion hazard at the site for both short and long periods. For peak ground acceleration (PGA), 0.2 second spectral acceleration ordinate (0.2s S_a), and one second spectral acceleration ordinate (1.0s S_a), the median bedrock ground motion hazard is 0.36 g, 0.54 g, and 0.19 g, respectively. The seismic hazard at the site is high because of the proximity of the New Madrid Seismic Zone (36.5 km from the site).

B.2 APPROACH

Scenario seismic hazard has been calculated using the seismic hazard model and computer codes of the USGS national seismic hazard mapping project [1]. For ENA ground motion prediction (attenuation) equations (GMPEs) specified in Table B1, the computer code hazFXnga7c.f [1] was used in deterministic mode to generate a list of median with natural-logarithmic standard deviation hard-rock ground motions for each GMPE. The site-specific ground motion estimates from each GMPE were combined using a weighted average and weights shown in Table B1 to form the final ground motion estimate.

B.3 SOURCE RUPTURES

Three source ruptures were specified in the scope of work for James E. Beavers Consultants: NM—New Madrid North Fault (NE New Madrid segment), WV—southern Wabash Valley, and PGDP—local source 22 km from the site. Figure B1 shows the location of these ruptures (red lines) along with M_w > 3 historical and recorded seismicity through 2006 (green dots) from Petersen et al. [1] relative to PGDP (black open circle). The closest distance from PGDP to the surface projection of these ruptures are 36.5, 99.9, and 22.4 km, respectively, for the NM, WV, and PGDP ruptures. As specified in the scope of work, the NM scenario is for an M_w 7.6 rupture, the WV scenario is for an M_w 7.0 rupture, and the PGDP scenarios are for M_w 5.5 and M_w 6.0 ruptures.

Table B1. ENA GMPEs and Weights Based by Petersen *et al.* [1] (i.e., USGS)

Single Corner—finite fault	Weight*
Toro and Others [2]	0.2
Silva and Others [3]—Constant stress drop w/saturation	0.1
Single Corner—point source with Moho bounce	
Frankel and Others [4]	0.1
Dynamic corner frequency	
Atkinson and Boore [5] 140 bar stress drop	0.1
Atkinson and Boore [5] 200 bar stress drop	0.1
Full waveform simulation	
Summerville and Others [6]	0.2
Hybrid empirical model	
Campbell [7]	0.1
Tavakoli and Pezeshk [8]	0.1

*Same weight as used by USGS.

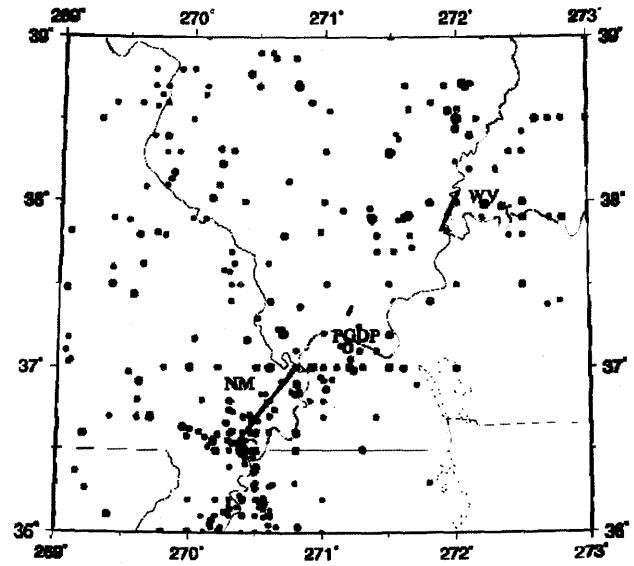

Figure B.1. PGDP Scenario Sources
(Red = Ruptures; Green = Earthquakes)

B.4 RESULTS

Table B2 presents the results of the scenario hazard analysis for PGDP. All entries in Table B2 are for the median ground motion hazard values as discussed in Section B.1. Clearly, the NM scenario controls the hazard at PGDP. The NE end of the NM scenario rupture is less than 40 km from PGDP and uses the largest magnitude earthquake.

Table B2. Median Motion Values for Scenario Earthquakes

		S1E	S2E	S3E	S3E
Motion Type & Distance	**Motion Value**	**New Madrid M_W 7.6**	**Wabash Valley M_W 7.0**	**Local M_W 5.5**	**Local M_W 6.0**
Top of Bedrock	PGA	0.36 g	0.07 g	0.10 g	0.16 g
	0.2s S_a	0.54 g	0.12 g	0.14 g	0.22 g
	1s S_a	0.19 g	0.04 g	0.02 g	0.05 g
Distance	All Values	36.5 km	100 km	22 km	22 km

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APPENDIX B

EVALUATION OF DURATION OF GROUND SHAKING

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Geosyntec consultants

Significant Duration of Strong Ground Shaking
Model: Kempton and Stewart (2006)

b1	2.79	
b2	0.82	
Magnitude, M_w	7.6	
$\delta\sigma$	60	
β	3.2	
c2	0.15	
Distance (km)	36.5	
c4	3	
c5	-0	
Vs30 (m/sec)	760	
c6	-0.44	
c7	0.001	
z1.5 (m)	1000	(assumed; assuption not critical)
ln(Duration)	3.37	

Mean Significant Duration, D_{a5-95} =	**29** sec
Mean+σ	36 sec
Mean-σ	22 sec

Reference: Kempton, J. J. and Stewart, J. P. (2006), "Prediction Equations for Significant Duration of Earthquake Ground Motions Considering Site and Near-Source Effects," Earthquake Spectra, Volume 22, No. 4, pp. 985-1013, November 2006, Earthquake Engineering Research Institute.

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APPENDIX C

TECHNICAL REFERENCE: MATASOVIC AND KAVAZANJIAN (1998)

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Cyclic Characterization of OII Landfill Solid Waste

By Neven Matasović[1] and Edward Kavazanjian Jr.,[2] Members, ASCE

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Abstract: As part of predesign studies for closure of the Operating Industries, Inc. (OII) landfill Superfund site, field and laboratory studies were combined with back analyses of strong motion data to characterize the behavior of the OII solid waste when subjected to strong earthquake shaking. Small strain shear modulus values for the solid waste material were established on the basis of field measurements of shear wave velocity and unit weight. Large-diameter (457 mm) cyclic direct simple shear (CyDSS) testing was performed on reconstituted solid waste specimens to investigate the modulus reduction and damping characteristics of solid waste at large strains. Results of two-dimensional finite element back analyses of strong motion data recorded at the site were combined with the results of CyDSS testing to establish solid waste modulus reduction and damping curves over the range of cyclic shear strain required for site closure design. One-dimensional deconvolution of motions recorded on fill at the base of the landfill was an essential step in the two-dimensional finite element back analyses of strong motion data. The resulting modulus reduction and damping curves indicate that OII solid waste is a fairly linear material in the small to intermediate strain range, but that a significant reduction of shear modulus occurs when the cyclic shear strain exceeds approximately 0.1%.

INTRODUCTION

Scope of Study

As part of predesign studies for closure of the Operating Industries, Inc. (OII) landfill Superfund site, the behavior of the OII solid waste when subject to earthquake-induced cyclic loading was characterized. This cyclic behavior characterization was needed for use in equivalent-linear seismic response analyses carried out in support of predesign analyses for landfill closure design. The cyclic behavior characterization of the OII solid waste includes shear wave velocity, unit weight, and Poisson's ratio profiles from field testing and modulus reduction and damping curves developed using a combination of back analysis of strong motions recorded at the landfill and large-diameter cyclic direct simple shear (CyDSS) laboratory tests on reconstituted solid waste specimens.

The shear wave velocity profile developed for OII solid waste in situ is based upon statistical analysis of the spectral analysis of surface wave (SASW) surveys at 27 locations on the landfill. The unit weight profile is based upon in-situ density testing conducted in three large-diameter (840 mm) bucket auger borings at depths of up to 45 m and in a test trench 6 m deep. The solid waste Poisson's ratio profile was calculated based upon the assumption of linear elastic behavior from compressional and shear wave velocities measured by two different techniques in one borehole.

Two-dimensional finite element equivalent-linear back analysis of strong motions recorded at the landfill was used to develop modulus reduction and damping curves for the solid waste for cyclic shear strains of up to 0.08%. The back analysis relied on the landfill foundation geometry and small strain material properties developed on the basis of the site investigation program. One-dimensional equivalent-linear deconvolution of earthquake motions recorded on compacted soil at the base of the landfill was an essential step of the back analysis. Large-diameter (457 mm) CyDSS testing on reconstituted samples was used to guide the development of the solid waste modulus reduction and damping characteristics at cyclic shear strains larger than 0.08%, the maximum cyclic shear strain calculated in the solid waste by back analysis.

Site Conditions

The OII landfill is located in southern California, approximately 16 km east of downtown Los Angeles (Fig. 1). The site is divided by California State Road 60 (the Pomona Freeway) into a relatively small and level north parcel and the steep-slope 58-ha south parcel where most of the landfilling occurred. The south parcel, the subject of the present study, has been moving toward final closure under the United States Environmental Protection Agency (EPA) Superfund program since 1985. The landfill site was formerly a sand and gravel quarry pit. The approximately 60-m deep pit was filled with solid waste over a 40-year period. There is no evidence that any subgrade preparation or liner installation took place prior to the disposal of solid waste. The top of the landfill ranges from 21 to 76 m above the adjacent ground surface. The maximum thickness of solid waste on the south parcel is approximately 100 m.

Native ground that underlies the landfill is primarily the Tertiary age Pico unit of the Fernando formation, consisting primarily of poorly indurated interbedded sands and gravels with occasional silt and clay lenses. Local pockets of ancient landslide and artificial fill materials are also found at the site. The site accepted residential, commercial, and industrial solid wastes. In addition, liquid wastes were accepted at the landfill at times, primarily at the west end of the south parcel. Waste was disposed of at the site without any separation or compaction. Soil cover was placed on the side slopes of the landfill and on the decks and waste faces as the landfill rose above grade. The landfill last received waste in 1984, after which an interim soil cover was placed on top of the landfill. The cover soils appear to have been derived primarily from local borrow sources and typically vary in classification from silty clay to silty sand. The thickness of the existing soil cover typically varies from 1 m to 5 m.

Seismic Stability Concerns

In September 1988, after the 1987 moment magnitude (M_w) 6.0 Whittier-Narrows earthquake, concerns were voiced about the seismic stability of the landfill mass (Siegel et al. 1990). These concerns were given special attention by EPA due to the proximity of the landfill to the Pomona Freeway and adjacent residences (Fig. 1). As part of the response to these concerns, EPA installed three-component strong motion instruments at the base and top deck of the landfill. Inclinometers

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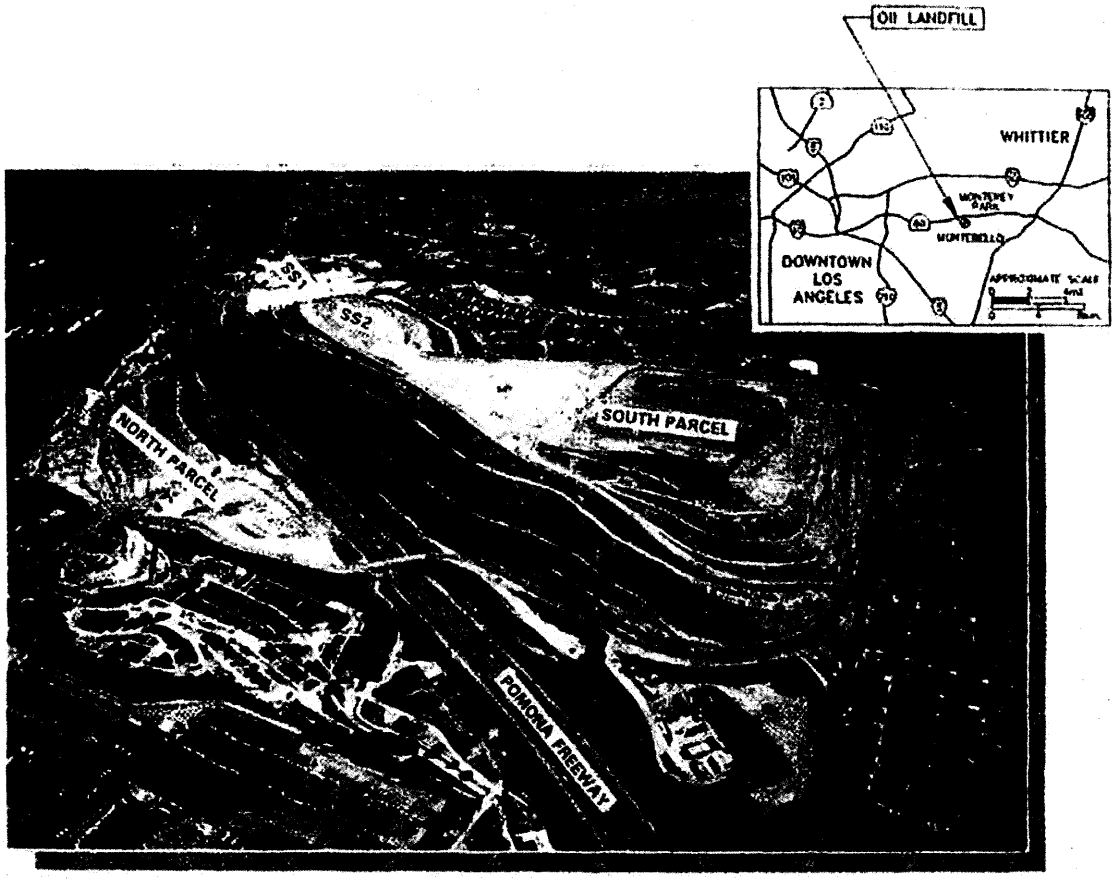

FIG. 1. Aerial View of OII Landfill

and survey monuments were also installed to monitor landfill deformations.

Along with instrumentation and monitoring of the landfill, a variety of site characterization and predesign analytical studies were conducted at the OII site after 1985. These studies were initially conducted by EPA contractors and later continued under EPA oversight by representatives of the potentially responsible parties (PRPs) who assumed responsibility for closure of the south parcel under the Superfund program. Due to continuing concern over seismic response and stability of the landfill, the studies included a comprehensive program of field and laboratory testing specifically focused on providing input for numerical analyses of landfill behavior under static and cyclic loading (GeoSyntec 1996b, 1996c). Results of the field and laboratory testing program and the numerical analyses carried out to characterize the behavior of the OII solid waste subjected to earthquake-induced cyclic loading (GeoSyntec 1996a) are presented herein.

Recorded Ground Motions

The strong motion instrument array at the OII landfill consists of two three-component strong motion instruments. The locations of the strong motion instruments are shown in Figs. 1 and 2. The first instrument, labeled SS1, is located adjacent to the base of the landfill, while the other instrument, labeled SS2, is on the top deck of the landfill. Through April 1994, 34 earthquakes and aftershocks were recorded by these instruments at the OII site. Seismological characterization of these events and the recovered data are presented in Hushmand Assoc. (1994) and PEA (1995).

The 34 events recorded at the OII site included both nearby small magnitude events and distant large magnitude events. Exclusive of the January 17, 1994 M_w 6.7 Northridge earthquake, the largest peak horizontal ground acceleration (PHGA) recorded at the top deck of the landfill was 0.10g in the M_w 7.3 Landers earthquake of June 28, 1992, and the largest PHGA recorded at the base of the landfill was 0.22g in the M_w 5.0 Pasadena earthquake of December 3, 1988. The M_w 7.3 Landers earthquake was the largest magnitude event captured by the instrumentation. The Northridge earthquake was the largest intensity earthquake recorded at the site. A PHGA of 0.25g was recorded at the top deck and a PHGA of 0.26g was recorded at the base of the landfill in the M_w 6.7 Northridge event.

PREVIOUS STUDIES

Previous studies that provide data on cyclic characterization of OII landfill solid waste include Hushmand et al. (1990), Anderson et al. (1992), Kavazanjian and Matasović (1995), Idriss et al. (1995), and Matasović et al. (1995).

Hushmand et al. (1990) studied ambient vibrations and strong motions recorded at the site in a number of small earthquakes, including two M_w 5 events. Based on comparison of base and top deck Fourier Amplitude Spectra, these investigators concluded that spectral energy at frequencies above 3 Hz is attenuated through the landfill, while spectral energy below a frequency of 3 Hz is amplified. Anderson et al. (1992)

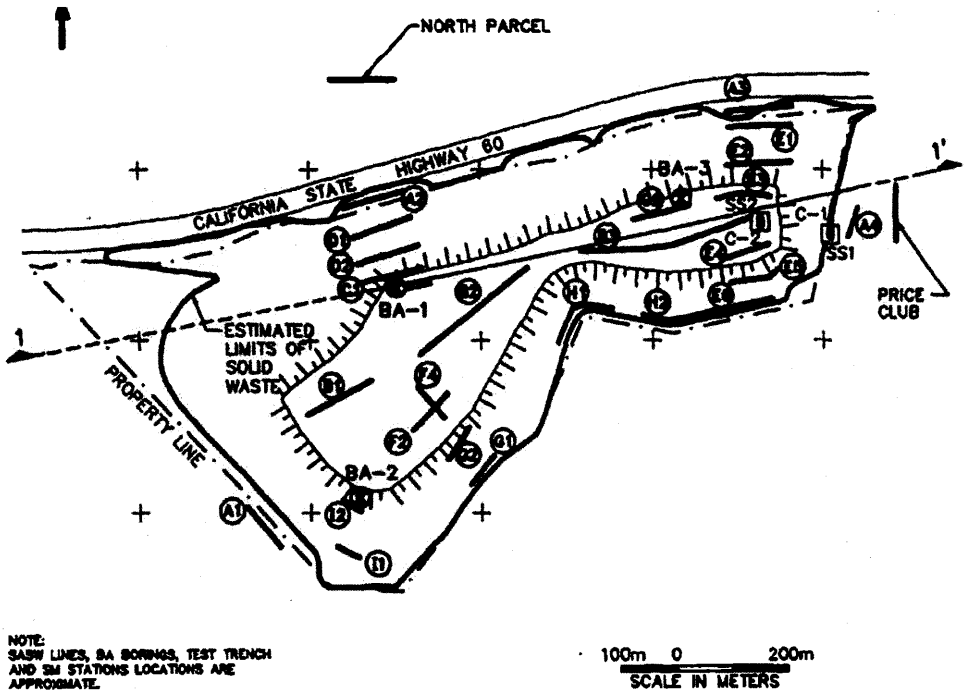

FIG. 2. Location of SASW Lines, Test Trench, and Borings

used the same techniques as Hushmand et al. (1990) to analyze another set of small ($M_W \sim 4$), relatively close earthquakes. They reported up to twelve-fold amplification of spectral amplitudes for frequencies below 1 – 2 Hz and attenuation in other frequency ranges for these small amplitude events.

Kavazanjian and Matasović (1995) performed equivalent-linear seismic site response analyses of the OII landfill using strong motion records from the January 17, 1994 M_W 6.7 Northridge earthquake. In this study, the authors assumed that the base station motion was a free-field weak rock motion, and they used "typical" solid waste properties from Kavazanjian et al. (1995) to develop modulus reduction and damping curves for solid waste. However, as Matasović et al. (1995) and Idriss et al. (1995) subsequently reported, the base station was later found to be located on compacted fill, not weak rock. In these Matasović et al. (1995) and Idriss et al. (1995) studies, seismic site response back analyses of the OII strong motion records were performed to develop solid waste modulus reduction and damping curves. Both of these studies included deconvolution of the base station records and used field-measured shear wave velocity profiles at the base and top deck stations. Matasović et al. (1995) used one-dimensional equivalent-linear and one-dimensional nonlinear models in their back analyses. Idriss et al. (1995) used a two-dimensional equivalent-linear finite element model for their back analysis.

SITE CHARACTERIZATION STUDIES

Site-Specific Exploration and Testing Program

As part of the OII landfill site characterization studies, extensive site-specific exploration and testing were performed at the site. Initial predesign field exploration studies included air-rotary borings with downhole seismic velocity surveys at the two strong motion stations (ESI 1995). Subsequent predesign field studies included SASW surveys at 27 locations on top of the waste and four locations on native material adjacent to the landfill, three 840 mm-diameter bucket auger borings with in-situ unit weight measurements to depths of up to 45 m, and an approximately 6-m long by 6-m deep test trench with in-situ unit weight measurements (GeoSyntec 1996b). Fig. 2 shows the exploration locations from these two field studies. Laboratory testing conducted on 457 mm-diameter reconstituted solid waste specimens in conjunction with the field work

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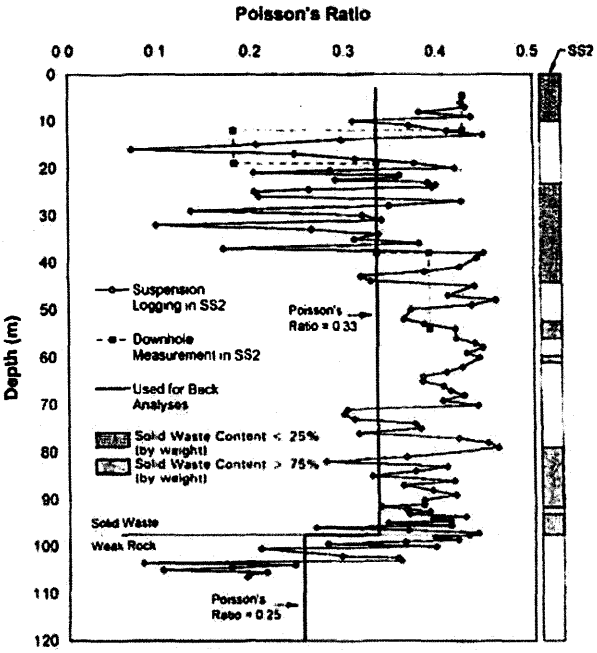

FIG. 3. Poisson's Ratio of OII Landfill Solid Waste

included one-dimensional consolidation, direct shear, and CyDSS testing (GeoSyntec 1996c).

Field Investigation

Shear and compressional wave velocity profiles were developed at both strong motion station locations using in-hole suspension logging and conventional downhole logging (ESI 1995). The shear wave velocity profiles at these locations have been reported previously by Matasović et al. (1995) and Idriss et al. (1995). The shear and compressional wave velocities measured in the borehole at strong motion station SS2 were used to calculate Poisson's ratio, ν, for the solid waste based upon basic equations from linear elasticity. Fig. 3 shows the Poisson's ratio values calculated in this manner. Zones of solid waste content lower than 25% and higher than 75% are indicated in the margin of Fig. 3 by shading. Given the large excursions of ν along the profile, a value of $\nu = 0.33$ was adopted as an appropriate approximation for OII solid waste.

SASW testing was performed at the landfill under the direction of Dr. Kenneth Stokoe of the University of Texas. A vibroseis, a truck-mounted servohydraulic actuator capable of applying a dynamic force of up to 133 kN at frequencies from 1 Hz to 200 Hz was used for the testing. Fig. 4 shows a composite shear wave velocity profile for OII landfill solid waste developed by statistical analysis of the SASW surveys at the 27 locations where testing was performed on waste. The "recommended" solid waste shear wave velocity profiles developed by Kavazanjian et al. (1995) and Kavazanjian et al.

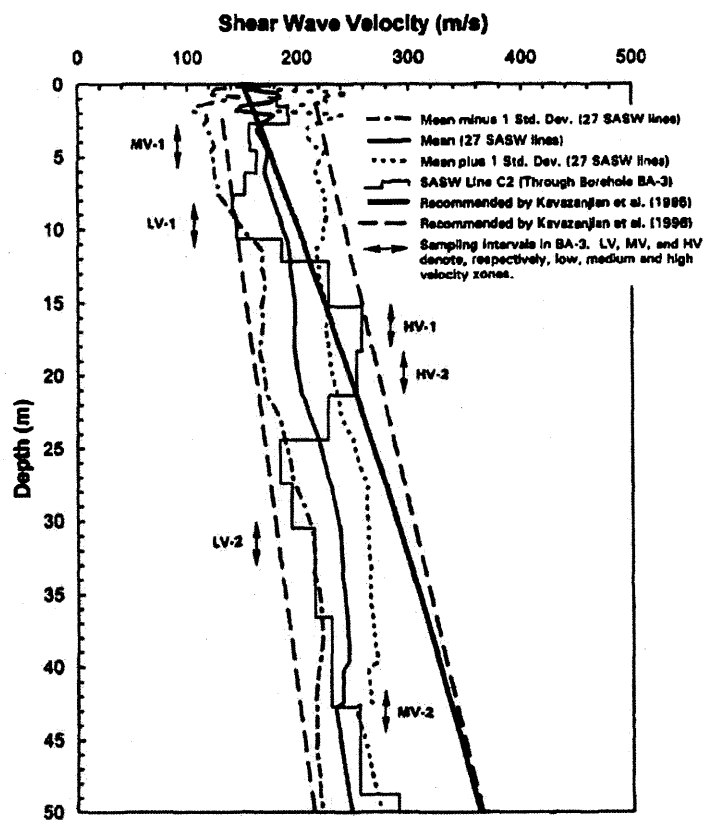

FIG. 4. Shear Wave Velocity of OII Landfill Solid Waste

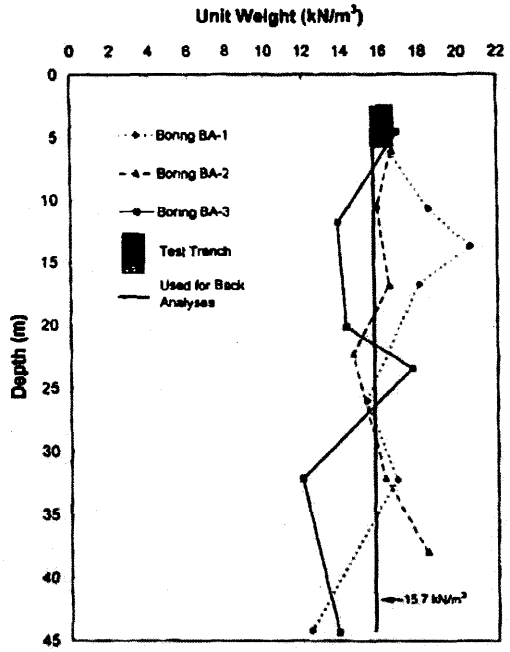

FIG. 5. Unit Weight of OII Landfill Solid Waste

(1996) for southern California municipal solid waste landfills are also shown in Fig. 4 for the purpose of comparison.

In-situ unit weight measurements were made at six locations in each of the three large-diameter bucket auger borings. Bulk samples recovered from these six locations were used subsequently in waste characterization and laboratory testing studies. The measurement and sampling locations were chosen such that unit weight measurements were made at both deep and shallow locations where the in-situ shear wave velocity from the SASW sounding closest to the boring was approximately one standard deviation below the mean velocity (LV locations), approximately one standard deviation above the mean velocity (HV locations), and approximately equal to the mean velocity (MV locations) calculated from all 27 SASW soundings. The measurement and sampling locations for boring BA-3 are shown in Fig. 4.

In-situ unit weight was initially evaluated using an adaptation of the conventional sand cone procedure (*ASTM D 1556*). In the adapted procedure, the weight of solid waste removed from a 2–3 m length of borehole was carefully measured, and the volume of the boring over this interval was evaluated by backfilling the 2–3 m interval with a "calibrated" gravel. However, this procedure gave anomalous results at several locations, most notably at intervals where liquids were seeping into the boring at a relatively rapid rate. Therefore, based upon evaluation of the OII data and data from another landfill where the adapted sand cone procedure was used successfully, the volume of the 2–3 m interval of the boring from which the solid waste was removed and weighed was calculated assuming a constant 16% overbore. Results of the calculations based upon a 16% overbore, shown in Fig. 5, indicated the in-situ unit weight of the solid waste varied in a nonsystematic manner between approximately 12 kN/m³ and 21 kN/m³, with most values between 14 kN/m³ and 18 kN/m³.

The in-situ unit weight of the solid waste was also evaluated in a large test trench excavated near the location of bucket auger boring BA-1. A trench approximately 6 m long, 6 m deep, and 1 m wide was excavated with a backhoe through approximately 1.5–2 m of soil cover. The solid waste excavated from a depth of 2.2 m to the bottom of the trench was carefully weighed. The volume of the trench interval from which the solid waste was excavated was determined by backfilling the trench with the calibrated gravel and was based upon measured trench dimensions. Results of both calculations indicated an average unit weight of approximately 16 kN/m³ for the solid waste in the test trench. The results from the test trench are also plotted in Fig. 5.

Laboratory Testing

Bulk samples of solid waste were recovered for waste characterization and for laboratory testing from each of the 18 intervals in boreholes BA-1, BA-2, and BA-3, in which an in-situ unit weight evaluation was conducted. Testing was conducted in a laboratory established at the landfill site using large-diameter (457 mm) testing equipment designed and fabricated for the project (GeoSyntec 1996c). Reconstituted samples were used in the testing program because of the difficulties in obtaining undisturbed specimens of solid waste of any size, let alone of the large diameter required for a representative sample. CyDSS testing was used for the cyclic characterization of the solid waste. The CyDSS apparatus developed for the OII landfill project is shown in Fig. 6.

The CyDSS testing program included staged testing at uniform cyclic shear strains of 0.1%, 0.3%, 1%, 3%, and 5% at a frequency of approximately 0.1 Hz on waste recovered from six of the bulk sampling intervals. Tables 1 and 2 provide information on the boring and depth from which each bulk sample used in the CyDSS testing program was recovered, the relative in-situ shear wave velocity (low, mean, high) of the sampling interval, the relative moisture content of the specimen (dry, moist), testing stress and strain levels, and the age of the waste as determined from information on the history of landfill development and from pieces of newspaper and other dated materials recovered during sampling. Tables 1 and 2 also provide information on the visual classification of the waste and of the soil or soil-like constituents of the bulk samples.

One set of unprocessed CyDSS testing results are presented in Fig. 7 in terms of cyclic stress-strain loops. These results indicate that solid waste materials follow Masing's (1926) rules for cyclic stress-strain behavior of soils.

Processed CyDSS testing results, expressed in terms of shear modulus reduction and equivalent viscous damping ratio,

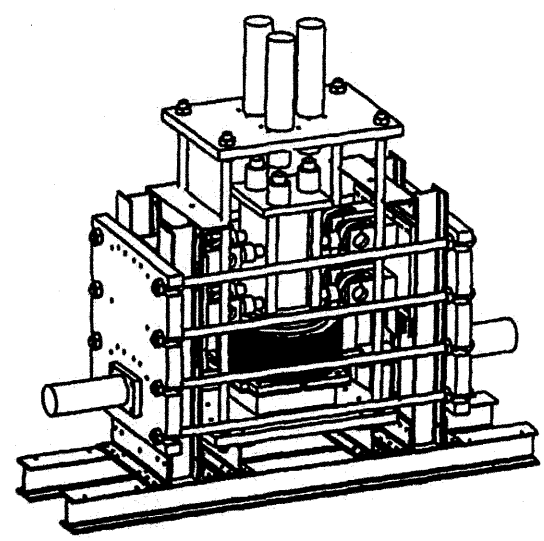

FIG. 6. Large-Diameter Cyclic Direct Simple Shear Device

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TABLE 1. CyDSS Testing Program

Test number (1)	Boring/sampling interval[a] (2)	Depth (3)	Age of sample[b] (4)	Applied normal stress (5)	Moisture content[c] (6)	Shear wave velocity[d] (7)	Unit weight[e] (8)	Number of stages (9)
1, 2, 3	BA-1/LV-1	3.4–6.1 m	—[f]	100.3; 95.8; 94.1 kPa	15.3%	122 m/s	16.0 kN/m³	6
4	BA-3/MV-1	3.4–6.1 m	1980	97.4 kPa	16.6%	162 m/s	16.9 kN/m³	2
5, 6	BA-1/HV-1	9.2–12.2 m	—[f]	176.2; 176.4 kPa	33.5%	231 m/s	18.5 kN/m³	6
7	BA-1/LV-2	15.2–18.3 m	1984	315.1 kPa	25.5%	148 m/s	18.1 kN/m³	4
8	BA-3/LV-2	30.5–33.5 m	1964	511.4 kPa	24.7%	195 m/s	12.0 kN/m³	4
9, 10	BA-2/HV-1	15.2–18.3 m	1983	292.1; 292.3 kPa	41.2%	231 m/s	16.5 kN/m³	6

[a]BA = bucket auger borehole indicated in Fig. 2; LV, MV, HV = low, mean, and high in-situ shear wave velocity zone, respectively, as indicated in Fig. 4.
[b]Age of the solid waste part of the sample estimated from partially decomposed newspapers.
[c]Moisture content of soil and soil-like materials measured prior to the test.
[d]Shear wave velocity measured in the 457-mm consolidation device for the same initial density and overburden pressure.
[e]In-situ unit weight. The unit weight achieved in CyDSS was ±2% of this value.
[f]Age of waste undetermined.

TABLE 2. CyDSS Testing Program

Test number (1)	Paper and cardboard (2)	Plastics and rubber (3)	Wood (4)	Metals (5)	Glass (6)	Textiles and miscellaneous (7)	Soil and soil-like materials composition[a] (8)
1, 2, 3	1.6%	7.0%	2.3%	0.6%	2.5%	1.2%	84.8% (SM; 10% gravel; 50–60% sand; 30–40% fines)
4	1.7%	1.1%	0.4%	0.8%	0.4%	0.9%	94.6% (CH; 10% gravel; 15% sand; 75% fines)
5, 6	6.9%	11.8%	4.0%	0.8%	5.6%	5.3%	64.6% (CH; 5% gravel; 5% sand; 90% fines)
7	9.5%	3.2%	3.7%	2.4%	1.6%	2.2%	77.5% (CL; 10–15% gravel; 30–40% sand; 50–55% fines)
8	10.3%	0.4%	2.9%	0.9%	0.1%	0.1%	85.4% (Fine-grained)
9, 10	1.2%	3.7%	3.4%	4.9%	0.4%	1.5%	84.8% (ML; 10% gravel; 30–40% sand; 50–60% fines)
[Average]	5.2%	4.5%	2.8%	1.7%	1.8%	2.0%	82.0%

[a]Unified Soil Classification System by visual classification.

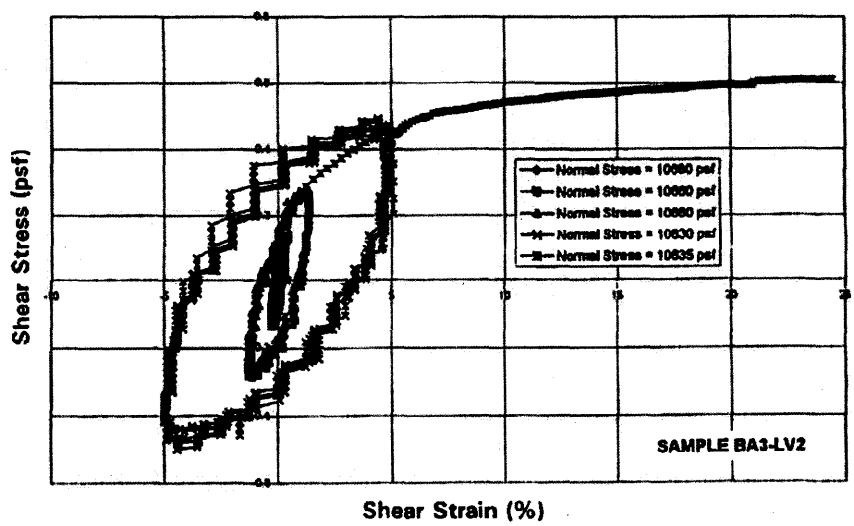

FIG. 7. Unprocessed Solid Waste Cyclic Direct Simple Shear Test Results

are shown in Fig. 8. The modulus reduction data were normalized by small strain moduli calculated from the mass density of the compacted specimen and the estimated shear wave velocity. Shear wave velocity was estimated on the basis of shear wave velocity measured in the laboratory in 457 mm diameter consolidometers on specimens from the same bulk sample compacted to the same density and subject to the same consolidation pressure as the CyDSS specimens (Geosyntec 1996c). Damping values were calculated from the cyclic loops based upon the assumption that material damping can be characterized with the strain-dependent equivalent viscous damping ratio, defined as a ratio of damping energy to the equivalent strain energy [see, e.g., Ishihara (1996)]. Damping calculated from the experimental cyclic hysteresis loops was corrected for system friction by subtracting 4% from the experimental damping ratio values. The value of 4% was based on the comparison of damping measured in tests run on a "standard" sand in the large-diameter CyDSS device to damping reported in the literature for the same sand when tested in a Norwegian Geotechnical Institute-type CyDSS apparatus (Matasović and Vucetic 1993) and on CyDSS test performed in the large-diameter apparatus on "dummy" neoprene specimens (GeoSyntec 1996c).

Fig. 8(a) also includes modulus reduction data points cal-

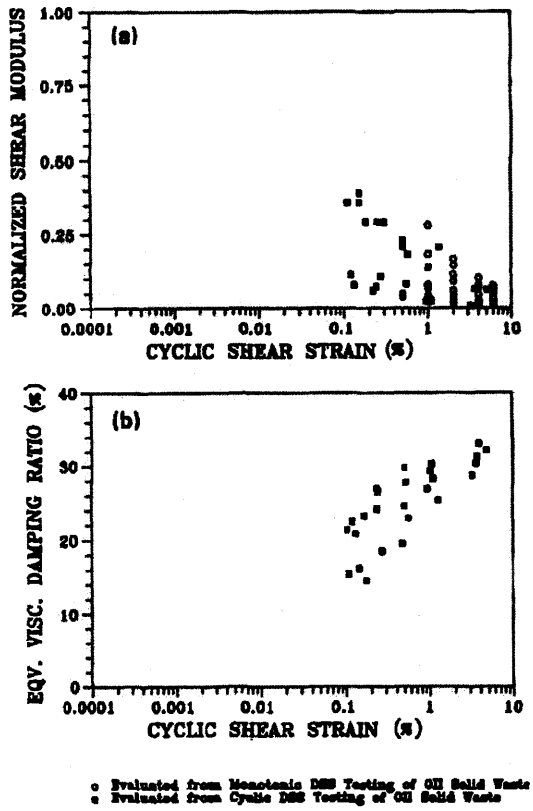

FIG. 8. Processed Solid Waste Cyclic Direct Simple Shear Test Results

culated using the secant modulus from monotonic loading (i.e., static) direct simple shear (DSS) tests on reconstituted specimens. These modulus values were calculated assuming the static stress strain curve represented the backbone curve for cyclic loading.

One goal of the testing program was to identify the influence of the waste characteristics identified in Tables 1 and 2 on the mechanical behavior of the waste. Evaluation of the data from both cyclic and static tests (including direct shear and consolidation tests) showed no discernable trends with respect to waste composition. Therefore, there was no distinguishing among data points on the basis of compositional factors when plotting or evaluating the data.

Waste Profile Idealization

Back analyses of the seismic response of the landfill were conducted on cross section 1-1′ of Fig. 2. Cross section 1-1′, shown in Fig. 9, was developed using a topographic map prepared approximately two months prior to the Northridge earthquake, a base-of-the-landfill contour map developed from historical data (ESI 1996b), and SASW results (GeoSyntec 1996a), as well as the results of other characterization and field investigation studies. The cross section was extended to elevation 55 m msl, approximately 130 m below the top deck of the landfill. Elevation 55 m mean sea level represented the lowest elevation reached by the SASW measurements.

Cross section 1-1′ was idealized for modeling purposes into zones of four materials: cover soil, compacted fill, weak rock, and solid waste. The dynamic characteristics of these materials and of the elastic half-space assumed to underlie the cross section are summarized in Table 3. The dashed lines with question marks on cross section 1-1′ in Fig. 9 indicate a relatively high degree of uncertainty relative to the geometry of the compacted fill and cover soils. The native subsurface material was characterized as a uniform material because, based on the available information, it is difficult, if not impossible, to make a distinction in geometry and material properties between discrete components of the Pico unit, which is present below the cross section. The modulus reduction and damping curves for the cover soil, compacted fill, and weak rock materials were selected on the basis of the classification of these materials. The Vucetic and Dobry (1991) curves for a plasticity index of 15 were selected to represent the cover soils and compacted fill, as these materials were classified primarily as low-plasticity silty clay and clayey silt. The Shibuya et al. (1990) curves for gravel were selected for the Pico unit because the poorly indurated sand and gravel weak rock materials that make up most of this unit appeared to be, in a mechanical sense, similar to a loose or poorly cemented gravel.

The shear wave velocity profile for the solid waste is summarized in Fig. 9. This profile was based upon actual shear wave velocity profiles measured in the SASW and borehole velocity surveys, and not on the average shear wave velocity profile from SASW measurements shown in Fig. 4. Shear wave velocity variations between the points illustrated in Fig. 9 were established by linear interpolation in order to avoid large impedance ratios in the horizontal direction. The shear wave velocity for the compacted fill was based upon the shear wave velocity profile from the in-hole suspension logging at the location of monitoring station SS1. The shear wave velocity profile for the Pico unit foundation soils was based upon the suspension logging at station SS1 and SASW profiles developed on native ground adjacent to the landfill.

Based upon the data shown in Fig. 5 from the field unit weight evaluations, the solid waste was characterized by a constant unit weight of 15.7 kN/m^3. Based upon unit weight measurements on Shelby Tube samples (ESI 1996a), the cover soils were characterized by a constant unit weight of 17.3 kN/m^3. Based upon typical values for compacted soils, the fill was characterized by a unit weight of 18.8 kN/m^3 to a depth of 22 m and 19.6 kN/m^3 at greater depths. Based upon available geotechnical data, the weak rock Pico formation materials were characterized by a unit weight of 18.8 kN/m^3.

The elastic half-space was characterize by a shear wave velocity of 1,220 m/s and a unit weight of 20.4 kN/m^3. Based upon the data in Fig. 3, the half-space and weak rock were characterized by Poisson's ratio equal to 0.25, and the solid waste was characterized by Poisson's ratio equal to 0.33. A Poisson's ratio of 0.30 was used to characterize the cover soils based upon typical values for similar soils.

BACK ANALYSIS OF STRONG MOTION RECORDS

Landfill Response Analyses

Back analyses of landfill response were conducted to assess the modulus reduction and damping characteristics of the waste mass in the small to intermediate strain range. The back analyses were conducted in the time domain using equivalent-linear finite element analysis. Because the base station (station SS1) was located on fill and not on a bedrock outcrop, ground motions recorded at SS1 had to be deconvolved to determine the bedrock outcrop motion for input to each finite element back analysis. Therefore, each back analysis was carried out in two steps: (1) Deconvolution of the strong ground motion recorded at SS1 using one-dimensional analysis; and (2) two-dimensional back analysis of site response using the deconvolved motion.

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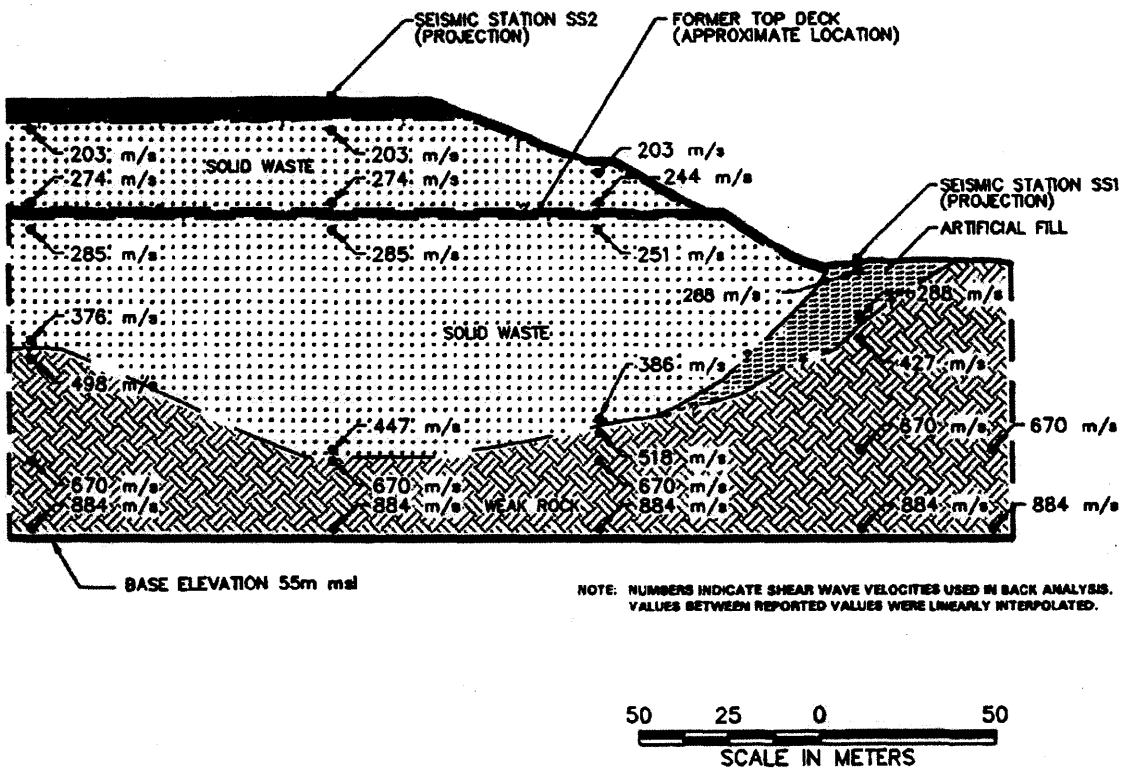

FIG. 9. Oil Landfill Cross Section 1-1′

TABLE 3. Dynamic Material Properties

Zone[a] (1)	Unit weight (2)	Poisson's ratio (3)	Shear wave velocity (4)	Modulus reduction and damping curves (5)
Solid waste	15.7 kN/m³	0.33	Varies[a]	Evaluated in this study
Cover soils	17.3 kN/m³	0.30	274 m/s	Vucetic and Dobry (1991) (PI = 15)
Artificial fill	18.8–19.6 kN/m³	0.30	288 m/s	Vucetic and Dobry (1991) (PI = 15)
Weak rock	18.8 kN/m³	0.25	Varies[a]	Shibuya et al. (1990)
Elastic half-space	20.4 kN/m³	0.25	1,220 m/s	—

[a]See Fig. 9.

TABLE 4. Characteristics of Selected Accelerograms

Event (1)	Record[a] (2)	PHGA[b] (3)	Significant duration[c] (4)	RMSA[d] (5)
Jan. 17, 1994 Northridge earthquake $M_w = 6.7$	Base (SS1)	0.258g	10.54 s	0.083g
Jan. 17, 1994 Northridge earthquake $M_w = 6.7$	Top deck (SS2)	0.254g	16.34 s	0.057g
June 28, 1992 Landers earthquake $M_w = 7.3$	Base (SS1)	0.042g	37.57 s	0.012g
June 28, 1992 Landers earthquake $M_w = 7.3$	Top deck (SS2)	0.100g	39.25 s	0.027g
Dec. 3, 1988 Pasadena earthquake $M_w = 5.0$	Base (SS1)	0.218g	3.29 s	0.067g
Dec. 3, 1988 Pasadena earthquake $M_w = 5.0$	Top deck (SS2)	0.091g	3.32 s	0.033g
Jan. 19, 1994 Northridge aftershock number 5 $M_w = 4.5$	Base (SS1)	0.043g	5.49 s	0.012g
Jan. 19, 1994 Northridge aftershock number 5 $M_w = 4.5$	Top deck (SS2)	0.031g	4.96 s	0.007g
Jan. 19, 1989 Malibu earthquake $M_w = 5.0$	Base (SS1)	0.012g	20.49 s	0.003g
Jan. 19, 1989 Malibu earthquake $M_w = 5.0$	Top deck (SS2)	0.010g	26.75 s	0.002g

[a]Baseline correction and conversion to east-west alignment from PEA (1995).
[b]PHGA = (uncorrected) recorded peak horizontal ground acceleration as reported by PEA (1995).
[c]Significant duration of strong shaking defined in accordance with Trifunac and Brady (1975).
[d]RMSA = root-mean-square acceleration over the significant duration of the record.

Out of the 34 events reported by Hushmand Assoc. (1994) and PEA (1995), a set of five ground motion records (accelerograms) were selected for use in the back analyses of the seismic response of the landfill. The criteria used to select these accelerograms were the intensity of the PHGA recorded at the top deck of the landfill in the east-west direction and the energy content and duration of strong shaking of the east-west component. Table 4 provides the characteristics of the

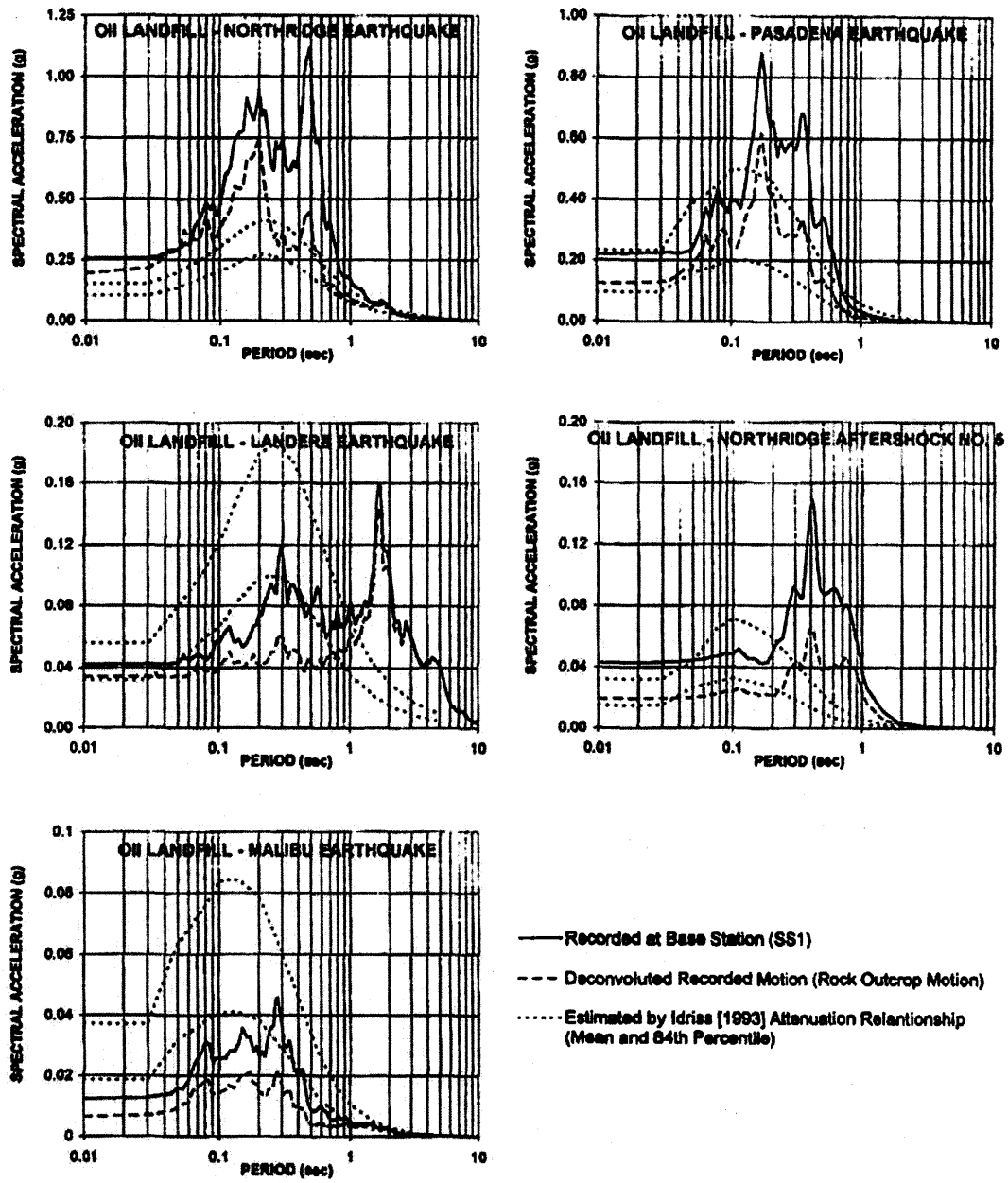

FIG. 10. One-Dimensional Deconvolution of Base Motions

selected accelerograms, with the energy content expressed in terms of the root-mean-square acceleration (RMSA) and with the duration of strong shaking expressed in terms of the significant duration (D_s) defined by Trifunac and Brady (1975). With the exception of the Landers earthquake, the top deck station recorded motions of lesser PHGA than the base station in all five of the selected events (though in the Northridge event, the PHGAs at top deck and base were almost equal).

To avoid circular arguments (i.e., to minimize the interdependence of assumptions and parameters), it was assumed that the data, parameters, and geometry given in Tables 1–3 and Fig. 9 represented best estimates, and thus these values were not varied in the back analyses.

One-Dimensional Deconvolution of Recorded Motions

The location of base station SS1 on compacted fill and the topography surrounding the base station, including its proximity to the edge of the landfill, suggest that the base station records are not representative of free-field outcrop ground motions suitable for direct input to the back analyses of landfill response. Therefore, the effect of the compacted fill on the ground motions at SS1 was evaluated using one-dimensional equivalent-linear deconvolution analyses. The effect of topography was not explicitly considered in the analyses but was qualitatively evaluated in two ways: initially by comparison

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TABLE 5. Earthquake Parameters for Selected Records

Event (1)	Moment magnitude (2)	Style of faulting (3)	Site-to-source distance (4)	PHGA recorded at base[a] (5)	PHGA Estimated at Base: Attenuation relationship[b] (6)	PHGA Estimated at Base: Deconvolution[c] (7)
Jan. 17, 1994—Northridge	6.7	Thrust	43 km	0.258g	0.104g	0.160g
June 28, 1992—Landers	7.3	Strike-slip	140 km	0.042g	0.032g	0.035g
Dec. 3, 1988—Pasadena	5.0	Strike-slip	13 km	0.218g	0.096g	0.118g
Jan. 19, 1994—Northridge aftershock number 5	4.5	Thrust	43 km	0.043g	0.015g	0.017g
Jan. 19, 1989—Malibu	5.0	Thrust	50 km	0.012g	0.019g	0.007g

[a]Larger of two horizontal acceleration components.
[b]Estimates from Idriss (1993) attenuation relationship (rock sites).
[c]Results of deconvolution by *SHAKE91* (Idriss and Sun 1992) (monitored as rock outcrop motion).

of the acceleration response spectra for the deconvolved motions to statistically based response spectra for free-field conditions, and subsequently by comparison of the response spectra for the motions predicted at SS1 in the two-dimensional finite element back analysis to the response spectra of the recorded motions.

Deconvolution through the compacted fill of the recorded base motions was performed using the computer program *SHAKE91* (Idriss and Sun 1992). *SHAKE91* is a one-dimensional equivalent-linear computer program that operates in the frequency domain. The idealized shear wave velocity profile used for the deconvolution analysis was based upon the results of the borehole velocity surveys at the location of SS1. These data are reported in Idriss et al. (1995). The material properties used in the deconvolution analyses for the fill, weak rock, and elastic half-space are given in Table 3. The acceleration response spectra from the deconvolution analyses (monitored in *SHAKE91* as a rock outcrop motion) are plotted in Fig. 10 versus the acceleration response spectral shapes derived from the Idriss (1993) acceleration attenuation relationship. Outcrop PHGA values from the deconvolution analyses are compared to mean PHGA values predicted by the Idriss (1993) attenuation relationship in Table 5.

Fig. 10 indicates that, with the exception of the Malibu earthquake, the deconvolved motions fall within (or close to) the range of anticipated values for free-field motions (i.e., between the estimated 16th and 84th percentile spectral values from the Idriss attenuation relationship). The deviation from the expected statistical shape is smallest for the two strongest records—the January 17, 1994 Northridge and December 3, 1988 Pasadena earthquakes. The motions from these two earthquakes govern the back calculation of solid waste modulus reduction and damping curves, since they induce the largest shear strains in the waste. Table 5 indicates that relatively good agreement was also achieved between the peak acceleration values of the deconvolved motions and the peak acceleration values estimated using the Idriss (1993) attenuation relationship. The deconvolved free-field PHGA values presented in Table 5 indicate amplification of the PHGA at the top of the fill at the location of SS1 in all five events considered in the back analysis (when compared to the hypothetic free-field bedrock PHGA). This, in turn, implies that the amplification of PHGA values by the OII waste fill, as represented by the motions recorded at SS2, is even greater than reported previously by Kavazanjian and Matasović (1995).

Two-Dimensional Back Analyses

The finite element mesh developed to back analyze the seismic response of cross section 1-1′ had more than 7,000 elements. Following recommendations by Lysmer et al. (1975), lateral boundaries of the mesh were extended more than 10 times the mesh thickness beyond the boundaries of the waste fill to minimize the influence of the lateral boundaries on the computed response. The material parameters used in the back analysis are summarized in Table 3 and are shown in Fig. 9.

The back analyses were carried out using the computer program *QUAD4M* (Idriss et al. 1973; Hudson et al. 1994). *QUAD4M* performs time domain seismic response analyses using the equivalent-linear constitutive model with frequency-dependent damping. The back analyses were performed using the deconvolved ground motions characterized in Table 5 and shown in Fig. 10 in the form of acceleration response spectra. Following an iterative procedure, the "best-fit" OII solid waste modulus reduction and damping curves were determined on the basis of qualitative examination of the observed and predicted acceleration response spectra at SS2. Results of the back analyses using the "best-fit" parameters are shown in Fig. 11. The "best fit" modulus reduction and damping curves, shown in Fig. 12, are truncated at a strain of 0.08% as this was the maximum cyclic shear strain in the solid waste calculated in the back analyses (induced by the deconvolved record from the January 17, 1994 Northridge earthquake).

MODULUS REDUCTION AND DAMPING DATA INTEGRATION AND INTERPRETATION

The modulus reduction and damping data from the back analysis were integrated with the data from the CyDSS testing program to create a family of "internally consistent" modulus reduction and damping curves that were considered to represent the range of likely values for the solid waste at OII. A set of modulus reduction and damping curves were considered internally consistent if the damping curve in the intermediate strain range could be derived from the modulus reduction curve using the Masing (1926) rules. The family of internally consistent modulus reduction and damping curves developed based upon the back analysis and laboratory data are shown in Fig. 12. The "upper bound" modulus reduction curve shown in this figure is internally consistent with the "lower bound" damping curve, and the "lower bound" modulus reduction curve is internally consistent with the "upper bound" damping curve.

From the family of internally consistent curves, a "best-estimate" set of modulus reduction and damping curves were identified to represent the cyclic characteristics of the OII solid waste for subsequent analytical studies of the seismic response of the landfill. The "upper bound" modulus reduction curve and corresponding "lower bound" damping curve were chosen as the "best-estimate" curves for the following reasons: (1) The "upper bound" modulus curve was more consistent with the back analysis results than were the other curves; (2) due to disturbance associated with sampling and sample preparation, the reconstituted specimens used in the laboratory testing were likely to be less "structured" and thus show increased modulus reduction and damping compared to the waste in situ; and (3) the lower rate of energy dissipation and the reduced modulus reduction associated with the "upper

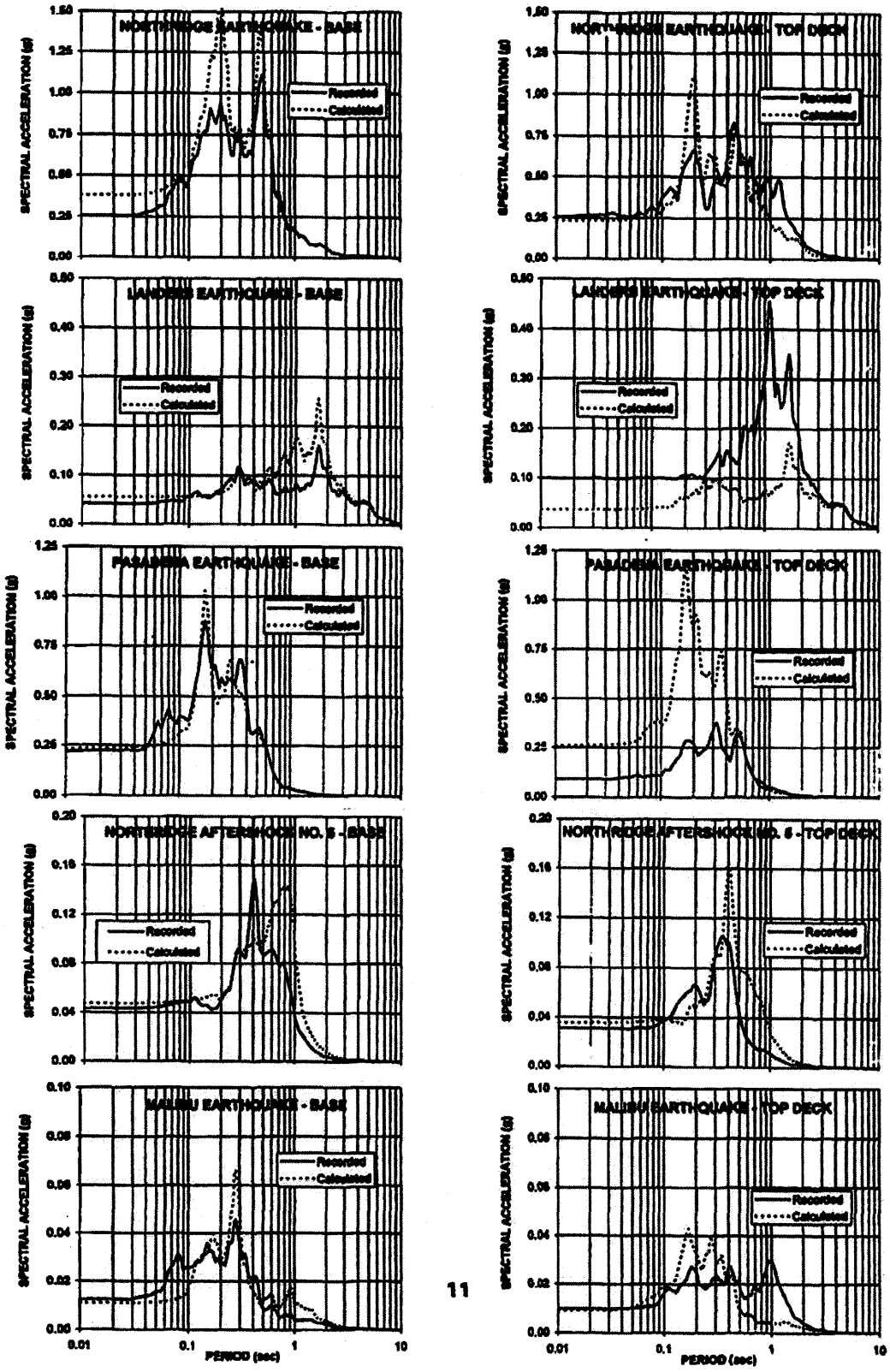

FIG. 11. Back Analysis of Strong Motion Data

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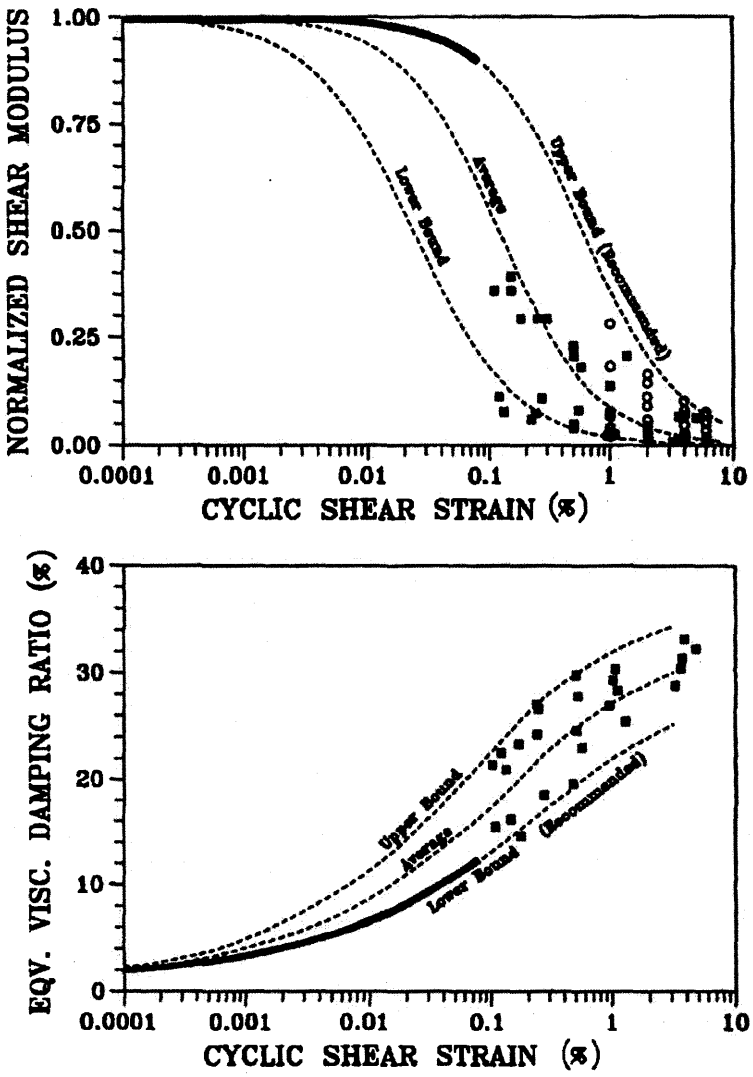

FIG. 12. Internally Consistent Modulus Reduction and Damping Curves

bound" modulus reduction and "lower bound" damping curves was considered to be conservative with respect to the acceleration response at the landfill surface (i.e., they generated larger peak accelerations at the landfill surface than did the other curves).

Fig. 13 compares the "best estimate" modulus reduction and damping curves developed in the present study to characterize the OII solid waste to modulus reduction and damping curves for solid waste derived by previous investigators from the OII data. While the damping curves from this and previous studies are all reasonably consistent, there are significant differences among the modulus reduction curves. The modulus reduction curve developed for the present study was used in subsequent analytical studies of landfill response in lieu of the curves developed by previous investigators because it is consistent with back analyses using geometry, shear wave velocity, and unit weight values based upon field and laboratory data; it is extrapolated to large strain values on the basis of site-specific laboratory testing; and it is internally consistent with the damping curve.

SUMMARY AND CONCLUSIONS

The cyclic characteristics of the OII landfill solid waste were established for use in subsequent analytical studies based upon field and laboratory testing and back analyses of strong motion data recorded at the base and top deck of the landfill. The shear wave velocity profile for the solid waste was developed on the basis of downhole and in-hole seismic velocity surveys and SASW testing. Poisson's ratio for the solid waste was evaluated based upon a comparison of compressional and shear wave velocities measured in the downhole and in-hole surveys. The unit weight of the solid waste was evaluated on the basis of the field investigation.

The modulus reduction and damping curves for the OII solid waste were based on a combination of laboratory test data and back analysis. The laboratory test data were based upon CyDSS tests performed on 457 mm diameter specimens reconstituted in the laboratory from bulk samples recovered from the landfill. The laboratory testing program provided information on the hysteretic damping and modulus reduction

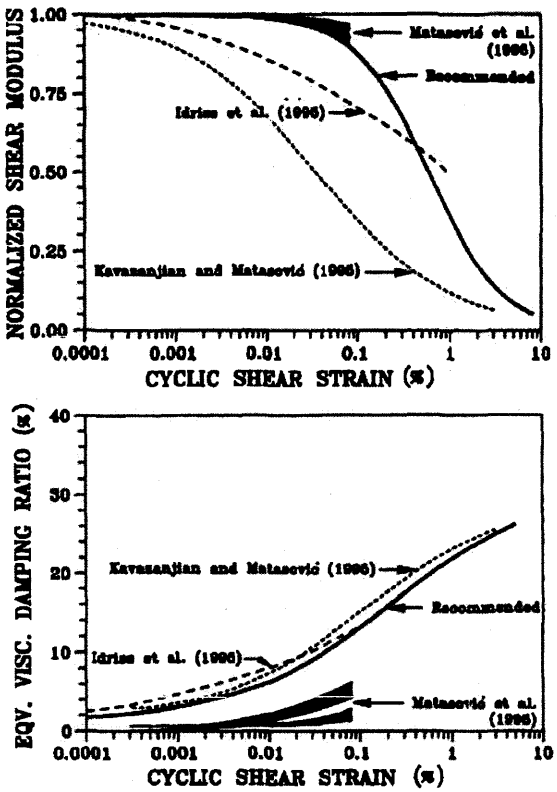

FIG. 13. Best Estimate OII Solid Waste Modulus Reduction and Damping Curves

of reconstituted samples at cyclic shear strains between 0.1% and 5%. The back analysis provided data on modulus reduction and damping at cyclic shear strains of up to 0.08% based upon recorded motions at the top deck and base of the landfill from five earthquakes, including the M_W 7.3 Landers event and the M_W 6.7 Northridge event. The geometry of the waste, soil, and weak rock materials used in the back analysis was based upon borings, topographic maps, and other information on the history of landfill development. The properties of the soil and weak rock materials were based upon the results of the field investigation and typical properties.

The back analysis was performed using two-dimensional equivalent-linear time domain response analyses with the computer program *QUAD4M*. However, as the base strong motion station was located on fill, the "outcrop" input motions for the two-dimensional back analyses were determined by deconvolution of the recorded base station motions. The deconvolution analyses were performed using the one-dimensional equivalent-linear frequency domain computer program *SHAKE91*. The deconvolution analyses indicated that the fill amplified the bedrock motions recorded at the base station and that amplification of bedrock motions by the OII waste fill was even greater than reported previously. Results of the back analysis using the deconvolved motions indicated little modulus reduction within the waste for cyclic shear strains up to 0.08%.

The modulus reduction and damping data from the laboratory testing program and back analyses were integrated to develop a family of internally consistent modulus reduction and damping curves. From this family of curves, a "best-estimate" set of modulus reduction and damping curves were selected to characterize the OII solid waste for use in subsequent analytical studies. These "best-estimate" curves were used for subsequent studies in lieu of previous modulus reduction and damping curves derived from the OII strong motion records because they are based upon field data on landfill geometry, shear wave velocity, and unit weight; they are internally consistent in the intermediate strain range; they are consistent with the strong motion data recorded at the top and base of the landfill; and they use laboratory data to extrapolate back calculated modulus reduction and damping curves into the large strain domain.

ACKNOWLEDGMENTS

The writers wish to express their sincere appreciation to New Cure, Inc. (NCI)—in particular, Les LaFountain and Ken Hewlett, representing the potentially responsible parties for design and construction of the final cover at the OII landfill, for authorizing the work described herein, and to the members of the NCI OII Seismic Working Group [John Christian, Geoffrey Martin, James K. Mitchell, Gerry Leonards (deceased), Lloyd Cluff, and Richard Mitchell]. Thanks are also extended to the EPA Technical Review Panel (Izzat M. Idriss, Raymond B. Seed, Arvid Landva, Ellis Krinitsky, and Mary Ellen Hynes) who provided many valuable suggestions during the course of this project. Additionally, we wish to thank Robert Bachus, Gary Schmertmann, Thomas Williamson, Lucas Fairborn, and Ken Daly of GeoSyntec Consultants for their assistance with the work described herein and the numerous other individuals who made this paper possible.

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APPENDIX D

SITE RESPONSE ANALYSIS—FREE FIELD

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*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85   : IBM-PC version of SHAKE                    *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88   : New modulus reduction curves for clays     *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 26, 1988                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; Input now is either *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & F. Dirrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91   : General cleanup and finalization of input / *
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake98   : Routine for direct calculation of average  *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing. The following   *
*             modulus reduction and damping curves are   *
*             added: Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SMB sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1993 - May 1998                     *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17

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********************
MATERIAL TYPE NO. 4
********************

CURVE NO.  7:   #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:   #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

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********************
MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.816	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```

SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 39
DEPTH TO BEDROCK 371.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	13.00	6.50	806.00	1386.	5.00	124.00	600.0
2	6	7.00	16.50	2046.00	2465.	5.00	124.00	800.0
3	6	10.00	25.00	3085.00	3391.	5.00	121.00	950.0
4	6	9.00	34.50	4234.50	4547.	5.00	121.00	1100.0
5	6	9.00	43.50	5323.50	4547.	5.00	121.00	1100.0
6	6	9.00	52.50	6412.50	4547.	5.00	121.00	1100.0
7	5	9.00	61.50	7497.00	4929.	5.00	120.00	1150.0
8	5	9.00	70.50	8577.00	4929.	5.00	120.00	1150.0
9	4	9.00	79.50	9657.00	5823.	5.00	120.00	1250.0
10	4	10.00	89.00	10797.00	5823.	5.00	120.00	1250.0
11	4	10.00	99.00	11997.00	5823.	5.00	120.00	1250.0
12	4	10.00	109.00	13197.00	5823.	5.00	120.00	1250.0
13	4	10.00	119.00	14397.00	5823.	5.00	120.00	1250.0
14	5	10.00	129.00	15617.00	7548.	5.00	124.00	1400.0
15	5	10.00	139.00	16857.00	7548.	5.00	124.00	1400.0
16	5	10.00	149.00	18097.00	7548.	5.00	124.00	1400.0
17	5	10.00	159.00	19337.00	7548.	5.00	124.00	1400.0
18	5	11.00	169.50	20639.00	7548.	5.00	124.00	1400.0
19	5	11.00	180.50	22003.00	7548.	5.00	124.00	1400.0
20	5	10.00	191.00	23315.00	9707.	5.00	126.00	1575.0
21	5	10.00	201.00	24575.00	9707.	5.00	126.00	1575.0
22	5	10.00	211.00	25835.00	9707.	5.00	126.00	1575.0
23	5	10.00	221.00	27095.00	9707.	5.00	126.00	1575.0
24	5	10.00	231.00	28355.00	9707.	5.00	126.00	1575.0
25	5	9.00	240.50	29552.00	9707.	5.00	126.00	1575.0
26	5	9.00	249.50	30686.00	9707.	5.00	126.00	1575.0
27	4	9.00	258.50	31995.50	10043.	5.00	165.00	1400.0
28	4	9.00	267.50	33480.50	10043.	5.00	165.00	1400.0
29	4	9.00	276.50	34965.50	10043.	5.00	165.00	1400.0
30	4	10.00	286.00	36533.00	10043.	5.00	165.00	1400.0
31	4	10.00	296.00	38183.01	10043.	5.00	165.00	1400.0
32	4	10.00	306.00	39833.01	10043.	5.00	165.00	1400.0
33	4	10.00	316.00	41483.01	10043.	5.00	165.00	1400.0
34	4	10.00	326.00	43133.01	10043.	5.00	165.00	1400.0
35	4	10.00	336.00	44783.01	10043.	5.00	165.00	1400.0
36	4	10.00	346.00	46433.02	10043.	5.00	165.00	1400.0
37	4	10.00	356.00	48083.02	10043.	5.00	165.00	1400.0
38	4	10.00	366.00	49733.02	10043.	5.00	165.00	1400.0
39	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.118 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1326.8 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 14.02
FOR FREQUENCY (f) = 1.04 c/sec
FOR PERIOD (1 / f) = .96 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = t56-ac2b.sar
NO. OF INPUT ACCEL. POINTS = 2248
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 3
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200
FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

Time history matched to spectrumidwr-tar.dat / WCC for El Sobrante
Max in file = 0.636577 g Dm = 25.8 s
2248 pts @ 0.02 s

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	.000525	.000548	.000616	.000729	.000866	.001030	.001169	.001291
2	.001324	.001299	.001149	.000959	.000688	.000405	.000059	-.000268
3	-.000617	-.000891	-.001129	-.001236	-.001257	-.001101	-.000812	-.000237
4	.000187	.000753	.001812	.003608	.004803	.003855	.002017	.006526
5	.009613	.005528	-.011607	.001042	.041819	.037028	-.025997	-.053567

..... INPUT MOTION READ NOT ECHOED.....

277	-.000568	-.000614	-.000644	-.000686	-.000714	-.000753	-.000778	-.000813
278	-.000836	-.000866	-.000886	-.000914	-.000931	-.000954	-.000969	-.000989
279	-.001001	-.001018	-.001027	-.001040	-.001047	-.001057	-.001062	-.001069
280	-.001071	-.001075	-.001075	-.001076	-.001074	-.001073	-.001065	-.001065
281	-.001059	-.001053	-.001046	-.001038	-.001029	-.001019	-.001009	-.000998

MAXIMUM ACCELERATION = .636577
AT TIME = 3.62 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .56552470
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.42 c/sec
MAXIMUM ACCELERATION = .359987 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.03178	.060	.050	16.5	1016.5	1386.3	-36.4	1.000
2	6	16.5	.04368	.067	.050	25.9	1673.5	2464.6	-47.3	1.000
3	6	25.0	.04626	.069	.050	27.3	2269.7	3391.4	-49.4	1.000
4	6	34.5	.04638	.069	.050	27.4	3041.0	4546.9	-49.5	1.000
5	6	43.5	.05730	.074	.050	32.4	2877.4	4546.9	-58.0	1.000
6	6	52.5	.06761	.078	.050	35.8	2749.3	4546.9	-65.4	1.000
7	5	61.5	.07120	.106	.050	52.7	2341.4	4928.6	-110.5	1.000
8	5	70.5	.07926	.109	.050	54.2	2232.3	4928.6	-120.8	1.000
9	4	79.5	.07368	.140	.050	64.2	1814.4	5823.0	-220.9	1.000
10	4	89.0	.08022	.144	.050	65.2	1719.4	5823.0	-238.7	1.000
11	4	99.0	.08632	.147	.050	66.0	1637.5	5823.0	-255.6	1.000
12	4	109.0	.09152	.150	.050	66.6	1572.2	5823.0	-270.4	1.000
13	4	119.0	.09577	.152	.050	67.1	1521.5	5823.0	-282.7	1.000
14	5	129.0	.07647	.108	.050	53.7	3474.5	7547.8	-117.2	1.000
15	5	139.0	.07849	.109	.050	54.1	3433.8	7547.8	-119.8	1.000
16	5	149.0	.08082	.110	.050	54.5	3388.4	7547.8	-122.8	1.000
17	5	159.0	.08364	.111	.050	54.8	3353.8	7547.8	-125.1	1.000
18	5	169.5	.08400	.111	.050	55.0	3326.3	7547.8	-126.8	1.000
19	5	180.5	.08530	.112	.050	55.2	3304.2	7547.8	-128.4	1.000
20	5	191.0	.06753	.104	.050	51.9	4717.1	9706.8	-105.8	1.000
21	5	201.0	.06835	.104	.050	52.1	4693.1	9706.8	-106.8	1.000
22	5	211.0	.06893	.105	.050	52.2	4676.2	9706.8	-107.6	1.000
23	5	221.0	.06997	.105	.050	52.4	4646.1	9706.8	-108.9	1.000
24	5	231.0	.07067	.105	.050	52.6	4626.3	9706.8	-109.8	1.000
25	5	240.5	.07098	.106	.050	52.7	4617.4	9706.8	-110.2	1.000
26	5	249.5	.07096	.106	.050	52.6	4618.2	9706.8	-110.2	1.000
27	4	258.5	.06895	.137	.050	63.4	3257.3	10043.5	-208.3	1.000
28	4	267.5	.06912	.137	.050	63.4	3252.6	10043.5	-208.6	1.000

29	4	276.5	.06888	.137	.050	63.4	3259.3	10043.5	-208.1	1.000
30	4	286.0	.06835	.136	.050	63.3	3274.2	10043.5	-206.7	1.000
31	4	296.0	.07011	.137	.050	63.8	3225.2	10043.5	-211.4	1.000
32	4	306.0	.07339	.140	.050	64.2	3137.1	10043.5	-220.2	1.000
33	4	316.0	.07607	.141	.050	64.8	3068.0	10043.5	-227.4	1.000
34	4	326.0	.07808	.142	.050	64.9	3017.6	10043.5	-232.8	1.000
35	4	336.0	.07942	.143	.050	65.1	2985.0	10043.5	-236.5	1.000
36	4	346.0	.08040	.144	.050	65.2	2961.3	10043.5	-239.2	1.000
37	4	356.0	.08094	.144	.050	65.3	2948.4	10043.5	-240.6	1.000
38	4	366.0	.08074	.144	.050	65.3	2953.2	10043.5	-240.1	1.000

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.02029	.051	.060	-16.4	1108.0	1016.5	8.3	.733
2	6	16.5	.03069	.059	.067	-13.9	1821.6	1673.5	8.1	.674
3	6	25.0	.03349	.061	.069	-12.6	2456.3	2269.7	7.6	.659
4	6	34.5	.03350	.061	.069	-12.7	3292.8	3041.0	7.6	.669
5	6	43.5	.04337	.067	.074	-9.9	3093.1	2877.4	7.0	.633
6	6	52.5	.05305	.072	.078	-8.0	2937.1	2749.3	6.4	.605
7	5	61.5	.06978	.105	.106	-.8	2361.8	2341.4	.9	.475
8	5	70.5	.08017	.110	.109	.3	2220.7	2232.3	-.5	.453
9	4	79.5	.10424	.156	.140	10.3	1441.7	1814.4	-25.9	.312
10	4	89.0	.11490	.160	.144	10.1	1367.8	1719.4	-25.7	.295
11	4	99.0	.12311	.163	.147	9.6	1315.4	1637.5	-24.5	.281
12	4	109.0	.12790	.164	.150	8.8	1286.4	1572.2	-22.2	.270
13	4	119.0	.13666	.167	.152	9.1	1236.1	1521.5	-23.1	.261
14	5	129.0	.06256	.102	.108	-6.4	3787.0	3474.5	8.3	.469
15	5	139.0	.06583	.103	.109	-5.5	3707.7	3433.9	7.4	.455
16	5	149.0	.06928	.105	.110	-4.8	3628.2	3388.4	6.6	.449
17	5	159.0	.07248	.106	.111	-4.0	3557.8	3353.8	5.7	.444
18	5	169.5	.07574	.108	.111	-3.1	3489.5	3328.3	4.6	.441
19	5	180.5	.07909	.109	.112	-2.2	3422.1	3304.2	3.4	.438
20	5	191.0	.05751	.099	.104	-5.3	5038.8	4717.1	6.4	.486
21	5	201.0	.05956	.100	.104	-4.5	4968.7	4693.1	5.5	.483
22	5	211.0	.06156	.101	.105	-3.8	4902.5	4676.2	4.6	.482
23	5	221.0	.06380	.102	.105	-2.9	4827.9	4646.1	3.8	.479
24	5	231.0	.06600	.103	.105	-2.1	4763.1	4626.3	2.9	.477
25	5	240.5	.06770	.104	.106	-1.5	4712.2	4617.4	2.0	.476
26	5	249.5	.06918	.105	.106	-.8	4669.0	4618.2	1.1	.476
27	4	258.5	.10221	.155	.137	11.8	2512.4	3257.3	-29.6	.324
28	4	267.5	.10499	.156	.137	12.4	2477.3	3252.6	-31.3	.324
29	4	276.5	.10687	.157	.137	12.9	2454.0	3259.3	-32.8	.325
30	4	286.0	.10897	.158	.136	13.8	2428.5	3274.2	-34.8	.326
31	4	296.0	.11068	.159	.137	13.6	2384.7	3225.2	-35.2	.321
32	4	306.0	.11846	.161	.140	13.4	2319.2	3137.1	-35.3	.312
33	4	316.0	.12292	.163	.141	13.2	2270.8	3068.0	-35.1	.305
34	4	326.0	.12727	.164	.142	13.2	2225.2	3017.6	-35.6	.300
35	4	336.0	.13044	.165	.143	13.3	2193.0	2985.0	-36.1	.297
36	4	346.0	.13331	.166	.144	13.4	2164.5	2961.3	-36.8	.295
37	4	356.0	.13562	.167	.144	13.6	2142.0	2948.4	-37.6	.294
38	4	366.0	.13646	.167	.144	13.8	2134.0	2953.2	-38.4	.294

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO

1	6	6.5	.01422	.045	.051	-14.9	1178.9	1108.0	6.0	.799
2	6	16.5	.02149	.053	.059	-12.7	1949.5	1821.6	6.6	.739
3	6	25.0	.02348	.054	.061	-12.7	2639.2	2456.3	6.9	.724
4	6	34.5	.02343	.054	.061	-12.8	3540.0	3292.8	7.0	.724
5	6	43.5	.03057	.059	.067	-13.7	3363.9	3093.1	8.1	.680
6	6	52.5	.03767	.064	.072	-12.8	3202.0	2937.1	8.3	.646
7	5	61.5	.05208	.096	.105	-9.9	2659.2	2361.8	11.2	.479
8	5	70.5	.06062	.100	.110	-9.0	2504.8	2220.7	11.1	.451
9	4	79.5	.09767	.153	.156	-1.9	1499.6	1441.7	3.9	.248
10	4	89.0	.10773	.157	.160	-1.7	1416.7	1367.8	3.5	.235
11	4	99.0	.12227	.162	.163	-.2	1320.6	1315.4	.4	.226
12	4	109.0	.13461	.166	.164	1.3	1247.6	1286.4	-3.1	.221
13	4	119.0	.14939	.171	.167	2.2	1168.5	1236.1	-5.8	.212
14	5	129.0	.05040	.095	.102	-7.4	4123.6	3787.0	8.2	.502
15	5	139.0	.05417	.097	.102	-6.5	4011.2	3707.7	7.4	.491
16	5	149.0	.05804	.099	.105	-5.8	3903.8	3628.2	7.1	.481
17	5	159.0	.06187	.101	.106	-5.1	3804.2	3557.8	6.5	.471
18	5	169.5	.06592	.103	.108	-4.4	3705.6	3489.5	5.8	.462
19	5	180.5	.07020	.105	.109	-3.7	3607.7	3422.1	5.1	.453
20	5	191.0	.04929	.094	.098	-5.3	5347.7	5038.8	5.8	.519
21	5	201.0	.05174	.095	.100	-4.6	5250.5	4968.7	5.4	.512
22	5	211.0	.05413	.097	.101	-4.3	5160.1	4902.5	5.0	.505
23	5	221.0	.05668	.098	.102	-3.9	5067.8	4827.9	4.7	.497
24	5	231.0	.05913	.100	.103	-3.6	4983.1	4763.1	4.4	.491
25	5	240.5	.06126	.101	.104	-3.2	4912.2	4712.2	4.1	.485
26	5	249.5	.06312	.102	.105	-2.9	4852.5	4669.0	3.8	.481
27	4	258.5	.12271	.163	.155	4.7	2273.1	2512.4	-10.5	.250
28	4	267.5	.12719	.164	.156	4.9	2236.1	2477.3	-11.3	.247
29	4	276.5	.13121	.165	.157	5.2	2185.4	2454.0	-12.1	.244
30	4	286.0	.13515	.167	.158	5.4	2146.6	2428.5	-13.1	.242
31	4	296.0	.14021	.168	.158	5.5	2098.5	2384.7	-13.6	.237
32	4	306.0	.14652	.170	.161	5.2	2049.8	2319.2	-13.8	.231
33	4	316.0	.15125	.171	.163	5.1	1999.2	2270.8	-13.8	.226
34	4	326.0	.15638	.173	.164	5.0	1955.5	2225.2	-13.8	.222
35	4	336.0	.16007	.174	.165	4.9	1925.0	2193.0	-13.8	.218
36	4	346.0	.16309	.175	.166	4.8	1900.5	2164.5	-13.8	.216
37	4	356.0	.16603	.175	.167	4.8	1877.1	2142.0	-13.1	.213
38	4	366.0	.16708	.176	.167	4.8	1866.8	2134.0	-13.2	.212

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01177	.041	.045	-8.6	1216.5	1178.9	3.1	.850
2	6	16.5	.01770	.049	.052	-7.4	2018.2	1949.5	3.4	.791
3	6	25.0	.01930	.051	.054	-7.3	2735.0	2639.2	3.5	.778
4	6	34.5	.01925	.050	.054	-7.3	3668.5	3540.0	3.5	.779
5	6	43.5	.02479	.055	.059	-7.1	3503.1	3363.9	4.0	.740
6	6	52.5	.03044	.059	.064	-8.2	3367.1	3202.0	4.9	.704
7	5	61.5	.04104	.088	.096	-8.8	2901.4	2659.2	8.1	.540
8	5	70.5	.04776	.093	.100	-8.3	2747.1	2504.9	8.8	.508
9	4	79.5	.08471	.146	.153	-4.6	1658.6	1499.6	9.4	.258
10	4	89.0	.09915	.154	.157	-2.3	1482.8	1416.7	4.5	.243
11	4	99.0	.11633	.160	.162	-1.3	1358.4	1320.6	2.8	.227
12	4	109.0	.13382	.166	.166	-.3	1257.8	1247.6	.8	.214
13	4	119.0	.15154	.171	.171	.3	1157.7	1168.5	-.9	.201
14	5	129.0	.04430	.090	.095	-4.6	4324.4	4123.6	4.9	.546
15	5	139.0	.04795	.093	.097	-4.3	4201.2	4011.2	4.7	.533
16	5	149.0	.05170	.095	.099	-3.9	4083.9	3903.8	4.6	.517
17	5	159.0	.05551	.098	.101	-3.6	3973.1	3804.2	4.5	.504
18	5	169.5	.05960	.100	.103	-3.3	3862.5	3705.6	4.1	.491
19	5	180.5	.06395	.102	.105	-3.0	3752.8	3607.7	3.8	.478
20	5	191.0	.04462	.091	.094	-3.6	5540.9	5347.7	3.6	.551

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MAR 08 2012
Division of Waste Management
Solid Waste Branch

21	5	201.0	.04708	.092	.095	-3.3	5439.3	5250.5	3.5	.541
22	5	211.0	.04952	.094	.097	-3.1	5338.3	5160.1	3.3	.532
23	5	221.0	.05198	.096	.098	-2.9	5241.2	5067.8	3.3	.522
24	5	231.0	.05433	.097	.100	-2.8	5152.5	4983.1	3.3	.513
25	5	240.5	.05657	.098	.101	-2.6	5071.9	4812.2	3.1	.506
26	5	249.5	.05859	.099	.102	-2.4	5001.5	4852.5	3.0	.500
27	4	258.5	.13050	.165	.163	1.6	2192.4	2273.1	-3.7	.226
28	4	267.5	.13651	.167	.164	1.8	2133.5	2226.1	-4.3	.222
29	4	276.5	.14149	.169	.165	1.9	2086.5	2185.4	-4.7	.218
30	4	286.0	.14701	.170	.167	2.1	2036.5	2146.6	-5.4	.214
31	4	296.0	.15268	.172	.168	2.1	1986.9	2098.5	-5.6	.209
32	4	306.0	.15902	.173	.170	2.0	1933.6	2040.8	-5.5	.203
33	4	316.0	.16401	.175	.171	1.9	1893.2	1999.2	-5.6	.199
34	4	326.0	.16864	.176	.173	1.8	1856.7	1955.5	-5.3	.195
35	4	336.0	.17227	.177	.174	1.7	1828.8	1925.0	-5.3	.192
36	4	346.0	.17540	.178	.175	1.7	1805.3	1900.5	-5.3	.189
37	4	356.0	.17777	.178	.175	1.6	1787.7	1877.1	-5.0	.187
38	4	366.0	.17808	.178	.176	1.5	1785.4	1868.9	-4.7	.186

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01082	.040	.041	-4.0	1233.4	1216.5	1.4	.878
2	6	16.5	.01621	.047	.049	-3.5	2049.3	2018.2	1.5	.819
3	6	25.0	.01765	.049	.051	-3.4	2778.4	2735.0	1.6	.806
4	6	34.5	.01761	.049	.050	-3.4	3726.8	3668.5	1.6	.807
5	6	43.5	.02263	.053	.055	-3.2	3562.6	3503.1	1.7	.770
6	6	52.5	.02762	.057	.059	-3.2	3432.4	3367.1	1.9	.741
7	5	61.5	.03577	.083	.088	-5.3	3041.0	2901.4	4.6	.589
8	5	70.5	.04148	.088	.093	-5.2	2890.4	2747.1	5.0	.557
9	4	79.5	.07474	.140	.146	-4.2	1798.5	1658.6	7.8	.285
10	4	89.0	.08259	.150	.154	-2.1	1559.3	1482.8	4.9	.255
11	4	99.0	.11068	.158	.160	-1.3	1396.2	1358.4	2.7	.233
12	4	109.0	.12908	.165	.166	-.7	1279.5	1257.8	1.7	.216
13	4	119.0	.15004	.171	.171	-.2	1165.2	1157.7	.6	.199
14	5	129.0	.04145	.088	.090	-2.4	4427.8	4324.4	2.3	.573
15	5	139.0	.04494	.091	.093	-2.3	4301.9	4201.2	2.3	.557
16	5	149.0	.04853	.093	.095	-2.2	4182.2	4083.9	2.4	.541
17	5	159.0	.05222	.096	.098	-2.1	4068.3	3973.1	2.3	.526
18	5	169.5	.05620	.098	.100	-1.9	3954.0	3862.5	2.3	.512
19	5	180.5	.06046	.100	.102	-1.8	3840.2	3752.8	2.3	.497
20	5	191.0	.04232	.089	.091	-1.9	5652.6	5546.9	1.9	.571
21	5	201.0	.04473	.091	.092	-1.8	5541.7	5439.3	1.8	.560
22	5	211.0	.04714	.092	.094	-1.7	5436.9	5338.3	1.8	.550
23	5	221.0	.04953	.094	.096	-1.7	5337.8	5241.2	1.8	.540
24	5	231.0	.05183	.095	.097	-1.6	5246.8	5152.5	1.8	.531
25	5	240.5	.05398	.097	.098	-1.6	5165.6	5071.9	1.8	.523
26	5	249.5	.05605	.098	.099	-1.5	5090.3	5001.5	1.7	.515
27	4	258.5	.13372	.166	.165	.6	2160.6	2192.4	-1.5	.218
28	4	267.5	.14047	.168	.167	.7	2096.1	2133.5	-1.8	.212
29	4	276.5	.14640	.170	.169	.8	2041.9	2086.5	-2.2	.208
30	4	286.0	.15270	.172	.170	.9	1986.8	2036.5	-2.5	.203
31	4	296.0	.15862	.173	.172	.9	1936.9	1986.9	-2.6	.198
32	4	306.0	.16514	.175	.173	.9	1884.2	1933.6	-2.6	.193
33	4	316.0	.16982	.176	.175	.8	1847.6	1893.2	-2.5	.188
34	4	326.0	.17385	.177	.176	.7	1816.9	1856.7	-2.2	.185
35	4	336.0	.17747	.178	.177	.7	1789.9	1828.8	-2.2	.182
36	4	346.0	.18021	.179	.178	.6	1769.8	1805.3	-2.0	.180
37	4	356.0	.18175	.179	.178	.5	1758.7	1787.7	-1.6	.178
38	4	366.0	.18133	.179	.178	.4	1761.7	1785.4	-1.3	.178

ACCELEROGRAM - t56-ac2b.sar

P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01043	.039	.040	-1.7	1240.6	1233.4	.6	.890
2	6	16.5	.01561	.047	.047	-1.5	2062.8	2049.3	.7	.832
3	6	25.0	.01700	.048	.049	-1.5	2796.9	2778.4	.7	.819
4	6	34.5	.01705	.048	.049	-1.3	3747.9	3726.8	.6	.820
5	6	43.5	.02189	.053	.053	-1.2	3584.4	3562.6	.6	.784
6	6	52.5	.02665	.057	.057	-1.2	3455.8	3432.4	.7	.755
7	5	61.5	.03359	.081	.083	-2.5	3104.9	3041.0	2.1	.617
8	5	70.5	.03891	.086	.088	-2.4	2955.6	2890.4	2.2	.586
9	4	79.5	.06808	.136	.140	-3.2	1902.7	1798.5	5.5	.309
10	4	89.0	.08707	.148	.150	-1.9	1627.9	1559.3	4.2	.268
11	4	99.0	.10659	.157	.158	-1.0	1424.7	1396.2	2.0	.240
12	4	109.0	.12570	.164	.165	-.7	1299.6	1279.5	1.6	.220
13	4	119.0	.14770	.170	.171	-.4	1177.2	1165.2	1.0	.200
14	5	129.0	.04014	.087	.088	-1.2	4477.8	4427.8	1.1	.587
15	5	139.0	.04355	.090	.091	-1.1	4350.7	4301.9	1.1	.570
16	5	149.0	.04705	.092	.093	-1.1	4230.6	4182.2	1.1	.554
17	5	159.0	.05062	.095	.096	-1.1	4116.5	4068.3	1.2	.539
18	5	169.5	.05451	.097	.098	-1.0	4001.5	3954.0	1.1	.524
19	5	180.5	.05868	.099	.100	-1.0	3886.8	3840.2	1.2	.509
20	5	191.0	.04128	.088	.089	-.9	5702.5	5652.6	.9	.583
21	5	201.0	.04365	.090	.091	-.9	5590.7	5541.7	.9	.571
22	5	211.0	.04602	.092	.092	-.8	5484.8	5436.9	.9	.560
23	5	221.0	.04838	.093	.094	-.8	5385.0	5337.8	.9	.550
24	5	231.0	.05065	.095	.095	-.8	5293.0	5246.9	.9	.541
25	5	240.5	.05273	.096	.097	-.8	5212.5	5165.6	.9	.532
26	5	249.5	.05481	.097	.098	-.7	5135.2	5090.3	.9	.524
27	4	258.5	.13519	.167	.166	.3	2146.2	2160.6	-.7	.215
28	4	267.5	.14230	.169	.168	.3	2079.1	2096.1	-.8	.209
29	4	276.5	.14902	.171	.170	.4	2018.7	2041.9	-1.2	.203
30	4	286.0	.15573	.173	.172	.3	1961.0	1986.8	-1.3	.196
31	4	296.0	.16201	.174	.173	.3	1909.2	1936.9	-1.5	.193
32	4	306.0	.16847	.176	.175	.3	1858.0	1884.2	-1.4	.186
33	4	316.0	.17271	.177	.176	.4	1825.5	1847.6	-1.2	.184
34	4	326.0	.17640	.178	.177	.3	1797.8	1816.9	-1.1	.181
35	4	336.0	.17980	.179	.178	.2	1772.9	1789.9	-1.0	.178
36	4	346.0	.18205	.179	.179	.2	1756.6	1769.8	-.8	.176
37	4	356.0	.18278	.179	.179	.1	1751.3	1758.7	-.4	.175
38	4	366.0	.18185	.179	.179	.1	1758.0	1761.7	-.2	.175

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01027	.039	.039	-.8	1243.8	1240.6	.3	.895
2	6	16.5	.01537	.046	.047	-.6	2068.3	2062.8	.3	.837
3	6	25.0	.01680	.048	.048	-.5	2802.6	2796.9	.2	.825
4	6	34.5	.01686	.048	.048	-.4	3755.3	3747.9	.2	.824
5	6	43.5	.02163	.053	.053	-.4	3592.2	3584.4	.2	.786
6	6	52.5	.02631	.056	.057	-.4	3464.2	3455.8	.2	.760
7	5	61.5	.03275	.081	.081	-1.0	3130.2	3104.9	.8	.630
8	5	70.5	.03788	.085	.086	-1.0	2982.2	2955.6	.9	.600
9	4	79.5	.06391	.133	.136	-2.2	1873.3	1802.7	3.9	.327
10	4	89.0	.08290	.145	.148	-1.6	1662.8	1627.9	3.3	.280
11	4	99.0	.10391	.156	.157	-.7	1444.1	1424.7	1.3	.245
12	4	109.0	.12318	.163	.164	-.5	1314.9	1299.6	1.2	.223

13	4	119.0	.14548	.170	.170	-.4	1188.6	1177.2	1.0	.202
14	5	129.0	.03955	.087	.087	-.6	4500.8	4477.8	.5	.593
15	5	139.0	.04292	.089	.090	-.5	4373.4	4350.7	.5	.576
16	5	149.0	.04637	.092	.092	-.5	4253.3	4230.6	.5	.561
17	5	159.0	.04989	.094	.095	-.5	4139.4	4116.5	.6	.545
18	5	169.5	.05369	.097	.097	-.5	4024.9	4001.5	.6	.530
19	5	180.5	.05782	.099	.099	-.5	3909.8	3886.6	.6	.515
20	5	191.0	.04082	.088	.088	-.4	5724.8	5702.5	.4	.587
21	5	201.0	.04317	.089	.090	-.4	5612.8	5590.7	.4	.576
22	5	211.0	.04553	.091	.092	-.4	5506.4	5484.8	.4	.565
23	5	221.0	.04786	.093	.093	-.4	5406.4	5385.0	.4	.555
24	5	231.0	.05013	.094	.095	-.4	5313.9	5293.0	.4	.545
25	5	240.5	.05218	.096	.096	-.4	5233.6	5212.5	.4	.537
26	5	249.5	.05424	.097	.097	-.3	5155.9	5135.2	.4	.529
27	4	258.5	.13596	.167	.167	.1	2138.8	2146.2	-.3	.214
28	4	267.5	.14325	.169	.169	.2	2070.4	2079.1	-.4	.207
29	4	276.5	.15057	.171	.171	.3	2005.1	2018.7	-.7	.201
30	4	286.0	.15751	.173	.173	.3	1946.1	1961.0	-.8	.195
31	4	296.0	.16413	.175	.174	.3	1892.2	1909.2	-.9	.190
32	4	306.0	.17047	.176	.176	.3	1842.6	1858.0	-.8	.185
33	4	316.0	.17427	.177	.177	.2	1813.7	1825.5	-.7	.182
34	4	326.0	.17775	.178	.178	.2	1787.9	1797.8	-.6	.179
35	4	336.0	.18086	.179	.179	.1	1765.1	1772.9	-.4	.177
36	4	346.0	.18265	.179	.179	.1	1752.2	1756.6	-.2	.175
37	4	356.0	.18272	.179	.179	.0	1751.7	1751.3	.0	.174
38	4	366.0	.18141	.179	.179	-.1	1761.1	1758.0	.2	.175

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	13.0	6.5	.01556	193.07	.23954	4.08
2	6	7.0	16.5	.02329	480.33	.23476	4.06
3	6	10.0	25.0	.02545	711.92	.23077	4.06
4	6	5.0	34.5	.02554	957.19	.22605	4.06
5	6	9.0	43.5	.03278	1174.78	.22068	4.06
6	6	9.0	52.5	.03986	1377.43	.21480	4.06
7	5	9.0	61.5	.04963	1540.87	.20553	4.06
8	5	9.0	70.5	.05739	1696.34	.19778	4.06
9	4	9.0	79.5	.09684	1842.51	.19080	3.68
10	4	10.0	89.0	.12560	2044.62	.18937	3.68
11	4	10.0	99.0	.15743	2243.03	.18697	3.68
12	4	10.0	109.0	.18664	2425.46	.18379	3.68
13	4	10.0	119.0	.22043	2594.80	.18023	3.70
14	5	10.0	129.0	.05993	2883.37	.17182	3.64
15	5	10.0	139.0	.06504	2829.59	.16786	3.64
16	5	10.0	149.0	.07025	2972.11	.16423	3.64
17	5	10.0	159.0	.07559	3111.58	.16091	3.64
18	5	11.0	169.5	.08135	3255.38	.15773	3.64
19	5	11.0	180.5	.08760	3404.64	.15474	3.66
20	5	10.0	191.0	.06185	3527.21	.15129	3.64
21	5	10.0	201.0	.06541	3657.16	.14882	3.64
22	5	10.0	211.0	.06898	3783.62	.14645	3.64
23	5	10.0	221.0	.07252	3905.16	.14413	3.64
24	5	10.0	231.0	.07595	4019.90	.14177	3.64
25	5	9.0	240.5	.07905	4120.65	.13944	3.64
26	5	9.0	249.5	.08218	4220.34	.13753	3.62
27	4	9.0	258.5	.20599	4421.03	.13816	3.64
28	4	9.0	267.5	.21705	4512.60	.13476	3.62
29	4	9.0	276.5	.22814	4605.42	.13171	3.62
30	4	10.0	286.0	.23865	4679.95	.12810	3.60
31	4	10.0	296.0	.24869	4748.00	.12435	3.60
32	4	10.0	306.0	.25828	4798.92	.12048	3.58
33	4	10.0	316.0	.26405	4820.24	.11620	3.56
34	4	10.0	326.0	.26932	4841.83	.11225	3.56
35	4	10.0	336.0	.27402	4858.20	.10848	3.54
36	4	10.0	346.0	.27674	4861.18	.10469	3.52
37	4	10.0	356.0	.27685	4848.52	.10084	3.50
38	4	10.0	366.0	.27487	4832.09	.09716	3.50

PERIOD = 1.777 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 635.0 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION - 3.85
FOR FREQUENCY (f) = .52 c/sec
FOR PERIOD (1 / f) = 1.93 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - t56-ac2b.sar
D E P O S I T - Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.24372	4.06	1.10	.000	512
WITHIN	13.0	.23526	4.06	1.01	.000	0
WITHIN	20.0	.22820	4.06	.95	.000	0
WITHIN	30.0	.21683	4.06	.88	.000	0
WITHIN	39.0	.20642	4.04	.84	.000	0
WITHIN	48.0	.19480	4.04	.81	.000	0
WITHIN	57.0	.18102	3.84	.79	.000	0
WITHIN	66.0	.17802	3.84	.79	.000	0
WITHIN	75.0	.17405	3.84	.79	.000	0
WITHIN	84.0	.16728	3.82	.83	.000	0
WITHIN	94.0	.15942	3.60	.92	.000	0
WITHIN	104.0	.15213	3.60	1.04	.000	0
WITHIN	114.0	.14344	3.58	1.15	.000	0
WITHIN	124.0	.15228	6.82	1.27	.000	0
WITHIN	134.0	.15216	6.82	1.27	.000	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - t56-ac2b.sar
D E P O S I T - Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	196.0	.13169	4.34	1.15	.000	0
WITHIN	371.0	.33874	3.62	3.43	.000	0
OUTCR.	371.0	.36000	3.62	3.42	.000	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 21

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 21

RECEIVED
MAR 08 2012
Division of Waste Management
Solid Waste Branch

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*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE  *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES      *
*             by: Per B. Schnabel & John Lysmer -- 1970   *
* ----------------------------------------------------- *
* Shake85   : IBM-PC version of SHAKE                     *
*             by: S.S. (Willie) Lai, January 1985         *
* ----------------------------------------------------- *
* Shake88   : New modulus reduction curves for clays      *
*             added using results from Sun et al. (1988)  *
*             by: J. I. Sun & Ramin Golesorkhi            *
*             February 26, 1988                           *
* ----------------------------------------------------- *
* Shake90/91: Adjust last iteration; Input now is either  *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can   *
*             be specified; object motion can be read in  *
*             from a separate file and can have user      *
*             specified format; Different periods for     *
*             response spectral calculations; options     *
*             are renumbered; and general cleanup         *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim     *
*             June 1990 - February 1991                   *
* ----------------------------------------------------- *
* Shake91   : General cleanup and finalization of input / *
*             output format ... etc                       *
*             by: I. M. Idriss                            *
*             December 1991                               *
* ----------------------------------------------------- *
* Shake98   : Routine for direct calculation of average   *
*             acceleration is added to the program. Out-  *
*             put format is modified to enable the two -  *
*             - page landscape printing.  The following   *
*             modulus reduction and  damping curves are   *
*             added:  Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic  *
*             (1993) for SMB sand; and Vucetic and Dobry  *
*             (1991) for clays of various plasticities.   *
*             by: Neven Matasovic                         *
*             August 1993 - May 1998                      *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OIl Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OIl Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.801	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


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********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0)  (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0)  (Vucetic and Dobry, 1991)
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CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.68
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

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********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:       #5 Modulus for CL (PI=15)  (Vucetic and Dobry, 1991)
CURVE NO. 10:       #5 Damping for CL (PI=15)  (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

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********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:       #6 Modulus for C  (PI=30)  (Vucetic and Dobry, 1991)
CURVE NO. 12:       #6 Damping for C  (PI=30)  (Vucetic and Dobry, 1991)
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CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```

SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 39
DEPTH TO BEDROCK 371.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	13.00	6.50	806.00	1386.	5.00	124.00	600.0
2	6	7.00	16.50	2046.00	2465.	5.00	124.00	800.0
3	6	10.00	25.00	3085.00	3391.	5.00	121.00	950.0
4	6	9.00	34.50	4234.50	4547.	5.00	121.00	1100.0
5	6	9.00	43.50	5323.50	4547.	5.00	121.00	1100.0
6	6	9.00	52.50	6412.50	4547.	5.00	121.00	1100.0
7	5	9.00	61.50	7497.00	4929.	5.00	120.00	1150.0
8	5	9.00	70.50	8577.00	4929.	5.00	120.00	1150.0
9	4	9.00	79.50	9657.00	5823.	5.00	120.00	1250.0
10	4	10.00	89.00	10797.00	5823.	5.00	120.00	1250.0
11	4	10.00	99.00	11997.00	5823.	5.00	120.00	1250.0
12	4	10.00	109.00	13197.00	5823.	5.00	120.00	1250.0
13	4	10.00	119.00	14397.00	5823.	5.00	120.00	1250.0
14	5	10.00	129.00	15617.00	7548.	5.00	124.00	1400.0
15	5	10.00	139.00	16857.00	7548.	5.00	124.00	1400.0
16	5	10.00	149.00	18097.00	7548.	5.00	124.00	1400.0
17	5	10.00	159.00	19337.00	7548.	5.00	124.00	1400.0
18	5	11.00	169.50	20639.00	7548.	5.00	124.00	1400.0
19	5	11.00	180.50	22003.00	7548.	5.00	124.00	1400.0
20	5	10.00	191.00	23315.00	9707.	5.00	126.00	1575.0
21	5	10.00	201.00	24575.00	9707.	5.00	126.00	1575.0
22	5	10.00	211.00	25835.00	9707.	5.00	126.00	1575.0
23	5	10.00	221.00	27095.00	9707.	5.00	126.00	1575.0
24	5	10.00	231.00	28355.00	9707.	5.00	126.00	1575.0
25	5	9.00	240.50	29552.00	9707.	5.00	126.00	1575.0
26	5	9.00	249.50	30686.00	9707.	5.00	126.00	1575.0
27	4	9.00	258.50	31995.50	10043.	5.00	165.00	1400.0
28	4	9.00	267.50	33480.50	10043.	5.00	165.00	1400.0
29	4	9.00	276.50	34965.50	10043.	5.00	165.00	1400.0
30	4	10.00	286.00	36533.00	10043.	5.00	165.00	1400.0
31	4	10.00	296.00	38183.01	10043.	5.00	165.00	1400.0
32	4	10.00	306.00	39833.01	10043.	5.00	165.00	1400.0
33	4	10.00	316.00	41483.01	10043.	5.00	165.00	1400.0
34	4	10.00	326.00	43133.01	10043.	5.00	165.00	1400.0
35	4	10.00	336.00	44783.01	10043.	5.00	165.00	1400.0
36	4	10.00	346.00	46433.02	10043.	5.00	165.00	1400.0
37	4	10.00	356.00	48083.02	10043.	5.00	165.00	1400.0
38	4	10.00	366.00	49733.02	10043.	5.00	165.00	1400.0
39	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.118 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1326.8 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 14.02
FOR FREQUENCY (f) = 1.04 c/sec
FOR PERIOD (1 / f) = .96 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = HBS-wcc.sar
NO. OF INPUT ACCEL. POINTS = 3784
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 6
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0100
FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

HBS-WCC Synthetic Accelerogram for very large earthquakes in near-field;
orig. generated by late Prof. H.B. Seed for Mw 7.5+ eq. on Hayward Fault
This accelerogram was used by USBR for Bradbury Dam, Santa Barbara, 1995

where there is Mw 7.25 @ Santa Inez & Mw 6.75 @ Bind Thrust / near-field
Max. in file 0.75 g; Ds = 19.2 sec
473*8 = 3784 pts. @ 0.01 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	-.000686	.004702	.007918	.012538	.015394	.002460	-.015849	-.033831
2	-.010565	.006040	.021866	.003959	-.025189	-.037765	-.004636	.021600
3	.036423	.015382	-.030232	-.033526	.008350	.046008	.051941	.004820
4	-.025389	-.013775	.011079	.030145	.027728	.018684	-.006837	-.021263
5	-.018395	-.011703	.009715	.015248	.012747	.004127	-.008467	-.012041

..... INPUT MOTION READ NOT ECHOED.....

469	-.321416	-.012910	-.004403	.004102	.012610	.021116	.029622	.038128
470	.036687	.035245	.033804	.032362	.030922	.029478	.028039	.026594
471	.015415	.004232	-.006949	-.016126	-.014140	-.010151	-.006166	-.002176
472	.001812	.005801	.009789	.013777	.017767	.021755	.013475	.005193
473	-.003085	-.011367	-.019647	-.027927	-.036208	-.044487	-.040335	.000000

MAXIMUM ACCELERATION = .750000
AT TIME = 7.75 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .48000000
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.88 c/sec
MAXIMUM ACCELERATION = .361911 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.03148	.060	.050	16.2	1018.7	1386.0	-26.[illegible]	1.000
2	6	16.5	.04219	.067	.050	24.9	1686.1	2464.6	-4[illegible]	1.000
3	6	25.0	.04288	.067	.050	25.4	2313.5	3391.4	-4[illegible]	1.000
4	6	34.5	.03984	.065	.050	23.4	3158.8	4546.9	-4[illegible]	1.000
5	6	43.5	.04545	.068	.050	26.9	3056.7	4546.9	-4[illegible]	1.000
6	6	52.5	.04958	.070	.050	29.0	2989.3	4546.9	-[illegible]	1.000
7	5	61.5	.04786	.093	.050	46.1	2745.1	4928.6	-[illegible]	1.000
8	5	70.5	.05282	.096	.050	47.9	2644.8	4928.6	-[illegible]	1.000
9	4	79.5	.04965	.121	.050	58.8	2255.4	5823.0	-[illegible]	1.000
10	4	89.0	.05493	.126	.050	60.3	2142.4	5823.0	-[illegible]	1.000
11	4	99.0	.06056	.131	.050	61.7	2033.4	5823.0	-[illegible]	1.000
12	4	109.0	.06630	.135	.050	63.9	1932.2	5823.0	-201.4	1.000
13	4	119.0	.07212	.139	.050	64.0	1838.4	5823.0	-[illegible]	1.000
14	5	129.0	.06019	.100	.050	50.1	3847.2	7547.8	-[illegible]	1.000
15	5	139.0	.06452	.103	.050	51.2	3739.1	7547.8	-[illegible]	1.000
16	5	149.0	.06883	.105	.050	52.2	3638.4	7547.8	-[illegible]	1.000
17	5	159.0	.07280	.106	.050	53.0	3551.0	7547.8	-112.4	1.000
18	5	169.5	.07685	.108	.050	53.8	3466.7	7547.8	-[illegible]	1.000
19	5	180.5	.08074	.110	.050	54.5	3385.8	7547.8	-[illegible]	1.000
20	5	191.0	.06546	.103	.050	51.4	4779.7	9706.8	-[illegible]	1.000
21	5	201.0	.06792	.104	.050	52.0	4705.8	9706.8	-[illegible]	1.000
22	5	211.0	.07019	.105	.050	52.5	4639.8	9706.8	-[illegible]	1.000
23	5	221.0	.07230	.106	.050	52.9	4580.5	9706.8	-[illegible]	1.000
24	5	231.0	.07424	.107	.050	53.3	4527.7	9706.8	-[illegible]	1.000
25	5	240.5	.07589	.108	.050	53.6	4483.4	9706.8	-[illegible]	1.000

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Solid Waste Branch

26	5	249.5	.07730	.108	.050	53.9	4446.6	9706.8	-118.3	1.000
27	4	258.5	.07617	.141	.050	64.6	3066.8	10043.5	-227.5	1.000
28	4	267.5	.07757	.142	.050	64.8	3030.4	10043.5	-231.4	1.000
29	4	276.5	.07891	.143	.050	65.0	2997.3	10043.5	-235.1	1.000
30	4	286.0	.08036	.144	.050	65.2	2962.2	10043.5	-239.1	1.000
31	4	296.0	.08186	.145	.050	65.4	2926.5	10043.5	-243.2	1.000
32	4	306.0	.08335	.145	.050	65.6	2892.0	10043.5	-247.3	1.000
33	4	316.0	.08469	.146	.050	65.8	2861.1	10043.5	-251.0	1.000
34	4	326.0	.08587	.147	.050	66.0	2834.6	10043.5	-254.3	1.000
35	4	336.0	.08682	.147	.050	66.1	2813.2	10043.5	-257.0	1.000
36	4	346.0	.08754	.148	.050	66.2	2797.3	10043.5	-259.0	1.000
37	4	356.0	.08808	.148	.050	66.2	2785.6	10043.5	-260.5	1.000
38	4	366.0	.08922	.149	.050	66.4	2760.8	10043.5	-263.8	1.000

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - free-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01765	.049	.060	-22.3	1135.8	1018.7	10.3	.735
2	6	16.5	.02671	.057	.067	-17.7	1872.3	1688.1	9.8	.685
3	6	25.0	.02903	.058	.067	-15.2	2535.7	2313.5	8.8	.682
4	6	34.5	.02878	.058	.065	-12.5	3405.6	3158.8	7.2	.695
5	6	43.5	.03684	.063	.068	-7.9	3219.4	3056.7	5.1	.672
6	6	52.5	.04469	.068	.070	-3.7	3069.8	2989.3	2.6	.657
7	5	61.5	.05558	.098	.093	5.0	2591.2	2745.1	-5.8	.557
8	5	70.5	.06505	.103	.096	6.6	2433.2	2644.8	-8.7	.537
9	4	79.5	.08399	.146	.121	16.9	1668.1	2255.4	-35.2	.387
10	4	89.0	.09702	.153	.126	17.4	1507.0	2142.4	-42.2	.368
11	4	99.0	.11128	.158	.131	17.6	1392.1	2033.4	-46.1	.349
12	4	109.0	.12603	.164	.135	17.7	1297.6	1932.2	-48.9	.332
13	4	119.0	.14119	.168	.139	17.7	1211.3	1838.4	-51.8	.316
14	5	129.0	.07197	.106	.100	5.5	3568.8	3847.2	-7.8	.510
15	5	139.0	.07807	.109	.103	5.7	3442.3	3739.1	-8.6	.495
16	5	149.0	.08424	.111	.105	5.9	3323.9	3638.4	-9.5	.482
17	5	159.0	.09020	.113	.106	6.1	3217.4	3551.0	-10.4	.470
18	5	169.5	.09632	.115	.108	6.3	3115.3	3466.7	-11.3	.459
19	5	180.5	.10237	.118	.110	6.7	3026.9	3389.8	-12.0	.448
20	5	191.0	.07510	.107	.103	4.1	4504.5	4779.7	-6.1	.492
21	5	201.0	.07843	.109	.104	4.3	4417.6	4705.8	-6.5	.485
22	5	211.0	.08155	.110	.105	4.4	4339.4	4639.8	-6.9	.478
23	5	221.0	.08447	.111	.106	4.5	4269.1	4580.5	-7.2	.472
24	5	231.0	.08726	.112	.107	4.7	4204.1	4527.7	-7.7	.466
25	5	240.5	.08991	.113	.108	4.8	4144.2	4483.4	-8.2	.462
26	5	249.5	.09265	.114	.108	5.1	4084.0	4446.6	-8.9	.458
27	4	258.5	.13816	.168	.141	15.7	2117.6	3066.8	-44.8	.305
28	4	267.5	.14335	.169	.142	16.0	2069.5	3030.4	-46.4	.302
29	4	276.5	.14905	.170	.143	16.2	2027.2	2997.3	-47.8	.298
30	4	286.0	.15260	.172	.144	16.3	1987.6	2962.2	-49.0	.295
31	4	296.0	.15673	.173	.145	16.3	1952.7	2926.5	-49.9	.291
32	4	306.0	.16002	.174	.145	16.3	1925.5	2892.0	-50.2	.288
33	4	316.0	.16248	.174	.146	16.1	1905.4	2861.1	-50.2	.285
34	4	326.0	.16384	.175	.147	15.9	1894.6	2834.6	-49.6	.282
35	4	336.0	.16421	.175	.147	15.7	1891.6	2813.2	-48.7	.280
36	4	346.0	.16366	.175	.148	15.4	1895.9	2797.3	-47.5	.279
37	4	356.0	.16247	.174	.148	15.1	1905.5	2785.6	-46.2	.277
38	4	366.0	.16167	.174	.149	14.8	1912.0	2760.8	-44.4	.275

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - free-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01182	.041	.049	-18.2	1215.8	1135.8	6.6	.819
2	6	16.5	.01800	.049	.057	-15.1	2012.2	1872.3	7.0	.760
3	6	25.0	.01985	.051	.058	-14.0	2721.1	2535.7	6.8	.748
4	6	34.5	.02008	.051	.056	-13.2	3640.8	3405.6	6.5	.749
5	6	43.5	.02638	.056	.063	-12.4	3462.6	3219.4	7.0	.708
6	6	52.5	.03289	.061	.068	-12.1	3307.2	3069.8	7.2	.675
7	5	61.5	.04447	.090	.098	-8.1	2819.9	2591.2	8.1	.526
8	5	70.5	.05343	.096	.103	-6.6	2633.2	2433.2	7.6	.494
9	4	79.5	.08506	.146	.146	.4	1653.9	1668.1	-.9	.286
10	4	89.0	.10343	.155	.153	1.8	1447.6	1507.0	-4.1	.259
11	4	99.0	.12189	.162	.158	2.4	1322.9	1392.1	-5.2	.239
12	4	109.0	.14058	.168	.164	2.7	1214.6	1297.6	-6.8	.223
13	4	119.0	.16010	.174	.168	3.0	1115.9	1211.3	-8.6	.208
14	5	129.0	.05852	.099	.106	-6.7	3890.9	3568.8	8.3	.473
15	5	139.0	.06364	.102	.109	-6.5	3780.4	3442.3	8.5	.456
16	5	149.0	.06877	.105	.111	-6.3	3639.6	3323.9	8.7	.440
17	5	159.0	.07379	.107	.113	-6.1	3529.9	3217.4	8.9	.426
18	5	169.5	.07895	.109	.115	-5.9	3424.9	3115.3	9.0	.413
19	5	180.5	.08396	.111	.118	-5.9	3329.0	3026.9	9.1	.401
20	5	191.0	.05832	.099	.107	-8.3	5010.7	4504.5	10.1	.464
21	5	201.0	.06124	.101	.109	-8.0	4913.1	4417.6	10.1	.455
22	5	211.0	.06429	.102	.110	-7.5	4815.8	4339.4	9.9	.447
23	5	221.0	.06729	.104	.111	-7.1	4724.4	4269.1	9.6	.440
24	5	231.0	.07020	.105	.112	-6.7	4639.5	4204.1	9.4	.433
25	5	240.5	.07290	.106	.113	-6.4	4564.0	4144.2	9.2	.427
26	5	249.5	.07546	.108	.114	-6.2	4495.0	4084.0	9.1	.421
27	4	258.5	.14756	.170	.168	1.6	2051.5	2117.6	-4.2	.211
28	4	267.5	.15338	.172	.169	1.7	1980.9	2069.5	-4.5	.206
29	4	276.5	.15832	.173	.170	1.6	1939.4	2027.2	-4.5	.202
30	4	286.0	.16253	.174	.172	1.5	1905.1	1987.6	-4.3	.198
31	4	296.0	.16571	.175	.173	1.3	1879.7	1952.7	-3.9	.194
32	4	306.0	.16745	.176	.174	1.1	1866.0	1925.5	-3.2	.192
33	4	316.0	.16836	.176	.174	.8	1858.9	1905.4	-2.5	.190
34	4	326.0	.17030	.176	.175	.9	1843.9	1894.6	-2.7	.189
35	4	336.0	.17123	.177	.175	1.0	1836.8	1891.6	-3.0	.188
36	4	346.0	.17134	.177	.175	1.1	1835.9	1895.9	-3.3	.188
37	4	356.0	.17094	.177	.174	1.2	1839.0	1905.5	-3.6	.190
38	4	366.0	.17099	.177	.174	1.3	1838.6	1912.0	-4.0	.190

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - free-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01081	.040	.041	-4.2	1233.6	[illegible]	[illegible]	[illegible]
2	6	16.5	.01639	.047	.049	-3.7	2045.4	[illegible]	[illegible]	[illegible]
3	6	25.0	.01812	.049	.051	-3.5	2765.7	[illegible]	[illegible]	[illegible]
4	6	34.5	.01841	.050	.051	-3.3	3697.6	[illegible]	[illegible]	[illegible]
5	6	43.5	.02406	.055	.056	-3.2	3522.5	[illegible]	[illegible]	[illegible]
6	6	52.5	.02999	.059	.061	-3.2	3378.5	[illegible]	[illegible]	[illegible]
7	5	61.5	.04016	.087	.090	-3.8	2923.4	[illegible]	[illegible]	[illegible]
8	5	70.5	.04852	.093	.096	-3.3	2731.1	[illegible]	[illegible]	[illegible]
9	4	79.5	.08410	.146	.146	-.4	1666.7	[illegible]	[illegible]	[illegible]
10	4	89.0	.10555	.156	.155	.5	1432.2	[illegible]	[illegible]	[illegible]
11	4	99.0	.12576	.164	.162	.8	1299.2	[illegible]	[illegible]	[illegible]
12	4	109.0	.14728	.170	.168	1.1	1179.3	[illegible]	[illegible]	[illegible]
13	4	119.0	.17028	.176	.174	1.5	1069.1	[illegible]	[illegible]	[illegible]
14	5	129.0	.05279	.096	.099	-3.5	4051.4	[illegible]	[illegible]	[illegible]
15	5	139.0	.05723	.099	.102	-3.5	3925.6	[illegible]	[illegible]	[illegible]
16	5	149.0	.06166	.101	.105	-3.5	3809.5	[illegible]	[illegible]	[illegible]
17	5	159.0	.06601	.103	.107	-3.5	3703.6	[illegible]	[illegible]	[illegible]

18	5	169.5	.07046	.105	.109	-3.5	3601.8	3424.9	4.9	.454
19	5	180.5	.07494	.107	.111	-3.4	3506.0	3329.0	5.0	.441
20	5	191.0	.05151	.095	.099	-4.2	5259.4	5010.7	4.7	.516
21	5	201.0	.05411	.097	.101	-4.1	5160.7	4913.1	4.8	.506
22	5	211.0	.05695	.098	.102	-4.0	5058.3	4815.8	4.8	.496
23	5	221.0	.05981	.100	.104	-3.8	4960.1	4724.4	4.8	.487
24	5	231.0	.06262	.102	.105	-3.6	4868.3	4639.5	4.7	.478
25	5	240.5	.06522	.103	.106	-3.5	4787.0	4564.0	4.7	.470
26	5	249.5	.06761	.104	.108	-3.4	4715.0	4495.0	4.7	.463
27	4	258.5	.15173	.172	.170	.7	1995.1	2031.5	-1.8	.202
28	4	267.5	.15825	.173	.172	.8	1940.0	1980.9	-2.1	.197
29	4	276.5	.16356	.175	.173	.8	1896.8	1939.4	-2.2	.193
30	4	286.0	.16773	.176	.174	.8	1863.8	1905.1	-2.2	.190
31	4	296.0	.17051	.176	.175	.7	1842.3	1879.7	-2.0	.187
32	4	306.0	.17135	.177	.176	.5	1835.8	1866.0	-1.6	.186
33	4	316.0	.17221	.177	.176	.5	1829.3	1858.9	-1.6	.185
34	4	326.0	.17454	.177	.176	.6	1811.7	1843.9	-1.8	.184
35	4	336.0	.17583	.178	.177	.6	1802.0	1836.8	-1.9	.183
36	4	346.0	.17633	.178	.177	.7	1798.4	1835.9	-2.1	.183
37	4	356.0	.17636	.178	.177	.7	1798.1	1839.0	-2.3	.183
38	4	366.0	.17692	.178	.177	.8	1794.0	1838.6	-2.5	.183

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01052	.039	.040	-1.3	1239.0	1233.6	.4	.890
2	6	16.5	.01593	.047	.047	-1.1	2055.6	2045.4	.5	.830
3	6	25.0	.01761	.049	.049	-1.1	2779.8	2765.7	.5	.816
4	6	34.5	.01790	.049	.050	-1.1	3716.0	3697.6	.5	.813
5	6	43.5	.02336	.054	.055	-1.0	3541.8	3522.5	.5	.775
6	6	52.5	.02901	.058	.059	-1.1	3400.3	3378.5	.6	.743
7	5	61.5	.03829	.086	.087	-1.8	2971.8	2923.4	1.6	.593
8	5	70.5	.04625	.092	.093	-1.7	2780.0	2731.1	1.8	.554
9	4	79.5	.08239	.145	.146	-.7	1689.6	1666.7	1.4	.286
10	4	89.0	.10528	.156	.158	-.1	1434.2	1432.2	.1	.246
11	4	99.0	.12639	.164	.164	.1	1295.4	1299.2	-.3	.223
12	4	109.0	.14972	.171	.170	.4	1166.8	1179.3	-1.1	.203
13	4	119.0	.17533	.178	.176	.7	1047.0	1069.1	-2.1	.184
14	5	129.0	.05012	.094	.096	-1.8	4132.0	4051.4	2.0	.537
15	5	139.0	.05419	.097	.099	-1.8	4010.7	3925.6	2.1	.520
16	5	149.0	.05821	.099	.101	-1.9	3899.2	3809.5	2.3	.505
17	5	159.0	.06216	.101	.103	-1.9	3797.1	3703.6	2.5	.491
18	5	169.5	.06620	.103	.105	-2.0	3699.0	3601.8	2.6	.477
19	5	180.5	.07031	.105	.107	-2.0	3605.1	3506.0	2.7	.465
20	5	191.0	.04851	.093	.095	-2.1	5379.4	5259.4	2.2	.542
21	5	201.0	.05094	.095	.097	-2.1	5281.8	5160.7	2.3	.532
22	5	211.0	.05362	.097	.098	-2.0	5178.8	5058.3	2.3	.521
23	5	221.0	.05636	.098	.100	-2.0	5079.2	4960.1	2.3	.511
24	5	231.0	.05905	.100	.102	-1.9	4985.8	4868.3	2.4	.502
25	5	240.5	.06155	.101	.103	-1.9	4903.0	4787.0	2.4	.493
26	5	249.5	.06383	.102	.104	-1.8	4830.1	4715.0	2.4	.486
27	4	258.5	.15296	.172	.172	.2	1984.5	1995.1	-.5	.199
28	4	267.5	.16008	.174	.173	.3	1925.0	1940.0	-.8	.193
29	4	276.5	.16568	.175	.175	.3	1879.9	1896.8	-.9	.189
30	4	286.0	.16997	.176	.176	.3	1846.4	1863.8	-.9	.186
31	4	296.0	.17252	.177	.176	.3	1827.0	1842.3	-.8	.183
32	4	306.0	.17294	.177	.177	.2	1823.8	1835.8	-.7	.183
33	4	316.0	.17457	.177	.177	.3	1811.5	1829.3	-1.0	.182
34	4	326.0	.17710	.178	.177	.3	1792.6	1811.7	-1.1	.180
35	4	336.0	.17867	.178	.178	.4	1781.1	1802.0	-1.2	.179
36	4	346.0	.17935	.179	.178	.4	1776.1	1798.4	-1.3	.179
37	4	356.0	.17965	.179	.178	.4	1773.9	1798.1	-1.4	.179
38	4	366.0	.18056	.179	.178	.5	1767.3	1794.0	-1.5	.179

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01040	.039	.039	-.5	1241.2	1239.0	.2	.894
2	6	16.5	.01574	.047	.047	-.5	2059.7	2055.6	.2	.834
3	6	25.0	.01740	.049	.049	-.5	2785.5	2779.8	.2	.820
4	6	34.5	.01769	.049	.049	-.5	3723.7	3716.0	.2	.817
5	6	43.5	.02308	.054	.054	-.4	3550.0	3541.8	.2	.779
6	6	52.5	.02862	.058	.058	-.4	3409.1	3400.3	.3	.746
7	5	61.5	.03742	.085	.086	-.9	2995.2	2971.8	.8	.603
8	5	70.5	.04514	.091	.092	-.9	2804.6	2780.0	.9	.564
9	4	79.5	.08069	.144	.145	-.7	1712.8	1689.6	1.4	.290
10	4	89.0	.10437	.156	.156	-.3	1440.7	1434.2	.5	.246
11	4	99.0	.12584	.164	.164	-.1	1298.8	1295.4	.3	.222
12	4	109.0	.15021	.171	.171	.1	1164.4	1166.8	-.2	.200
13	4	119.0	.17771	.178	.178	.3	1036.7	1047.0	-1.0	.180
14	5	129.0	.04884	.093	.094	-.9	4172.6	4132.0	1.0	.547
15	5	139.0	.05270	.096	.097	-.9	4054.1	4010.7	1.1	.531
16	5	149.0	.05651	.098	.099	-1.0	3945.4	3899.2	1.2	.517
17	5	159.0	.06024	.100	.101	-1.0	3845.9	3797.1	1.3	.503
18	5	169.5	.06405	.102	.103	-1.0	3750.3	3699.0	1.4	.490
19	5	180.5	.06796	.104	.105	-1.1	3658.1	3605.1	1.4	.478
20	5	191.0	.04714	.092	.093	-1.0	5436.6	5379.4	1.1	.554
21	5	201.0	.04948	.094	.095	-1.0	5340.0	5281.8	1.1	.544
22	5	211.0	.05208	.096	.097	-1.0	5237.4	5178.8	1.1	.534
23	5	221.0	.05473	.097	.098	-1.0	5137.9	5079.2	1.1	.525
24	5	231.0	.05735	.099	.100	-1.0	5044.3	4985.8	1.2	.517
25	5	240.5	.05978	.100	.101	-.9	4961.2	4903.0	1.2	.509
26	5	249.5	.06200	.101	.102	-.9	4888.3	4830.1	1.2	.502
27	4	258.5	.15304	.172	.172	.0	1983.8	1984.5	.0	.198
28	4	267.5	.16057	.174	.174	.1	1921.0	1925.0	-.2	.192
29	4	276.5	.16640	.175	.175	.1	1874.2	1879.9	-.3	.187
30	4	286.0	.17084	.176	.176	.1	1839.8	1846.4	-.4	.184
31	4	296.0	.17326	.177	.177	.1	1821.4	1827.0	-.3	.182
32	4	306.0	.17389	.177	.177	.1	1816.6	1823.8	-.4	.182
33	4	316.0	.17608	.178	.177	.2	1800.2	1811.5	-.6	.181
34	4	326.0	.17873	.178	.178	.2	1780.6	1792.6	-.7	.178
35	4	336.0	.18048	.179	.178	.2	1767.9	1781.1	-.7	.177
36	4	346.0	.18124	.179	.179	.2	1762.4	1776.1	-.8	.177
37	4	356.0	.18174	.179	.179	.3	1758.8	1773.9	-.9	.177
38	4	366.0	.18287	.179	.179	.3	1750.7	1767.3	-.9	.176

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01034	.039	.039	-.3	1242.4	1241.2	.1	.895
2	6	16.5	.01565	.047	.047	-.2	2061.9	2059.7	.1	.836
3	6	25.0	.01729	.048	.049	-.2	2788.5	2785.5	.1	.821
4	6	34.5	.01758	.049	.049	-.2	3727.8	3723.7	.1	.819
5	6	43.5	.02292	.054	.054	-.2	3554.3	3550.0	.1	.781
6	6	52.5	.02843	.058	.058	-.2	3413.5	3409.1	.1	.750
7	5	61.5	.03697	.084	.085	-.5	3007.4	2995.2	.4	.606
8	5	70.5	.04456	.091	.091	-.5	2817.7	2804.6	.5	.569
9	4	79.5	.07926	.143	.144	-.6	1732.9	1712.8	1.2	.294

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10	4	89.0	.10344	.155	.156	-.2	1447.6	1440.7	.5	.247
11	4	99.0	.12496	.163	.164	-.2	1304.0	1298.8	.4	.223
12	4	109.0	.14986	.171	.171	-.1	1166.1	1164.4	.1	.200
13	4	119.0	.17866	.178	.178	.1	1032.7	1036.7	-.4	.178
14	5	129.0	.04818	.093	.093	-.5	4193.7	4172.6	.5	.553
15	5	139.0	.05194	.095	.096	-.5	4076.7	4054.1	.6	.537
16	5	149.0	.05564	.098	.098	-.5	3969.5	3945.4	.6	.523
17	5	159.0	.05926	.100	.100	-.5	3871.4	3845.9	.7	.510
18	5	169.5	.06296	.102	.102	-.2	3777.2	3750.3	.9	.497
19	5	180.5	.06675	.104	.104	-.2	3686.1	3658.1	.8	.485
20	5	191.0	.04649	.092	.092	-.5	5464.5	5436.6	.5	.560
21	5	201.0	.04878	.093	.094	-.5	5368.4	5340.0	.5	.550
22	5	211.0	.05133	.095	.096	-.5	5266.3	5237.4	.5	.540
23	5	221.0	.05394	.097	.097	-.5	5167.0	5137.9	.6	.529
24	5	231.0	.05652	.098	.099	-.5	5073.5	5044.3	.6	.520
25	5	240.5	.05891	.100	.100	-.5	4990.5	4961.2	.6	.511
26	5	249.5	.06110	.101	.101	-.5	4917.5	4888.3	.6	.504
27	4	258.5	.15270	.172	.172	-.1	1986.7	1983.8	.1	.198
28	4	267.5	.16051	.174	.174	.0	1921.4	1921.0	.0	.191
29	4	276.5	.16654	.175	.175	.0	1873.1	1874.2	-.1	.187
30	4	286.0	.17109	.177	.176	.0	1837.8	1839.8	-.1	.183
31	4	296.0	.17344	.177	.177	.0	1819.9	1821.4	-.1	.181
32	4	306.0	.17453	.177	.177	.1	1811.8	1816.6	-.3	.181
33	4	316.0	.17711	.178	.178	.1	1792.6	1800.2	-.4	.179
34	4	326.0	.17983	.179	.178	.1	1772.6	1780.6	-.5	.177
35	4	336.0	.18168	.179	.179	.2	1759.2	1767.9	-.5	.176
36	4	346.0	.18248	.179	.179	.2	1753.5	1762.4	-.5	.175
37	4	356.0	.18309	.179	.179	.2	1749.1	1758.8	-.6	.175
38	4	366.0	.18435	.180	.179	.2	1740.1	1750.7	-.6	.174

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN ( )	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	13.0	6.5	.01567	194.49	.24130	3.81
2	6	7.0	16.5	.02371	488.32	.23867	3.81
3	6	10.0	25.0	.02620	729.76	.23655	3.81
4	6	9.0	34.5	.02664	981.92	.23425	3.81
5	6	9.0	43.5	.03473	1232.99	.23161	3.82
6	6	9.0	52.5	.04307	1468.40	.22899	3.82
7	5	9.0	61.5	.05602	1677.95	.22382	3.83
8	5	9.0	70.5	.06751	1863.52	.22077	3.83
9	4	9.0	79.5	.12009	2056.96	.21300	3.86
10	4	10.0	89.0	.15672	2257.95	.20913	3.86
11	4	10.0	99.0	.18934	2459.00	.20497	3.87
12	4	10.0	109.0	.22707	2643.86	.20034	3.88
13	4	10.0	119.0	.27069	2806.39	.19453	3.89
14	5	10.0	129.0	.07300	3045.83	.19503	3.86
15	5	10.0	139.0	.07869	3180.23	.18925	3.86
16	5	10.0	149.0	.08430	3326.05	.18379	3.86
17	5	10.0	159.0	.08978	3453.04	.17857	3.86
18	5	11.0	169.5	.09539	3577.41	.17233	3.86
19	5	11.0	180.5	.10114	3699.74	.16815	3.87
20	5	10.0	191.0	.07044	3829.85	.16427	3.87
21	5	10.0	201.0	.07391	3946.65	.16060	3.90
22	5	10.0	211.0	.07777	4073.42	.15767	3.91
23	5	10.0	221.0	.08173	4199.19	.15498	3.91
24	5	10.0	231.0	.08564	4319.83	.15235	3.91
25	5	9.0	240.5	.08926	4428.63	.14986	3.91
26	5	9.0	249.5	.09258	4525.36	.14747	3.91
27	4	9.0	258.5	.23137	4590.01	.14346	3.93
28	4	9.0	267.5	.24320	4671.72	.13954	3.92
29	4	9.0	276.5	.25234	4729.36	.13526	3.92
30	4	10.0	286.0	.25923	4769.33	.13055	3.91
31	4	10.0	296.0	.26280	4786.50	.12536	3.90
32	4	10.0	306.0	.26443	4803.59	.12059	3.19
33	4	10.0	316.0	.26834	4830.65	.11645	3.17
34	4	10.0	326.0	.27248	4851.85	.11249	3.16
35	4	10.0	336.0	.27528	4866.58	.10867	3.14
36	4	10.0	346.0	.27648	4872.71	.10494	3.13

37	4	10.0	356.0	.27740	4876.98	.10147	3.11
38	4	10.0	366.0	.27932	4889.93	.09832	3.09

PERIOD = 1.820 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 815.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 3.82
FOR FREQUENCY (f) = .51 c/sec
FOR PERIOD (1 / f) = 1.98 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - HBS-wcc.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.24520	3.80	1.21	.130	512
WITHIN	13.0	.24107	3.80	1.11	.128	0
WITHIN	20.0	.23771	3.80	1.04	.127	0
WITHIN	30.0	.23257	3.81	.97	.126	0
WITHIN	39.0	.22822	3.81	.92	.125	0
WITHIN	48.0	.22287	3.81	.89	.125	0
WITHIN	57.0	.21749	3.83	.86	.123	0
WITHIN	66.0	.21199	3.84	.86	.119	0
WITHIN	75.0	.20637	3.85	.88	.113	0
WITHIN	84.0	.19634	3.86	.96	.104	0
WITHIN	94.0	.18327	3.88	1.11	.097	0
WITHIN	104.0	.16832	3.88	1.26	.104	0
WITHIN	114.0	.14933	3.87	1.39	.121	0
WITHIN	124.0	.14857	8.06	1.53	.135	0
WITHIN	134.0	.15143	8.06	1.54	.131	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - HBS-wcc.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	196.0	.13485	8.00	1.45	.137	0
WITHIN	371.0	.33623	7.75	3.97	.125	0
OUTCR.	371.0	.36181	7.75	3.96	.122	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 21

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 21

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85     : IBM-PC version of SHAKE                  *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88     : New modulus reduction curves for clays   *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Romin Golesorkhi           *
*             February 26, 1988                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; Input now is either *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & P. Birrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91     : General cleanup and finalization of input /
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake99     : Routine for direct calculation of average *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing. The following   *
*             modulus reduction and damping curves are   *
*             added: Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for EMB sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1993 - May 1995                     *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =     4096
NECESSARY LENGTH OF BLANK COMMON X         =    25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.984	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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MAR 08 2012
Division of Waste Management
Solid Waste Branch

SOIL PROFILE NO. 1 **Paducah U Landfill - fee-field prof**

NUMBER OF LAYERS 39
DEPTH TO BEDROCK 371.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	13.00	6.50	806.00	1386.	5.00	124.00	600.0
2	6	7.00	16.50	2046.00	2465.	5.00	124.00	800.0
3	6	10.00	25.00	3085.00	3391.	5.00	121.00	950.0
4	6	9.00	34.50	4234.50	4547.	5.00	121.00	1100.0
5	6	9.00	43.50	5323.50	4547.	5.00	121.00	1100.0
6	6	9.00	52.50	6412.50	4547.	5.00	121.00	1100.0
7	5	9.00	61.50	7497.00	4929.	5.00	120.00	1150.0
8	5	9.00	70.50	8577.00	4929.	5.00	120.00	1150.0
9	4	9.00	79.50	9657.00	5823.	5.00	120.00	1250.0
10	4	10.00	89.00	10797.00	5823.	5.00	120.00	1250.0
11	4	10.00	99.00	11997.00	5823.	5.00	120.00	1250.0
12	4	10.00	109.00	13197.00	5823.	5.00	120.00	1250.0
13	4	10.00	119.00	14397.00	5823.	5.00	120.00	1250.0
14	5	10.00	129.00	15617.00	7548.	5.00	124.00	1400.0
15	5	10.00	139.00	16857.00	7548.	5.00	124.00	1400.0
16	5	10.00	149.00	18097.00	7548.	5.00	124.00	1400.0
17	5	10.00	159.00	19337.00	7548.	5.00	124.00	1400.0
18	5	11.00	169.50	20639.00	7548.	5.00	124.00	1400.0
19	5	11.00	180.50	22003.00	7548.	5.00	124.00	1400.0
20	5	10.00	191.00	23315.00	9707.	5.00	126.00	1575.0
21	5	10.00	201.00	24575.00	9707.	5.00	126.00	1575.0
22	5	10.00	211.00	25835.00	9707.	5.00	126.00	1575.0
23	5	10.00	221.00	27095.00	9707.	5.00	126.00	1575.0
24	5	10.00	231.00	28355.00	9707.	5.00	126.00	1575.0
25	5	9.00	240.50	29552.00	9707.	5.00	126.00	1575.0
26	5	9.00	249.50	30686.00	9707.	5.00	126.00	1575.0
27	4	9.00	258.50	31995.50	10043.	5.00	165.00	1400.0
28	4	9.00	267.50	33480.50	10043.	5.00	165.00	1400.0
29	4	9.00	276.50	34965.50	10043.	5.00	165.00	1400.0
30	4	10.00	286.00	36533.00	10043.	5.00	165.00	1400.0
31	4	10.00	296.00	38183.01	10043.	5.00	165.00	1400.0
32	4	10.00	306.00	39833.01	10043.	5.00	165.00	1400.0
33	4	10.00	316.00	41483.01	10043.	5.00	165.00	1400.0
34	4	10.00	326.00	43133.01	10043.	5.00	165.00	1400.0
35	4	10.00	336.00	44783.01	10043.	5.00	165.00	1400.0
36	4	10.00	346.00	46433.02	10043.	5.00	165.00	1400.0
37	4	10.00	356.00	48083.02	10043.	5.00	165.00	1400.0
38	4	10.00	366.00	49733.02	10043.	5.00	165.00	1400.0
39	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.118 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1326.8 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 14.02
FOR FREQUENCY (f) = 1.04 c/sec
FOR PERIOD (1 / f) = .96 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = mag8eq.sar
NO. OF INPUT ACCEL. POINTS = 3760
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 3
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200
FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

Seed and Idriss (1969) M 6.25 Eq.(for rock sites approx. 70 mi. from S.A
Max. in file = 0.60 g @ 25.92 sec (originally 0.42 g); Mean Sq. Freq = 3
8 * 470 = 3760 pts. @ 0.02 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	.062761	.073796	.074938	.075872	.062602	.052252	.051858	.044955
2	.031522	.027570	.023296	.023945	.022443	.021225	.012130	.003501
3	.001423	-.017165	-.026398	-.031722	-.038444	-.049085	-.061570	-.073038
4	-.084124	-.092176	-.100385	-.082172	-.062311	-.025014	-.017026	-.011280
5	-.017022	-.018943	-.021842	-.029682	-.035054	-.030838	-.029899	-.026261

..... INPUT MOTION READ NOT ECHOED.....

466	-.031961	-.008844	-.002331	.003973	.052467	.056858	.060505	.062610
467	.063975	.065884	.067351	.069606	.070892	.072492	.070844	.065096
468	.060221	.057258	.054201	.051875	.049411	.043016	.034124	.029108
469	.024519	.010956	-.004150	-.024819	-.030046	-.034114	-.036601	-.037012
470	-.034063	-.029237	-.018126	.001685	.002426	.002465	.000067	-.002264

MAXIMUM ACCELERATION = .600000
AT TIME = 25.92 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .60000000
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.12 c/sec
MAXIMUM ACCELERATION = .360000 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - mag8eq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.02544	.056	.050	10.2	1062.9	1386.3	-30.4	1.000
2	6	16.5	.03547	.062	.050	20.0	1760.9	2464.6	-40.0	1.000
3	6	25.0	.03744	.064	.050	21.6	2391.5	3351.4	-41.8	1.000
4	6	34.5	.03621	.063	.050	20.6	3232.6	4546.9	-40.7	1.000
5	6	43.5	.04351	.067	.050	25.8	3090.5	4546.9	-47.1	1.000
6	6	52.5	.05111	.071	.050	29.8	2965.8	4546.9	-53.3	1.000
7	5	61.5	.05423	.097	.050	48.4	2618.1	4928.6	-88.2	1.000
8	5	70.5	.06109	.101	.050	50.4	2497.1	4928.6	-97.4	1.000
9	4	79.5	.05694	.128	.050	60.8	2102.3	5823.0	-177.0	1.000
10	4	89.0	.06172	.131	.050	62.0	2012.2	5823.0	-189.4	1.000
11	4	99.0	.06652	.135	.050	62.9	1928.6	5823.0	-201.9	1.000
12	4	109.0	.07045	.138	.050	63.7	1864.4	5823.0	-212.3	1.000
13	4	119.0	.07332	.139	.050	64.2	1819.9	5823.0	-220.0	1.000
14	5	129.0	.05925	.100	.050	49.9	3871.6	7547.8	-95.9	1.000
15	5	139.0	.06207	.101	.050	50.6	3799.3	7547.8	-98.7	1.000
16	5	149.0	.06452	.103	.050	51.2	3739.0	7547.8	-101.9	1.000
17	5	159.0	.06657	.104	.050	51.7	3690.3	7547.8	-104.5	1.000
18	5	169.5	.06827	.104	.050	52.1	3651.0	7547.8	-106.7	1.000
19	5	180.5	.06957	.105	.050	52.4	3621.7	7547.8	-108.4	1.000
20	5	191.0	.05617	.098	.050	48.0	5085.8	9706.8	-90.9	1.000
21	5	201.0	.05849	.099	.050	49.7	5005.1	9706.8	-93.5	1.000
22	5	211.0	.06066	.101	.050	50.3	4932.1	9706.8	-96.8	1.000
23	5	221.0	.06264	.102	.050	50.8	4867.7	9706.8	-99.4	1.000
24	5	231.0	.06439	.102	.050	51.2	4812.7	9706.8	-101.7	1.000
25	5	240.5	.06581	.103	.050	51.5	4768.8	9706.8	-103.5	1.000
26	5	249.5	.06685	.104	.050	51.8	4734.5	9706.8	-105.0	1.000
27	4	258.5	.06573	.134	.050	63.8	3349.6	10043.5	-158.6	1.000
28	4	267.5	.06662	.135	.050	63.0	3323.5	10043.5	-202.2	1.000

29	4	276.5	.06724	.135	.050	63.1	3305.7	10043.5	-203.8	1.000
30	4	286.0	.06761	.136	.050	63.1	3295.2	10043.5	-204.8	1.000
31	4	296.0	.06776	.136	.050	63.2	3290.8	10043.5	-205.2	1.000
32	4	306.0	.06774	.136	.050	63.2	3291.4	10043.5	-205.1	1.000
33	4	316.0	.06745	.136	.050	63.1	3299.7	10043.5	-204.4	1.000
34	4	326.0	.06652	.135	.050	63.0	3314.8	10043.5	-203.0	1.000
35	4	336.0	.06723	.135	.050	63.1	3305.9	10043.5	-203.8	1.000
36	4	346.0	.06866	.136	.050	63.3	3265.4	10043.5	-207.6	1.000
37	4	356.0	.06996	.137	.050	63.6	3229.3	10043.5	-211.0	1.000
38	4	366.0	.07138	.138	.050	63.8	3190.7	10043.5	-214.8	1.000

ACCELEROGRAM - magReq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01557	.046	.056	-19.0	1160.8	1062.9	8.4	.767
2	6	16.5	.02345	.054	.062	-15.3	1918.5	1760.9	8.2	.714
3	6	25.0	.02553	.056	.064	-14.2	2598.4	2391.9	8.0	.705
4	6	34.5	.02533	.056	.063	-13.2	3489.1	3232.6	7.3	.711
5	6	43.5	.03257	.060	.067	-11.5	3314.8	3090.5	6.8	.680
6	6	52.5	.03986	.065	.072	-9.1	3158.2	2965.8	6.1	.652
7	5	61.5	.05144	.095	.097	-1.8	2671.8	2618.1	2.0	.531
8	5	70.5	.05961	.100	.101	-.8	2522.0	2497.1	1.0	.507
9	4	79.5	.07660	.142	.128	9.8	1771.0	2102.3	-18.7	.361
10	4	89.0	.08540	.147	.131	10.4	1649.5	2012.2	-22.0	.346
11	4	99.0	.09846	.153	.135	12.0	1490.5	1928.6	-29.4	.331
12	4	109.0	.11083	.158	.138	13.1	1395.1	1864.4	-33.6	.320
13	4	119.0	.12242	.162	.139	14.2	1319.7	1819.9	-37.9	.313
14	5	129.0	.06058	.100	.100	.7	3837.2	3871.6	-.9	.513
15	5	139.0	.06581	.103	.101	1.8	3708.2	3799.3	-2.5	.503
16	5	149.0	.07060	.105	.103	2.8	3598.7	3739.0	-3.9	.495
17	5	159.0	.07509	.107	.104	3.6	3502.9	3690.3	-5.4	.489
18	5	169.5	.07929	.109	.104	4.4	3418.2	3651.0	-6.8	.484
19	5	180.5	.08276	.111	.105	5.1	3351.5	3621.7	-8.1	.480
20	5	191.0	.06025	.100	.098	2.3	4945.7	5085.8	-2.8	.524
21	5	201.0	.06256	.102	.099	2.1	4870.3	5005.1	-2.8	.516
22	5	211.0	.06470	.103	.101	2.0	4803.1	4932.1	-2.7	.508
23	5	221.0	.06652	.103	.102	1.9	4747.4	4867.7	-2.5	.501
24	5	231.0	.06976	.105	.102	2.5	4652.3	4812.7	-3.4	.496
25	5	240.5	.07291	.106	.103	3.1	4563.8	4768.8	-4.5	.491
26	5	249.5	.07576	.108	.104	3.7	4487.1	4734.5	-5.5	.488
27	4	258.5	.10984	.158	.138	14.9	2418.1	3349.6	-38.5	.334
28	4	267.5	.11434	.160	.135	15.4	2365.5	3323.5	-40.5	.331
29	4	276.5	.11758	.161	.135	15.8	2326.9	3305.7	-41.9	.329
30	4	286.0	.12087	.162	.136	16.2	2292.9	3295.2	-43.7	.328
31	4	296.0	.12369	.163	.136	16.7	2262.7	3290.8	-45.4	.328
32	4	306.0	.12587	.164	.136	17.0	2239.8	3291.4	-47.0	.328
33	4	316.0	.12717	.164	.136	17.4	2226.2	3299.7	-48.2	.329
34	4	326.0	.12733	.164	.135	17.6	2224.6	3314.8	-49.0	.330
35	4	336.0	.12748	.164	.135	17.5	2223.1	3305.9	-48.7	.329
36	4	346.0	.12832	.164	.136	17.1	2214.5	3265.4	-47.5	.325
37	4	356.0	.12964	.165	.137	16.7	2201.1	3229.3	-46.7	.322
38	4	366.0	.13238	.166	.138	16.6	2173.7	3190.7	-46.8	.318

ACCELEROGRAM - magReq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO

1	6	6.5	.01211	.042	.046	-11.3	1211.0	1160.8	4.1	.837
2	6	16.5	.01834	.050	.054	-9.3	2005.7	1918.5	4.3	.778
3	6	25.0	.02011	.051	.056	-8.7	2714.8	2598.4	4.3	.766
4	6	34.5	.02019	.051	.056	-8.3	3637.3	3489.1	4.1	.767
5	6	43.5	.02622	.056	.060	-7.4	3466.4	3314.8	4.4	.729
6	6	52.5	.03245	.060	.065	-8.2	3317.6	3158.2	4.8	.695
7	5	61.5	.04357	.090	.095	-6.0	2840.5	2671.8	5.6	.542
8	5	70.5	.05196	.095	.100	-4.7	2661.5	2522.0	5.2	.512
9	4	79.5	.08361	.146	.142	2.8	1673.1	1771.0	-5.9	.304
10	4	89.0	.09901	.154	.147	4.5	1484.3	1649.5	-11.1	.283
11	4	99.0	.11990	.162	.153	5.2	1335.4	1490.5	-11.6	.256
12	4	109.0	.13811	.168	.158	5.5	1228.1	1395.1	-13.4	.240
13	4	119.0	.15513	.172	.162	5.8	1139.9	1319.7	-15.8	.227
14	5	129.0	.05594	.098	.100	-2.6	3961.2	3837.2	3.1	.508
15	5	139.0	.06070	.101	.103	-2.6	3834.1	3708.2	3.3	.491
16	5	149.0	.06529	.103	.105	-2.5	3720.5	3598.7	3.3	.477
17	5	159.0	.06966	.105	.107	-2.3	3619.6	3502.9	3.2	.464
18	5	169.5	.07391	.107	.109	-2.1	3527.5	3418.2	3.1	.453
19	5	180.5	.07777	.109	.111	-1.9	3448.2	3351.5	2.9	.444
20	5	191.0	.05402	.097	.100	-3.7	5164.0	4845.7	4.2	.510
21	5	201.0	.05602	.098	.102	-3.6	5091.2	4870.3	4.5	.502
22	5	211.0	.05782	.099	.103	-3.7	5027.8	4803.1	4.5	.495
23	5	221.0	.05933	.100	.103	-3.7	4976.3	4747.4	4.4	.489
24	5	231.0	.06117	.101	.105	-4.2	4915.3	4652.3	5.4	.479
25	5	240.5	.06277	.102	.106	-4.8	4863.4	4563.8	6.2	.470
26	5	249.5	.06506	.103	.108	-4.8	4791.9	4487.1	6.4	.462
27	4	258.5	.12188	.162	.158	2.7	2281.9	2418.1	-6.0	.241
28	4	267.5	.12724	.164	.160	2.7	2225.6	2365.5	-6.[illegible]	.236
29	4	276.5	.13075	.165	.161	2.7	2190.0	2328.9	-6.[illegible]	.232
30	4	286.0	.13399	.166	.162	2.6	2157.9	2292.9	-6.[illegible]	.228
31	4	296.0	.13590	.167	.163	2.4	2139.3	2262.7	-5.5	.225
32	4	306.0	.13815	.168	.164	2.3	2117.9	2239.8	-5.6	.223
33	4	316.0	.13911	.168	.164	2.2	2108.8	2226.2	-5.4	.222
34	4	326.0	.14407	.169	.164	3.1	2062.9	2224.6	-7.8	.222
35	4	336.0	.15126	.171	.164	4.2	1999.1	2223.1	-11.1	.221
36	4	346.0	.15795	.173	.164	5.0	1942.5	2214.5	-14.0	.220
37	4	356.0	.16399	.175	.165	5.6	1893.4	2201.1	-16.3	.219
38	4	366.0	.17135	.177	.166	6.1	1835.8	2173.7	-18.4	.216

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ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01076	.040	.042	-5.6	1234.4	1211.0	1.9	.874
2	6	16.5	.01624	.047	.050	-4.8	2048.7	2005.7	2.1	.814
3	6	25.0	.01782	.049	.051	-4.6	2771.5	2714.8	2.1	.801
4	6	34.5	.01794	.049	.051	-4.5	3714.7	3637.3	2.1	.800
5	6	43.5	.02321	.054	.056	-4.2	3546.2	3466.4	2.3	.762
6	6	52.5	.02880	.058	.060	-4.2	3409.7	3317.6	2.7	.730
7	5	61.5	.03791	.085	.090	-5.3	2981.5	2840.5	4.9	.576
8	5	70.5	.04579	.091	.095	-4.5	2790.1	2661.5	4.8	.540
9	4	79.5	.08207	.145	.146	-.6	1693.9	1673.1	1.2	.287
10	4	89.0	.10190	.155	.154	.8	1458.8	1484.3	-1.7	.255
11	4	99.0	.12327	.163	.162	.7	1314.4	1335.4	-1.6	.228
12	4	109.0	.14401	.169	.168	1.0	1196.3	1228.1	-2.7	.211
13	4	119.0	.16459	.175	.172	1.4	1094.9	1139.9	-4.1	.196
14	5	129.0	.04963	.094	.098	-4.1	4147.4	3961.2	4.5	.525
15	5	139.0	.05256	.096	.101	-4.2	4028.8	3834.1	4.8	.508
16	5	149.0	.05747	.099	.103	-4.2	3819.1	3720.5	5.1	.493
17	5	159.0	.06134	.101	.105	-4.1	3817.7	3619.6	5.1	.480
18	5	169.5	.06525	.103	.107	-3.9	3721.6	3527.5	5.1	.467
19	5	180.5	.06902	.105	.109	-3.7	3634.0	3448.2	5.1	.457
20	5	191.0	.04736	.092	.097	-4.6	5427.5	5164.0	4.9	.532

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21	5	201.0	.04914	.094	.098	-4.5	5353.5	5091.2	4.9	.524
22	5	211.0	.05071	.095	.099	-4.5	5290.5	5027.8	5.0	.518
23	5	221.0	.05200	.096	.100	-4.5	5240.4	4976.3	5.0	.513
24	5	231.0	.05340	.096	.101	-4.6	5187.1	4915.3	5.2	.506
25	5	240.5	.05548	.098	.102	-4.1	5110.8	4863.4	4.8	.501
26	5	249.5	.05753	.099	.103	-4.0	5038.1	4791.9	4.5	.494
27	4	258.5	.12065	.162	.162	-.3	2295.2	2281.9	.6	.227
28	4	267.5	.12580	.164	.164	-.4	2243.6	2225.6	.8	.222
29	4	276.5	.12854	.165	.165	-.4	2212.3	2190.0	1.0	.218
30	4	266.0	.13119	.165	.166	-.5	2185.6	2157.9	1.3	.215
31	4	296.0	.13317	.166	.167	-.5	2165.9	2139.3	1.2	.213
32	4	306.0	.13450	.166	.168	-.7	2152.9	2117.9	1.6	.211
33	4	316.0	.13784	.167	.168	-.2	2120.8	2108.8	.6	.210
34	4	326.0	.14745	.170	.169	.6	2032.5	2062.9	-1.5	.205
35	4	336.0	.15849	.173	.171	1.1	1938.0	1999.1	-3.2	.199
36	4	346.0	.16926	.176	.173	1.6	1851.9	1942.5	-4.9	.192
37	4	356.0	.17896	.178	.175	2.1	1779.0	1893.4	-6.4	.189
38	4	366.0	.18808	.181	.177	2.2	1713.9	1835.9	-7.1	.183

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ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01034	.039	.040	-1.9	1242.3	1234.4	.6	.890
2	6	16.5	.01559	.046	.047	-1.7	2063.3	2048.7	.7	.831
3	6	25.0	.01711	.049	.049	-1.6	2793.7	2773.9	.7	.818
4	6	34.5	.01724	.048	.049	-1.5	3740.6	3714.7	.7	.817
5	6	43.5	.02229	.053	.054	-1.4	3572.7	3546.2	.7	.780
6	6	52.5	.02735	.057	.058	-1.5	3438.8	3409.7	.8	.750
7	5	61.5	.03549	.083	.085	-2.6	3049.3	2981.9	2.2	.605
8	5	70.5	.04315	.089	.091	-2.1	2850.4	2790.1	2.1	.566
9	4	79.5	.08009	.144	.145	-.8	1721.2	1693.9	1.6	.291
10	4	89.0	.10247	.155	.155	.2	1454.7	1458.9	-.3	.251
11	4	99.0	.12376	.163	.163	.1	1311.4	1314.4	-.2	.226
12	4	109.0	.14584	.170	.169	.9	1186.7	1196.3	-.8	.205
13	4	119.0	.16895	.176	.175	.6	1075.1	1094.9	-1.8	.188
14	5	129.0	.04673	.092	.094	-2.1	4241.2	4147.4	2.2	.549
15	5	139.0	.05022	.094	.096	-2.2	4128.9	4028.8	2.4	.534
16	5	149.0	.05372	.097	.099	-2.3	4024.2	3919.1	2.6	.519
17	5	159.0	.05727	.099	.101	-2.3	3924.6	3817.7	2.7	.506
18	5	169.5	.06092	.101	.103	-2.2	3828.4	3721.6	2.8	.493
19	5	180.5	.06455	.103	.105	-2.1	3738.2	3634.0	2.8	.481
20	5	191.0	.04445	.090	.092	-2.3	5554.3	5427.5	2.3	.559
21	5	201.0	.04615	.092	.094	-2.2	5479.2	5353.5	2.3	.552
22	5	211.0	.04765	.093	.095	-2.2	5415.3	5290.5	2.3	.545
23	5	221.0	.04889	.094	.096	-2.1	5364.0	5240.4	2.3	.540
24	5	231.0	.05031	.094	.096	-2.0	5306.6	5187.1	2.3	.534
25	5	240.5	.05247	.096	.098	-1.9	5222.3	5110.8	2.1	.527
26	5	249.5	.05439	.097	.099	-1.9	5150.3	5038.1	2.2	.519
27	4	258.5	.11903	.161	.162	-.4	2312.9	2295.2	.8	.229
28	4	267.5	.12361	.163	.164	-.4	2263.4	2243.6	.9	.223
29	4	276.5	.12638	.164	.165	-.4	2234.4	2212.3	1.0	.220
30	4	286.0	.12880	.165	.165	-.5	2209.6	2185.6	1.1	.218
31	4	296.0	.13086	.165	.166	-.4	2188.8	2165.9	1.0	.216
32	4	306.0	.13154	.166	.166	-.6	2182.0	2152.9	1.3	.214
33	4	316.0	.13512	.167	.167	-.5	2146.8	2120.8	1.2	.211
34	4	326.0	.14750	.170	.170	.0	2032.1	2032.5	.0	.202
35	4	336.0	.16112	.174	.173	.4	1916.5	1938.0	-1.1	.193
36	4	346.0	.17547	.178	.176	.9	1804.8	1851.9	-2.6	.184
37	4	356.0	.18801	.181	.178	1.1	1714.3	1779.0	-3.8	.177
38	4	366.0	.19857	.183	.181	1.2	1642.8	1713.9	-4.3	.171

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ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01019	.039	.039	-.7	1245.3	1242.3	.2	.896
2	6	16.5	.01535	.046	.046	-.6	2068.8	2063.3	.3	.837
3	6	25.0	.01685	.048	.048	-.6	2801.1	2793.7	.3	.824
4	6	34.5	.01699	.048	.048	-.6	3750.2	3740.6	.3	.823
5	6	43.5	.02196	.053	.053	-.5	3582.5	3572.7	.3	.786
6	6	52.5	.02693	.057	.057	-.5	3449.0	3438.8	.3	.756
7	5	61.5	.03454	.082	.083	-1.1	3076.6	3049.3	.9	.619
8	5	70.5	.04205	.089	.089	-.9	2876.7	2850.4	.9	.578
9	4	79.5	.07845	.143	.144	-.7	1744.4	1721.2	1.3	.296
10	4	89.0	.10250	.155	.155	.0	1456.0	1454.7	.1	.250
11	4	99.0	.12347	.163	.163	-.1	1313.2	1311.4	.1	.225
12	4	109.0	.14634	.170	.170	.1	1184.2	1186.7	-.2	.204
13	4	119.0	.17121	.177	.176	.3	1065.0	1075.1	-.9	.185
14	5	129.0	.04545	.091	.092	-1.0	4284.3	4241.2	1.0	.562
15	5	139.0	.04874	.093	.094	-1.0	4175.7	4128.9	1.1	.547
16	5	149.0	.05202	.096	.097	-1.1	4074.3	4024.2	1.2	.533
17	5	159.0	.05539	.098	.099	-1.1	3976.6	3924.6	1.3	.520
18	5	169.5	.05888	.100	.101	-1.1	3881.3	3828.4	1.4	.507
19	5	180.5	.06241	.101	.103	-1.1	3790.7	3738.2	1.4	.495
20	5	191.0	.04322	.090	.090	-1.0	5610.8	5554.3	1.0	.572
21	5	201.0	.04469	.091	.092	-1.0	5534.9	5479.2	1.0	.564
22	5	211.0	.04636	.092	.093	-1.0	5470.1	5415.3	1.0	.558
23	5	221.0	.04761	.093	.094	-.9	5417.1	5364.0	1.0	.553
24	5	231.0	.04906	.094	.094	-.5	5356.9	5306.6	.9	.547
25	5	240.5	.05123	.095	.096	-.8	5270.3	5222.3	.9	.538
26	5	249.5	.05309	.096	.097	-.6	5198.9	5150.3	.9	.531
27	4	258.5	.11779	.161	.161	-.3	2326.6	2312.9	.6	.230
28	4	267.5	.12223	.162	.163	-.3	2278.2	2263.4	.6	.225
29	4	276.5	.12487	.163	.164	-.3	2250.2	2234.4	.7	.222
30	4	286.0	.12722	.164	.165	-.3	2225.6	2209.6	.7	.220
31	4	296.0	.12936	.165	.165	-.3	2204.0	2188.8	.7	.218
32	4	306.0	.12972	.165	.166	-.4	2200.3	2182.0	.8	.217
33	4	316.0	.13258	.166	.167	-.5	2171.8	2146.8	1.1	.214
34	4	326.0	.14650	.170	.170	-.2	2041.0	2032.1	.4	.202
35	4	336.0	.16188	.174	.174	.1	1910.2	1916.5	-.3	.191
36	4	346.0	.17907	.178	.178	.5	1778.1	1804.8	-1.5	.180
37	4	356.0	.19382	.182	.181	.7	1673.8	1714.3	-2.4	.171
38	4	366.0	.20572	.184	.183	.8	1596.5	1642.8	-2.9	.164

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ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01012	.039	.039	-.3	1246.7	1245.3	.1	.896
2	6	16.5	.01524	.046	.046	-.3	2071.2	2068.8	.1	.839
3	6	25.0	.01674	.048	.048	-.3	2804.4	2801.1	.1	.826
4	6	34.5	.01688	.048	.048	-.3	3754.5	3750.2	.1	.825
5	6	43.5	.02181	.053	.053	-.2	3586.8	3582.5	.1	.788
6	6	52.5	.02675	.057	.057	-.2	3453.4	3449.0	.1	.758
7	5	61.5	.03415	.082	.082	-.4	3080.2	3076.6	.4	.624
8	5	70.5	.04156	.088	.089	-.4	2888.5	2876.7	.4	.584
9	4	79.5	.07720	.142	.143	-.5	1762.3	1744.4	1.0	.300
10	4	89.0	.10185	.155	.155	-.1	1458.5	1456.0	.2	.250
11	4	99.0	.12299	.163	.163	-.1	1316.1	1313.2	.2	.226
12	4	109.0	.14630	.170	.170	.0	1184.4	1184.2	.0	.203

13	4	119.0	.17243	.177	.177	.2	1059.6	1065.0	-.5	.183
14	5	129.0	.04488	.091	.091	-.5	4304.2	4284.3	.5	.568
15	5	139.0	.04806	.093	.093	-.5	4197.5	4175.7	.5	.553
16	5	149.0	.05123	.095	.096	-.5	4098.0	4074.3	.6	.540
17	5	159.0	.05451	.097	.098	-.5	4001.6	3976.6	.6	.527
18	5	169.5	.05791	.099	.100	-.5	3907.1	3881.3	.7	.514
19	5	180.5	.06138	.101	.101	-.5	3816.6	3790.7	.7	.502
20	5	191.0	.06267	.089	.090	-.5	5636.1	5610.8	.5	.578
21	5	201.0	.06433	.090	.091	-.4	5559.9	5534.9	.4	.570
22	5	211.0	.06580	.091	.092	-.4	5494.5	5470.1	.4	.564
23	5	221.0	.06706	.092	.093	-.4	5440.2	5417.1	.4	.558
24	5	231.0	.06852	.093	.094	-.4	5379.0	5356.9	.4	.552
25	5	240.5	.05068	.095	.095	-.4	5291.8	5270.3	.4	.543
26	5	249.5	.05251	.096	.096	-.4	5220.8	5198.9	.4	.536
27	4	258.5	.11690	.161	.161	-.2	2336.6	2326.6	.4	.232
28	4	267.5	.12125	.162	.162	-.2	2288.7	2278.2	.5	.227
29	4	276.5	.12384	.163	.163	-.2	2261.0	2250.2	.5	.224
30	4	286.0	.12620	.164	.164	-.2	2236.3	2225.8	.5	.222
31	4	296.0	.12840	.164	.165	-.2	2213.7	2204.0	.4	.219
32	4	306.0	.12863	.165	.165	-.2	2211.4	2200.3	.5	.219
33	4	316.0	.13053	.165	.166	-.4	2192.1	2171.8	.9	.216
34	4	326.0	.14525	.170	.170	-.2	2052.2	2041.0	.5	.203
35	4	336.0	.16192	.174	.174	.0	1910.0	1910.2	.0	.190
36	4	346.0	.18115	.179	.178	.3	1763.0	1778.1	-.9	.177
37	4	356.0	.19784	.183	.182	.5	1647.6	1673.8	-1.6	.167
38	4	366.0	.21090	.185	.184	.6	1564.0	1596.5	-2.1	.159

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	13.0	6.5	.01534	190.98	.23695	21.12
2	6	7.0	16.5	.02309	477.78	.23352	21.12
3	6	10.0	25.0	.02536	710.35	.23026	21.12
4	6	9.0	34.5	.02557	959.05	.22649	21.12
5	6	9.0	43.5	.03305	1183.97	.22241	21.12
6	6	9.0	52.5	.04053	1397.77	.21798	21.12
7	5	9.0	61.5	.05174	1591.97	.21235	28.86
8	5	9.0	70.5	.06298	1811.61	.21122	28.86
9	4	9.0	79.5	.11696	2040.26	.21127	28.90
10	4	10.0	89.0	.15447	2249.05	.20830	28.90
11	4	10.0	99.0	.18635	2447.14	.20398	28.90
12	4	10.0	109.0	.22166	2624.86	.19890	28.90
13	4	10.0	119.0	.26126	2782.35	.19326	28.90
14	5	10.0	129.0	.06799	2913.05	.18653	28.86
15	5	10.0	139.0	.07282	3040.62	.18038	28.86
16	5	10.0	149.0	.07762	3162.63	.17476	28.86
17	5	10.0	159.0	.08258	3284.01	.16983	28.84
18	5	11.0	169.5	.08775	3405.82	.16502	28.84
19	5	11.0	180.5	.09300	3525.44	.16023	28.84
20	5	10.0	191.0	.06466	3627.70	.15560	28.84
21	5	10.0	201.0	.06717	3717.56	.15127	28.84
22	5	10.0	211.0	.06940	3796.09	.14694	28.84
23	5	10.0	221.0	.07131	3862.67	.14256	28.82
24	5	10.0	231.0	.07352	3938.16	.13889	28.40
25	5	9.0	240.5	.07679	4047.04	.13695	28.40
26	5	9.0	249.5	.07956	4136.33	.13480	28.40
27	4	9.0	258.5	.17711	4120.76	.12679	28.40
28	4	9.0	267.5	.18372	4185.44	.12501	28.40
29	4	9.0	276.5	.18764	4222.20	.12075	28.40
30	4	10.0	286.0	.19121	4255.86	.11649	28.42
31	4	10.0	296.0	.19455	4287.75	.11229	28.42
32	4	10.0	306.0	.19489	4288.26	.10766	28.42
33	4	10.0	316.0	.19777	4295.17	.10354	29.74
34	4	10.0	326.0	.22008	4491.88	.10414	29.72
35	4	10.0	336.0	.24533	4686.29	.10464	29.72
36	4	10.0	346.0	.27447	4880.40	.10511	29.70
37	4	10.0	356.0	.29976	5017.57	.10435	29.68
38	4	10.0	366.0	.31954	5101.45	.10258	29.68

PERIOD = 1.775 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 836.0 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 4.11
FOR FREQUENCY (f) = .53 c/sec
FOR PERIOD (1 / f) = 1.88 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - mag8eq.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.23905	21.12	1.22	.199	512
WITHIN	13.0	.23224	21.12	1.16	.202	0
WITHIN	20.0	.22675	21.12	1.12	.204	0
WITHIN	30.0	.21824	21.12	1.07	.207	0
WITHIN	39.0	.21053	21.12	1.03	.210	0
WITHIN	48.0	.20405	28.88	.99	.210	0
WITHIN	57.0	.20117	28.86	.96	.205	0
WITHIN	66.0	.19786	28.86	.93	.201	0
WITHIN	75.0	.19487	28.84	.90	.195	0
WITHIN	84.0	.18956	28.84	.92	.188	0
WITHIN	94.0	.17989	27.94	1.02	.201	0
WITHIN	104.0	.18195	24.44	1.19	.208	0
WITHIN	114.0	.19387	21.32	1.39	.203	0
WITHIN	124.0	.22043	26.20	1.56	.175	0
WITHIN	134.0	.23460	26.20	1.58	.176	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - mag8eq.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	196.0	.20550	26.14	1.45	.203	0
WITHIN	371.0	.33383	25.92	3.14	.126	0
OUTCR.	371.0	.36000	25.92	3.12	.123	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 21

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 21

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*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85     : IBM-PC version of SHAKE                  *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88     : New modulus reduction curves for clays   *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 16, 1988                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; input now is either *
*             GMax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & R. Dirrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91     : General cleanup and finalization of input /
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake98     : Routine for direct calculation of average *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing.  The following  *
*             modulus reduction and  damping curves are  *
*             added:  Matasovic & Kavazanjian (1998) for *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SMR sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1993 - May 1998                     *
*********************************************************
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MAX. NUMBER OF TERMS IN FOURIER TRANSFORM = 4096
NECESSARY LENGTH OF BLANK COMMON X = 25615

****** OPTION 1 *** READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

****
MATERIAL TYPE NO. 1
****

CURVE NO. 1: #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO. 2: #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998

CURVE NO. 1

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	1.000
.0032	.994
.0100	.983
.0316	.959
.1000	.881
.3160	.655
1.0000	.316
3.1600	.130

CURVE NO. 2

STRAIN	DAMPING
.0001	1.13
.0003	1.77
.0010	2.58
.0032	4.03
.0100	5.89
.0316	8.97
.1000	12.91
.3160	17.63
1.0000	21.92
3.1600	25.17

****
MATERIAL TYPE NO. 4
****

CURVE NO. 7: #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO. 8: #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)

CURVE NO. 7

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	.964
.0032	.870
.0100	.712
.0316	.474
.1000	.253
.3160	.103
1.0000	.028
3.1600	.004

CURVE NO. 8

STRAIN	DAMPING
.0001	.85
.0003	1.04
.0010	1.66
.0032	3.06
.0100	5.46
.0316	10.01
.1000	15.40
.3160	20.23
1.0000	23.94
.0000	.00

****
MATERIAL TYPE NO. 5
****

CURVE NO. 9: #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10: #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)

CURVE NO. 9

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	.995
.0030	.936
.0100	.818
.0320	.640
.1000	.405
.3160	.210
1.0000	.095
3.1600	.034

CURVE NO.10

STRAIN	DAMPING
.0001	2.58
.0003	2.58
.0010	2.58
.0030	2.58
.0100	4.64
.0300	7.77
.1000	11.67
.3000	16.08
1.0000	20.12
.0000	.00

****
MATERIAL TYPE NO. 6
****

CURVE NO. 11: #6 Modulus for C (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12: #6 Damping for C (PI=30) (Vucetic and Dobry, 1991)

CURVE NO.11

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	1.000
.0030	.976
.0100	.901
.0320	.743
.1000	.538
.3000	.332
1.0000	.158
3.0000	.048

CURVE NO.12

STRAIN	DAMPING
.0001	.85
.0003	.85
.0010	1.36
.0030	2.18
.0100	3.82
.0320	6.00
.1000	8.72
.3160	12.41
1.0000	16.90
3.1600	21.26

****** OPTION 2 *** READ SOIL / WASTE PROFILE

SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 39
DEPTH TO BEDROCK 371.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	13.00	6.50	806.00	1386.	5.00	124.00	600.0
2	6	7.00	16.50	2046.00	2465.	5.00	124.00	800.0
3	6	10.00	25.00	3085.00	3391.	5.00	121.00	950.0
4	6	9.00	34.50	4234.50	4547.	5.00	121.00	1100.0
5	6	9.00	43.50	5323.50	4547.	5.00	121.00	1100.0
6	6	9.00	52.50	6412.50	4547.	5.00	121.00	1100.0
7	5	9.00	61.50	7497.00	4929.	5.00	120.00	1150.0
8	5	9.00	70.50	8577.00	4929.	5.00	120.00	1150.0
9	4	9.00	79.50	9657.00	5823.	5.00	120.00	1250.0
10	4	10.00	89.00	10797.00	5823.	5.00	120.00	1250.0
11	4	10.00	99.00	11997.00	5823.	5.00	120.00	1250.0
12	4	10.00	109.00	13197.00	5823.	5.00	120.00	1250.0
13	4	10.00	119.00	14397.00	5823.	5.00	120.00	1250.0
14	5	10.00	129.00	15617.00	7548.	5.00	124.00	1400.0
15	5	10.00	139.00	16857.00	7548.	5.00	124.00	1400.0
16	5	10.00	149.00	18097.00	7548.	5.00	124.00	1400.0
17	5	10.00	159.00	19337.00	7548.	5.00	124.00	1400.0
18	5	11.00	169.50	20639.00	7548.	5.00	124.00	1400.0
19	5	11.00	180.50	22003.00	7548.	5.00	124.00	1400.0
20	5	10.00	191.00	23315.00	9707.	5.00	126.00	1575.0
21	5	10.00	201.00	24575.00	9707.	5.00	126.00	1575.0
22	5	10.00	211.00	25835.00	9707.	5.00	126.00	1575.0
23	5	10.00	221.00	27095.00	9707.	5.00	126.00	1575.0
24	5	10.00	231.00	28355.00	9707.	5.00	126.00	1575.0
25	5	9.00	240.50	29552.00	9707.	5.00	126.00	1575.0
26	5	9.00	249.50	30686.00	9707.	5.00	126.00	1575.0
27	4	9.00	258.50	31995.50	10043.	5.00	165.00	1400.0
28	4	9.00	267.50	33460.50	10043.	5.00	165.00	1400.0
29	4	9.00	276.50	34965.50	10043.	5.00	165.00	1400.0
30	4	10.00	286.00	36533.00	10043.	5.00	165.00	1400.0
31	4	10.00	296.00	38183.01	10043.	5.00	165.00	1400.0
32	4	10.00	306.00	39833.01	10043.	5.00	165.00	1400.0
33	4	10.00	316.00	41483.01	10043.	5.00	165.00	1400.0
34	4	10.00	326.00	43133.01	10043.	5.00	165.00	1400.0
35	4	10.00	336.00	44783.01	10043.	5.00	165.00	1400.0
36	4	10.00	346.00	46433.02	10043.	5.00	165.00	1400.0
37	4	10.00	356.00	48083.02	10043.	5.00	165.00	1400.0
38	4	10.00	366.00	49733.02	10043.	5.00	165.00	1400.0
39	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.118 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1326.8 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 14.02
FOR FREQUENCY (f) = 1.04 c/sec
FOR PERIOD (1 / f) = .96 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = riodl-hz.sar
NO. OF INPUT ACCEL. POINTS = 1800
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 6
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200
FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

CAPE MENDOCINO, CA EQ. 1992; Mw = 7.0 (4.1 J & B); Ms = 7.1
RIO DELL - 101/PAINTER ST. OVERPASS; CHAN 4: (270 deg) (free-field)
Thrust fault; H = 15 km; R = 24 km (Naeim) or 12.3 km (J & B)

Uncor. Max. = -0.78 g @ 5.575 sec; Max. in file = 0.385732 @ 5.58 sec
J & B Site Class B; Mean sq. freq. = 3.01 Hz; Ds = 15.4 s; To = 0.2171 s
225*8 = 1800 pts @ 0.02 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	-.002296	-.001777	.000568	.000731	-.003668	-.000583	.004051	.002788
2	.000964	-.002422	-.004550	-.004451	-.005422	-.008852	-.014746	-.015439
3	-.011380	-.006311	-.005492	-.008705	-.008035	-.006091	-.004255	-.001129
4	.002864	.006916	.010118	.005313	-.004705	-.003748	.003541	.005366
5	.000370	-.000956	.004816	.007193	.010419	.013203	.011265	.008016

..... INPUT MOTION READ NOT ECHOED.....

221	-.005527	-.003620	-.002145	-.002337	-.002461	-.004595	-.007541	-.008303
222	-.007946	-.006056	-.005096	-.005324	-.005166	-.005233	-.004498	-.004398
223	-.002852	-.002130	-.002072	-.002438	-.002967	-.001687	.001138	.004567
224	.006282	.006832	.006628	.008012	.009033	.007818	.006191	.003176
225	.000796	-.001581	-.001767	.000490	.000460	-.001572	.000280	.001179

MAXIMUM ACCELERATION = .385732
AT TIME = 5.58 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .93329050
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.02 c/sec
MAXIMUM ACCELERATION = .359998 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - riodl-hz.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.03140	.060	.050	16.2	1019.3	1386.3	-16.0	1.000
2	6	16.5	.04445	.068	.050	26.3	1666.2	2464.6	-47.5	1.000
3	6	25.0	.04640	.070	.050	28.5	2243.6	3391.4	-51.2	1.000
4	6	34.5	.04896	.070	.050	28.7	2599.1	4546.9	-51.4	1.000
5	6	43.5	.06060	.075	.050	33.6	2834.0	4546.9	-66.4	1.000
6	6	52.5	.07150	.079	.050	38.9	2705.9	4546.9	-68.0	1.000
7	5	61.5	.07513	.107	.050	53.5	2286.7	4828.6	-115.5	1.000
8	5	70.5	.08333	.111	.050	54.9	2181.4	4828.6	-125.8	1.000
9	4	79.5	.07664	.142	.050	64.7	1770.3	5823.0	-128.4	1.000
10	4	89.0	.08227	.145	.050	65.5	1691.2	5823.0	-144.3	1.000
11	4	99.0	.08753	.148	.050	66.2	1622.0	5823.0	-159.5	1.000
12	4	109.0	.09325	.151	.050	66.8	1551.3	5823.0	-176.4	1.000
13	4	119.0	.09836	.153	.050	67.4	1491.7	5823.0	-192.4	1.000
14	5	129.0	.08003	.109	.050	54.3	3403.6	7547.8	-121.1	1.000
15	5	139.0	.08426	.111	.050	55.0	3323.5	7547.8	-121.1	1.000
16	5	149.0	.08793	.113	.050	55.6	3257.2	7547.8	-121.1	1.000
17	5	159.0	.09101	.114	.050	56.0	3203.6	7547.8	-125.1	1.000
18	5	169.5	.09362	.115	.050	56.4	3159.4	7547.8	-128.5	1.000
19	5	180.5	.09641	.116	.050	56.7	3113.8	7547.8	-132.4	1.000
20	5	191.0	.07657	.108	.050	53.7	4465.7	9706.8	-117.4	1.000
21	5	201.0	.07774	.109	.050	53.9	4435.3	9706.8	-118.3	1.000
22	5	211.0	.07863	.109	.050	54.1	4412.7	9706.8	-119.0	1.000
23	5	221.0	.07930	.109	.050	54.2	4395.7	9706.8	-119.5	1.000
24	5	231.0	.07982	.109	.050	54.3	4382.4	9706.8	-120.1	1.000
25	5	240.5	.08024	.110	.050	54.4	4372.0	9706.8	-120.5	1.000

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26	5	249.5	.08057	.110	.050	54.4	4363.6	9706.8	-122.4	1.000
27	4	258.5	.07819	.142	.050	64.9	3015.1	10043.5	-233.1	1.000
28	4	267.5	.07847	.143	.050	65.0	3008.2	10043.5	-233.9	1.000
29	4	276.5	.07867	.143	.050	65.0	3003.2	10043.5	-234.4	1.000
30	4	286.0	.08064	.144	.050	65.3	2955.5	10043.5	-239.8	1.000
31	4	296.0	.08321	.145	.050	65.6	2895.1	10043.5	-246.9	1.000
32	4	306.0	.08539	.147	.050	65.9	2845.3	10043.5	-253.0	1.000
33	4	316.0	.08761	.148	.050	66.2	2795.8	10043.5	-259.2	1.000
34	4	326.0	.08982	.149	.050	66.4	2747.8	10043.5	-265.5	1.000
35	4	336.0	.09160	.150	.050	66.6	2710.0	10043.5	-270.6	1.000
36	4	346.0	.09297	.151	.050	66.8	2681.4	10043.5	-274.6	1.000
37	4	356.0	.09412	.151	.050	66.9	2657.7	10043.5	-277.9	1.000
38	4	366.0	.09526	.152	.050	67.0	2634.5	10043.5	-281.2	1.000

ACCELEROGRAM - riod1-hz.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.02350	.054	.060	-10.0	1078.7	1019.3	5.5	.735
2	6	16.5	.03590	.063	.068	-8.1	1755.8	1666.2	5.1	.676
3	6	25.0	.03950	.065	.070	-7.5	2361.0	2243.6	5.0	.662
4	6	34.5	.03868	.065	.070	-7.7	3161.8	2999.1	5.1	.660
5	6	43.5	.05162	.071	.075	-5.4	2958.2	2834.0	4.2	.623
6	6	52.5	.06350	.076	.079	-3.7	2797.9	2705.9	3.3	.595
7	5	61.5	.08505	.111	.107	3.6	2160.7	2286.7	-5.8	.464
8	5	70.5	.09868	.116	.111	4.7	2009.6	2161.4	-8.6	.443
9	4	79.5	.13089	.165	.142	14.4	1268.9	1770.3	-39.5	.304
10	4	89.0	.14642	.170	.145	14.5	1183.7	1691.2	-42.9	.290
11	4	99.0	.16096	.174	.148	15.1	1111.9	1622.0	-45.9	.279
12	4	109.0	.17486	.177	.151	15.1	1049.0	1551.3	-47.9	.266
13	4	119.0	.18658	.180	.152	15.8	999.7	1491.7	-49.2	.256
14	5	129.0	.08421	.111	.109	1.5	3324.5	3403.6	-2.4	.451
15	5	139.0	.08710	.112	.111	1.0	3271.8	3323.5	-1.6	.440
16	5	149.0	.08930	.113	.113	.4	3233.0	3257.2	-.7	.432
17	5	159.0	.09080	.114	.114	-.1	3207.1	3203.6	.1	.424
18	5	169.5	.09367	.115	.115	.0	3158.7	3159.4	.0	.419
19	5	180.5	.09861	.116	.116	.0	3078.7	3113.8	-1.1	.413
20	5	191.0	.07062	.105	.108	-2.5	4627.6	4465.7	3.5	.460
21	5	201.0	.07274	.106	.109	-2.0	4568.5	4435.3	2.9	.457
22	5	211.0	.07435	.107	.109	-1.7	4524.7	4412.7	2.5	.455
23	5	221.0	.07544	.108	.109	-1.5	4495.5	4395.7	2.2	.453
24	5	231.0	.07608	.108	.109	-1.4	4478.5	4382.4	2.1	.451
25	5	240.5	.07655	.108	.110	-1.4	4466.2	4372.0	2.1	.450
26	5	249.5	.07664	.108	.110	-1.5	4464.0	4363.6	2.2	.450
27	4	258.5	.11066	.158	.142	10.0	2408.3	3015.1	-25.2	.300
28	4	267.5	.10970	.158	.143	9.6	2419.8	3008.2	-24.3	.300
29	4	276.5	.10857	.157	.143	9.3	2433.3	3003.2	-23.4	.299
30	4	286.0	.10892	.158	.144	8.7	2429.1	2955.5	-21.7	.294
31	4	296.0	.11002	.158	.145	8.0	2415.9	2895.1	-19.8	.288
32	4	306.0	.11096	.158	.147	7.4	2404.8	2845.3	-18.3	.283
33	4	316.0	.11165	.159	.148	6.8	2396.8	2795.8	-16.7	.278
34	4	326.0	.11647	.160	.149	7.1	2341.3	2747.8	-17.4	.274
35	4	336.0	.12138	.162	.150	7.5	2287.3	2710.0	-18.5	.270
36	4	346.0	.12504	.163	.151	7.6	2248.4	2681.4	-19.3	.267
37	4	356.0	.12804	.164	.151	8.0	2217.4	2657.7	-19.9	.265
38	4	366.0	.12997	.165	.152	8.0	2197.7	2634.5	-19.9	.262

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ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01865	.050	.054	-8.7	1124.8	1078.7	4.1	.778
2	6	16.5	.02862	.058	.063	-8.4	1847.8	1755.8	5.0	.712
3	6	25.0	.03157	.060	.065	-8.6	2490.4	2361.0	5.2	.696
4	6	34.5	.03172	.060	.065	-8.9	3335.2	3161.8	5.2	.695
5	6	43.5	.04175	.066	.071	-7.6	3122.5	2958.2	5.3	.651
6	6	52.5	.05198	.072	.076	-6.7	2952.8	2797.9	5.2	.615
7	5	61.5	.07609	.108	.111	-3.3	2273.9	2160.7	5.0	.438
8	5	70.5	.09075	.114	.116	-2.4	2094.7	2009.6	4.1	.408
9	4	79.5	.15347	.172	.165	3.9	1148.1	1268.9	-10.5	.218
10	4	89.0	.17617	.178	.170	4.4	1043.3	1183.7	-13.5	.203
11	4	99.0	.19766	.183	.174	4.7	955.9	1111.9	-16.3	.191
12	4	109.0	.21705	.187	.177	4.9	884.9	1049.0	-18.5	.180
13	4	119.0	.23313	.190	.180	4.9	830.7	999.7	-20.4	.172
14	5	129.0	.07225	.106	.111	-4.7	3562.9	3324.5	6.7	.440
15	5	139.0	.07534	.108	.112	-4.4	3497.7	3271.8	6.5	.433
16	5	149.0	.07926	.109	.113	-3.5	3418.8	3233.0	5.4	.428
17	5	159.0	.08255	.110	.114	-2.8	3355.5	3207.1	4.4	.425
18	5	169.5	.08611	.112	.115	-2.4	3289.6	3158.7	4.0	.418
19	5	180.5	.09012	.113	.116	-2.6	3218.8	3078.7	4.4	.408
20	5	191.0	.06038	.100	.105	-5.1	4941.2	4627.6	6.1	.477
21	5	201.0	.06143	.101	.106	-5.4	4906.7	4568.5	6.5	.471
22	5	211.0	.06231	.101	.107	-5.6	4878.4	4524.7	7.3	.466
23	5	221.0	.06270	.102	.108	-5.9	4865.7	4495.5	7.6	.463
24	5	231.0	.06262	.102	.108	-6.2	4868.2	4478.5	8.0	.461
25	5	240.5	.06223	.101	.108	-6.6	4880.7	4466.2	8.5	.460
26	5	249.5	.06187	.101	.108	-6.9	4892.5	4464.0	8.8	.460
27	4	258.5	.11351	.159	.158	.7	2375.1	2408.3	-1.4	.240
28	4	267.5	.11133	.159	.159	.4	2400.4	2419.8	-.8	.241
29	4	276.5	.10999	.158	.157	.3	2416.3	2433.3	-.7	.242
30	4	286.0	.11049	.158	.158	.4	2410.3	2429.1	-.8	.242
31	4	296.0	.11198	.159	.158	.5	2392.9	2415.9	-1.0	.241
32	4	306.0	.11358	.159	.158	.6	2374.3	2404.8	-1.3	.239
33	4	316.0	.11474	.160	.159	.7	2360.9	2396.8	-1.5	.239
34	4	326.0	.11728	.161	.160	.2	2332.7	2341.3	-.4	.233
35	4	336.0	.11985	.162	.162	-.3	2303.9	2287.3	.7	.226
36	4	346.0	.12331	.163	.163	-.4	2266.6	2248.4	.8	.224
37	4	356.0	.12672	.164	.164	-.3	2230.9	2217.4	.6	.221
38	4	366.0	.12828	.164	.165	-.3	2214.9	2197.7	.8	.219

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ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01716	.048	.050	-3.2	1141.5	1124.8	1.5	.811
2	6	16.5	.02610	.056	.058	-3.1	1880.5	1847.8	1.7	.750
3	6	25.0	.02875	.058	.060	-3.0	2540.5	2490.4	2.0	.734
4	6	34.5	.02893	.058	.060	-3.0	3402.0	3335.2	2.0	.734
5	6	43.5	.03809	.064	.066	-3.4	3193.5	3122.5	2.2	.687
6	6	52.5	.04749	.069	.072	-3.1	3022.8	2952.8	2.3	.649
7	5	61.5	.06955	.105	.108	-2.8	2365.2	2273.9	3.8	.461
8	5	70.5	.08385	.111	.114	-2.8	2175.1	2094.7	3.7	.425
9	4	79.5	.16354	.175	.172	1.4	1099.8	1148.1	-4.4	.197
10	4	89.0	.19271	.182	.178	2.1	975.2	1043.3	-7.0	.179
11	4	99.0	.22268	.188	.183	2.7	865.5	955.9	-10.5	.164
12	4	109.0	.24978	.192	.187	3.1	778.3	884.9	-12.7	.152
13	4	119.0	.27543	.197	.190	3.6	704.1	830.7	-15.1	.143
14	5	129.0	.06649	.103	.106	-2.6	3652.3	3562.9	2.5	.472
15	5	139.0	.07063	.105	.108	-2.8	3598.1	3497.7	2.9	.463
16	5	149.0	.07496	.107	.109	-1.7	3505.6	3418.8	2.5	.453
17	5	159.0	.07871	.109	.110	-1.4	3429.6	3355.5	2.2	.445

18	5	169.5	.08224	.110	.112	-1.4	3361.3	3289.6	2.1	.436
19	5	180.5	.08543	.112	.113	-1.6	3302.0	3218.8	2.5	.426
20	5	191.0	.05586	.098	.100	-2.6	5097.0	4941.2	3.1	.509
21	5	201.0	.05632	.098	.101	-2.9	5080.7	4906.7	3.4	.505
22	5	211.0	.05658	.098	.101	-3.2	5071.4	4878.4	3.8	.503
23	5	221.0	.05663	.098	.102	-3.4	5069.8	4865.7	4.0	.501
24	5	231.0	.05623	.098	.102	-3.6	5083.8	4868.2	4.2	.502
25	5	240.5	.05552	.098	.101	-3.8	5109.4	4880.7	4.5	.503
26	5	249.5	.05498	.097	.101	-3.9	5128.7	4892.5	4.6	.504
27	4	258.5	.11222	.159	.159	-.3	2390.0	2375.1	.6	.236
28	4	267.5	.10949	.159	.159	-.4	2422.3	2400.4	.9	.239
29	4	276.5	.10849	.157	.158	-.4	2434.3	2416.3	.7	.241
30	4	286.0	.11002	.158	.158	-.1	2416.0	2410.3	.2	.240
31	4	296.0	.11301	.159	.159	.2	2380.8	2392.9	-.5	.238
32	4	306.0	.11575	.160	.159	.5	2349.5	2374.3	-1.1	.236
33	4	316.0	.11846	.161	.160	.8	2319.1	2360.9	-1.8	.235
34	4	326.0	.12091	.162	.161	.8	2292.4	2332.3	-1.7	.232
35	4	336.0	.12276	.162	.162	.6	2272.5	2303.9	-1.4	.229
36	4	346.0	.12467	.163	.163	.3	2252.3	2266.6	-.6	.226
37	4	356.0	.12533	.163	.164	-.3	2245.3	2230.9	.6	.222
38	4	366.0	.12549	.164	.164	-.6	2243.7	2214.9	1.3	.221

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ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01627	.047	.048	-2.1	1152.0	1141.5	.9	.823
2	6	16.5	.02468	.055	.056	-1.9	1900.4	1880.5	1.0	.763
3	6	25.0	.02713	.057	.058	-1.9	2568.8	2540.5	1.1	.749
4	6	34.5	.02733	.057	.058	-1.9	3439.4	3402.0	1.1	.748
5	6	43.5	.03589	.063	.064	-2.3	3239.6	3193.5	1.4	.702
6	6	52.5	.04471	.068	.069	-2.1	3069.4	3022.8	1.5	.665
7	5	61.5	.06434	.102	.105	-2.5	2444.3	2365.2	3.2	.480
8	5	70.5	.07805	.109	.111	-2.1	2247.9	2175.1	3.2	.441
9	4	79.5	.16455	.175	.175	.1	1095.1	1099.8	-.4	.189
10	4	89.0	.19999	.183	.182	.9	947.1	975.2	-3.0	.167
11	4	99.0	.23839	.190	.188	1.5	813.7	865.5	-6.4	.149
12	4	109.0	.27713	.197	.192	2.2	699.4	778.3	-11.3	.134
13	4	119.0	.32326	.203	.197	3.2	591.2	704.1	-19.1	.121
14	5	129.0	.06388	.102	.103	-1.3	3754.6	3692.3	1.7	.489
15	5	139.0	.06840	.104	.105	-1.0	3648.1	3598.1	1.4	.477
16	5	149.0	.07286	.106	.107	-.8	3549.7	3505.6	1.2	.464
17	5	159.0	.07660	.108	.109	-.8	3471.9	3429.6	1.2	.454
18	5	169.5	.07969	.109	.110	-.9	3410.2	3361.3	1.4	.445
19	5	180.5	.08221	.110	.112	-1.1	3361.8	3302.0	1.8	.437
20	5	191.0	.05337	.096	.098	-1.5	5188.4	5097.0	1.8	.525
21	5	201.0	.05348	.096	.098	-1.7	5184.3	5080.7	2.0	.523
22	5	211.0	.05327	.096	.099	-2.0	5192.1	5071.4	2.3	.522
23	5	221.0	.05311	.096	.098	-2.2	5198.1	5069.8	2.5	.522
24	5	231.0	.05255	.096	.098	-2.3	5219.3	5083.8	2.6	.524
25	5	240.5	.05169	.095	.098	-2.4	5252.2	5109.4	2.7	.526
26	5	249.5	.05108	.095	.097	-2.5	5276.3	5128.7	2.8	.528
27	4	258.5	.10865	.157	.159	-.9	2432.4	2390.0	1.7	.238
28	4	267.5	.10564	.156	.158	-.9	2466.7	2422.3	1.8	.241
29	4	276.5	.10545	.156	.157	-.8	2471.5	2434.3	1.5	.242
30	4	286.0	.10823	.157	.158	-.4	2437.5	2416.0	.9	.241
31	4	296.0	.11293	.159	.159	.0	2381.8	2380.8	.0	.237
32	4	306.0	.11721	.161	.160	.3	2333.1	2349.5	-.7	.234
33	4	316.0	.12130	.162	.161	.6	2288.2	2319.1	-1.4	.231
34	4	326.0	.12451	.163	.162	.8	2253.9	2292.4	-1.7	.228
35	4	336.0	.12632	.164	.163	.7	2235.0	2272.5	-1.7	.226
36	4	346.0	.12797	.164	.163	.7	2218.1	2252.3	-1.5	.224
37	4	356.0	.12754	.164	.163	.4	2222.5	2245.3	-1.0	.224
38	4	366.0	.12635	.164	.164	.2	2234.7	2243.7	-.4	.223

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ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01549	.046	.047	-2.0	1161.9	1152.0	.8	.831
2	6	16.5	.02345	.054	.055	-1.8	1918.4	1900.4	.9	.771
3	6	25.0	.02578	.056	.057	-1.7	2593.7	2568.8	1.0	.757
4	6	34.5	.02599	.056	.057	-1.7	3472.3	3439.4	.9	.756
5	6	43.5	.03402	.061	.063	-2.1	3281.0	3239.6	1.3	.712
6	6	52.5	.04235	.067	.068	-1.8	3111.5	3069.4	1.4	.675
7	5	61.5	.06018	.100	.102	-2.2	2512.3	2444.3	2.7	.496
8	5	70.5	.07300	.107	.109	-2.0	2315.9	2247.9	2.9	.456
9	4	79.5	.15976	.174	.175	-.7	1117.5	1095.1	2.0	.188
10	4	89.0	.19899	.183	.183	-.1	950.9	947.1	.4	.163
11	4	99.0	.24690	.192	.190	.8	787.1	813.7	-3.4	.140
12	4	109.0	.30266	.200	.197	1.6	632.5	699.4	-10.6	.120
13	4	119.0	.39278	.208	.203	2.6	527.1	591.2	-12.2	.102
14	5	129.0	.06242	.101	.102	-.7	3790.5	3754.6	.9	.497
15	5	139.0	.06710	.104	.104	-.6	3678.0	3648.1	.8	.483
16	5	149.0	.07145	.106	.106	-.6	3580.3	3549.7	.6	.470
17	5	159.0	.07500	.107	.108	-.6	3504.6	3471.9	.9	.460
18	5	169.5	.07772	.109	.109	-.7	3449.2	3410.2	1.1	.452
19	5	180.5	.07949	.109	.110	-1.0	3414.1	3361.8	1.5	.445
20	5	191.0	.05156	.095	.096	-1.2	5257.3	5188.4	1.3	.535
21	5	201.0	.05145	.095	.096	-1.3	5261.5	5184.3	1.5	.534
22	5	211.0	.05099	.095	.096	-1.5	5279.5	5192.1	1.7	.535
23	5	221.0	.05059	.095	.096	-1.7	5295.5	5198.1	1.8	.536
24	5	231.0	.04993	.094	.096	-1.8	5321.5	5219.3	1.9	.538
25	5	240.5	.04901	.094	.095	-1.8	5359.1	5252.2	2.0	.541
26	5	249.5	.04832	.093	.095	-1.9	5387.2	5276.3	2.1	.544
27	4	258.5	.10393	.156	.157	-1.2	2490.5	2432.4	2.3	.242
28	4	267.5	.10131	.155	.156	-1.2	2523.9	2466.7	2.3	.246
29	4	276.5	.10162	.155	.156	-1.0	2519.9	2471.5	1.9	.246
30	4	286.0	.10558	.156	.157	-.7	2469.9	2437.5	1.3	.243
31	4	296.0	.11187	.159	.158	-.2	2394.2	2381.8	.5	.237
32	4	306.0	.11770	.161	.161	.1	2327.6	2333.1	-.2	.232
33	4	316.0	.12299	.163	.162	.4	2270.1	2288.2	-.8	.228
34	4	326.0	.12730	.164	.162	.6	2224.9	2253.9	-1.3	.224
35	4	336.0	.12942	.165	.164	.6	2203.3	2235.0	-1.4	.223
36	4	346.0	.13145	.165	.164	.7	2183.0	2218.1	-1.6	.221
37	4	356.0	.12076	.165	.164	.6	2189.8	2222.5	-1.5	.221
38	4	366.0	.12889	.165	.164	.5	2208.7	2234.7	-1.2	.223

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ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01487	.046	.046	-1.7	1170.0	1161.9	.7	.838
2	6	16.5	.02249	.053	.054	-1.5	1933.3	1918.4	.8	.778
3	6	25.0	.02472	.055	.056	-1.4	2614.1	2593.7	.8	.765
4	6	34.5	.02493	.055	.056	-1.4	3499.3	3472.3	.8	.764
5	6	43.5	.03255	.060	.061	-1.8	3315.3	3281.0	1.0	.722
6	6	52.5	.04052	.066	.067	-1.6	3145.5	3111.5	1.1	.684
7	5	61.5	.05692	.098	.100	-1.8	2568.8	2512.3	2.2	.510
8	5	70.5	.06891	.105	.107	-1.8	2374.5	2315.9	2.5	.470
9	4	79.5	.15229	.172	.174	-1.2	1153.9	1117.5	3.2	.192

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10	4	89.0	.19367	.182	.183	-.6	971.4	950.9	2.1	.163
11	4	99.0	.24958	.192	.193	.2	778.9	787.1	-1.1	.135
12	4	109.0	.33095	.204	.200	1.6	582.2	632.5	-8.6	.109
13	4	119.0	.42632	.212	.208	1.6	486.2	527.1	-8.4	.091
14	5	129.0	.06151	.101	.101	-.5	3813.4	3790.5	.6	.502
15	5	139.0	.06615	.103	.104	-.4	3700.3	3678.0	.6	.487
16	5	149.0	.07034	.105	.106	-.5	3604.6	3580.3	.7	.474
17	5	159.0	.07372	.107	.107	-.5	3531.6	3504.6	.8	.464
18	5	169.5	.07617	.108	.108	-.6	3480.7	3449.2	.9	.457
19	5	180.5	.07746	.108	.109	-.8	3454.4	3414.1	1.2	.452
20	5	191.0	.05027	.094	.095	-.9	5308.0	5257.3	1.0	.542
21	5	201.0	.05004	.094	.095	-1.0	5317.3	5261.5	1.0	.542
22	5	211.0	.04944	.094	.095	-1.1	5341.3	5279.5	1.2	.544
23	5	221.0	.04886	.094	.095	-1.2	5365.0	5295.5	1.3	.546
24	5	231.0	.04816	.093	.094	-1.2	5394.1	5321.5	1.3	.548
25	5	240.5	.04719	.092	.094	-1.2	5434.6	5359.1	1.4	.552
26	5	249.5	.04647	.092	.093	-1.4	5465.5	5387.2	1.4	.555
27	4	258.5	.09969	.154	.156	-1.1	2546.9	2490.5	2.2	.248
28	4	267.5	.09733	.153	.155	-1.2	2593.1	2523.9	2.7	.251
29	4	276.5	.09820	.153	.155	-1.0	2575.9	2519.9	2.2	.251
30	4	286.0	.10308	.155	.156	-.6	2501.3	2469.9	1.3	.246
31	4	296.0	.11061	.158	.159	-.3	2409.0	2394.2	.6	.238
32	4	306.0	.11777	.161	.161	.0	2326.8	2327.6	.0	.232
33	4	316.0	.12406	.163	.163	.2	2258.7	2270.1	-.5	.226
34	4	326.0	.12951	.165	.164	.4	2202.4	2224.9	-1.0	.222
35	4	336.0	.13224	.166	.165	.5	2175.1	2203.3	-1.3	.219
36	4	346.0	.13474	.167	.165	.6	2150.5	2183.0	-1.5	.217
37	4	356.0	.13417	.166	.165	.7	2156.1	2189.8	-1.6	.218
38	4	366.0	.13196	.166	.165	.6	2177.9	2208.7	-1.4	.220

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN ( )	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	13.0	6.5	.02253	261.72	.32472	6.06
2	6	7.0	16.5	.03408	653.74	.31952	6.06
3	6	10.0	25.0	.03746	971.60	.31494	6.06
4	6	9.0	34.5	.03778	1311.78	.30978	6.06
5	6	9.0	43.5	.04931	1617.94	.30392	6.06
6	6	9.0	52.5	.06140	1910.48	.29793	6.08
7	5	9.0	61.5	.08625	2166.81	.28902	6.08
8	5	9.0	70.5	.10441	2418.18	.28154	6.08
9	4	9.0	79.5	.23074	2578.63	.26702	6.10
10	4	10.0	89.0	.29344	2790.27	.25843	6.12
11	4	10.0	99.0	.37815	2976.42	.24810	6.14
12	4	10.0	109.0	.50144	3171.71	.24034	6.18
13	4	10.0	119.0	.64594	3404.63	.23648	6.18
14	5	10.0	129.0	.09319	3532.50	.22620	6.16
15	5	10.0	139.0	.10022	3686.12	.21867	6.16
16	5	10.0	149.0	.10657	3815.63	.21084	6.16
17	5	10.0	159.0	.11169	3914.33	.20243	6.16
18	5	11.0	169.5	.11540	3980.42	.19286	6.16
19	5	11.0	180.5	.11737	4007.08	.18212	6.16
20	5	10.0	191.0	.07617	4004.63	.17176	6.14
21	5	10.0	201.0	.07582	3989.12	.16232	6.14
22	5	10.0	211.0	.07492	3955.16	.15309	6.14
23	5	10.0	221.0	.07403	3920.35	.14469	6.12
24	5	10.0	231.0	.07296	3882.74	.13693	6.12
25	5	9.0	240.5	.07150	3831.94	.12967	6.12
26	5	9.0	249.5	.07041	3793.09	.12361	6.10
27	4	9.0	258.5	.15105	3761.91	.11758	6.10
28	4	9.0	267.5	.14747	3722.05	.11117	6.08
29	4	9.0	276.5	.14879	3749.51	.10723	6.06
30	4	10.0	286.0	.15618	3857.47	.10559	6.04
31	4	10.0	296.0	.16759	4012.43	.10508	6.02
32	4	10.0	306.0	.17844	4153.34	.10427	6.00
33	4	10.0	316.0	.18797	4267.09	.10286	6.00
34	4	10.0	326.0	.19623	4365.89	.10122	5.98
35	4	10.0	336.0	.20036	4414.46	.09857	5.96
36	4	10.0	346.0	.20416	4456.74	.09598	5.96

37	4	10.0	356.0	.20329	4451.74	.09258	5.94
38	4	10.0	366.0	.19993	4415.97	.08879	5.94

PERIOD = 1.824 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 809.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 4.43
FOR FREQUENCY (f) = .53 c/sec
FOR PERIOD (1 / f) = 1.87 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - riod1-hz.ser
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	CH SAVED ACC.REC.
WITHIN	.0	.33067	6.06	1.09	.000	512
WITHIN	13.0	.32114	6.06	1.02	.000	0
WITHIN	20.0	.31349	6.06	.98	.000	0
WITHIN	30.0	.30182	6.06	.92	.000	0
WITHIN	39.0	.29172	6.06	.89	.000	0
WITHIN	48.0	.27923	6.06	.85	.000	0
WITHIN	57.0	.26479	6.06	.84	.000	0
WITHIN	66.0	.25224	6.12	.84	.000	0
WITHIN	75.0	.24315	6.12	.87	.000	0
WITHIN	84.0	.22925	6.18	1.01	.000	0
WITHIN	94.0	.23182	6.20	1.26	.000	0
WITHIN	104.0	.22024	6.18	1.52	.000	0
WITHIN	114.0	.20826	5.86	1.72	.000	0
WITHIN	124.0	.25314	5.86	1.91	.000	0
WITHIN	134.0	.25520	5.84	1.89	.000	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - riod1-hz.ser
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	CH SAVED ACC.REC.
WITHIN	196.0	.22498	5.78	1.63	.000	0
WITHIN	371.0	.33278	5.58	3.02	.000	0
OUTCR.	371.0	.36000	5.58	3.02	.000	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 21

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 21

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85     : IBM-PC version of SHAKE                  *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88     : New modulus reduction curves for clays   *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 26, 1988                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; Input now is either *
*             Gmax or max Vs; up to 13 materia. types can *
*             be specified by user; up to 50 Layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91     : General cleanup and finalization of input /
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake98     : Routine for direct calculation of average *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing. The following   *
*             modulus reduction and damping curves are   *
*             added: Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SMB sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1993 - May 1998                     *
*********************************************************

 MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
 NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	1.000
.0032	.994
.0100	.983
.0316	.959
.1000	.881
.3160	.655
1.0000	.316
3.1600	.130

CURVE NO. 2

STRAIN	DAMPING
.0001	1.13
.0003	1.77
.0010	2.58
.0032	4.03
.0100	5.89
.0316	8.97
.1000	12.91
.3160	17.63
1.0000	21.92
3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	.964
.0032	.870
.0100	.712
.0316	.474
.1000	.253
.3160	.103
1.0000	.028
3.1600	.004

CURVE NO. 8

STRAIN	DAMPING
.0001	.85
.0003	1.04
.0010	1.66
.0032	3.00
.0100	5.48
.0316	10.01
.1000	15.40
.3160	20.23
1.0000	23.94
3.1600	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	.995
.0030	.936
.0100	.818
.0320	.640
.1000	.405
.3160	.210
1.0000	.095
3.1600	.034

CURVE NO.10

STRAIN	DAMPING
.0001	2.58
.0003	2.58
.0010	2.58
.0030	2.58
.0100	4.64
.0300	7.77
.1000	11.67
.3000	16.08
1.0000	20.12
.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11

STRAIN	G/Gmax
.0001	1.000
.0003	1.000
.0010	1.000
.0030	.976
.0100	.901
.0300	.743
.1000	.538
.3000	.332
1.0000	.158
3.0000	.048

CURVE NO.12

STRAIN	DAMPING
.0001	.85
.0003	.85
.0010	1.36
.0030	2.18
.0100	3.82
.0300	6.00
.1000	8.72
.3000	12.41
1.0000	16.90
3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 39
DEPTH TO BEDROCK 371.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	13.00	6.50	806.00	1386.	5.00	124.00	600.0
2	6	7.00	16.50	2046.00	2465.	5.00	124.00	800.0
3	6	10.00	25.00	3085.00	3391.	5.00	121.00	950.0
4	6	9.00	34.50	4234.50	4547.	5.00	121.00	1100.0
5	6	9.00	43.50	5323.50	4547.	5.00	121.00	1100.0
6	6	9.00	52.50	6412.50	4547.	5.00	121.00	1100.0
7	5	9.00	61.50	7497.00	4929.	5.00	120.00	1150.0
8	5	9.00	70.50	8577.00	4929.	5.00	120.00	1150.0
9	4	9.00	79.50	9657.00	5823.	5.00	120.00	1250.0
10	4	10.00	89.00	10797.00	5823.	5.00	120.00	1250.0
11	4	10.00	99.00	11997.00	5823.	5.00	120.00	1250.0
12	4	10.00	109.00	13197.00	5823.	5.00	120.00	1250.0
13	4	10.00	119.00	14397.00	5823.	5.00	120.00	1250.0
14	5	10.00	129.00	15617.00	7548.	5.00	124.00	1400.0
15	5	10.00	139.00	16857.00	7548.	5.00	124.00	1400.0
16	5	10.00	149.00	18097.00	7548.	5.00	124.00	1400.0
17	5	10.00	159.00	19337.00	7548.	5.00	124.00	1400.0
18	5	11.00	169.50	20639.00	7548.	5.00	124.00	1400.0
19	5	11.00	180.50	22003.00	7548.	5.00	124.00	1400.0
20	5	10.00	191.00	23315.00	9707.	5.00	126.00	1575.0
21	5	10.00	201.00	24575.00	9707.	5.00	126.00	1575.0
22	5	10.00	211.00	25835.00	9707.	5.00	126.00	1575.0
23	5	10.00	221.00	27095.00	9707.	5.00	126.00	1575.0
24	5	10.00	231.00	28355.00	9707.	5.00	126.00	1575.0
25	5	9.00	240.50	29552.00	9707.	5.00	126.00	1575.0
26	5	9.00	249.50	30686.00	9707.	5.00	126.00	1575.0
27	4	9.00	258.50	31995.50	10043.	5.00	165.00	1400.0
28	4	9.00	267.50	33480.50	10043.	5.00	165.00	1400.0
29	4	9.00	276.50	34965.50	10043.	5.00	165.00	1400.0
30	4	10.00	286.00	36533.00	10043.	5.00	165.00	1400.0
31	4	10.00	296.00	38183.01	10043.	5.00	165.00	1400.0
32	4	10.00	306.00	39833.01	10043.	5.00	165.00	1400.0
33	4	10.00	316.00	41483.01	10043.	5.00	165.00	1400.0
34	4	10.00	326.00	43133.01	10043.	5.00	165.00	1400.0
35	4	10.00	336.00	44783.01	10043.	5.00	165.00	1400.0
36	4	10.00	346.00	46433.02	10043.	5.00	165.00	1400.0
37	4	10.00	356.00	48083.02	10043.	5.00	165.00	1400.0
38	4	10.00	366.00	49733.02	10043.	5.00	165.00	1400.0
39	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.118 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1326.8 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 14.02
FOR FREQUENCY (f) = 1.04 c/sec
FOR PERIOD (1 / f) = .96 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = tabas.sar
NO. OF INPUT ACCEL. POINTS = 2904
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 5
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0100
FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

Tabas Accelerogram; Tabas-e-Golshan, Iran Eq. Of 09-16-1978; Mw = 7.39
Epic. Dist. = 3 km; Thrust Fault
1-Story Building; Rock ; Predom. Period = 0.1540 sec; Ds = 16.3 s

Uncorr. Max. Acc. = 0.78516 g; Max. in file = 0.811560 g; To = 0.1540 s
363*8=2904 pts. @ 0.01 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	-.005890	-.010260	-.010540	-.009570	-.007780	-.005980	-.004440	-.003040
2	-.002460	-.003650	-.006020	-.008090	-.009720	-.011810	-.014020	-.014990
3	-.014750	-.014370	-.013550	-.011130	-.007750	-.005220	-.004000	-.002460
4	-.000930	-.001030	-.002500	-.003290	-.003020	-.003440	-.005170	-.006860
5	-.007910	-.009080	-.010120	-.009670	-.007840	-.006180	-.004950	-.003170

..... INPUT MOTION READ NOT ECHOED.....

359	-.008320	-.000200	.010240	.016040	.015310	.012190	.010050	.006790
360	-.000560	-.010860	-.022440	-.036560	-.051930	-.060490	-.055670	-.042240
361	-.030870	-.024900	-.019760	-.013470	-.009080	-.006700	-.002250	.003530
362	.002460	-.010120	-.027280	-.037640	-.037170	-.030500	-.023900	-.020440
363	-.019670	-.018510	-.013770	-.011960	.000000	.000000	.000000	.000000

MAXIMUM ACCELERATION = .811560
AT TIME = 10.95 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .44359020
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.94 c/sec
MAXIMUM ACCELERATION = .359997 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.03157	.060	.050	16.3	1018.0	1386.3	[illegible]	1.000
2	6	16.5	.04205	.067	.050	24.8	1689.5	2464.6	[illegible]	1.000
3	6	25.0	.04303	.067	.050	25.5	2311.5	3391.4	[illegible]	1.000
4	6	34.5	.04058	.066	.050	23.9	3144.2	4546.9	[illegible]	1.000
5	6	43.5	.04700	.069	.050	27.7	3030.7	4546.9	[illegible]	1.000
6	6	52.5	.05188	.072	.050	30.1	2954.3	4546.9	[illegible]	1.000
7	5	61.5	.05103	.095	.050	47.3	2680.0	4928.6	[illegible]	1.000
8	5	70.5	.05469	.097	.050	48.5	2609.4	4928.6	[illegible]	1.000
9	4	79.5	.05082	.122	.050	59.1	2229.3	5823.0	[illegible]	1.000
10	4	89.0	.05507	.126	.050	60.3	2139.6	5823.0	[illegible]	1.000
11	4	99.0	.05886	.129	.050	61.3	2065.3	5823.0	[illegible]	1.000
12	4	109.0	.06201	.132	.050	62.0	2007.1	5823.0	[illegible]	1.000
13	4	119.0	.06467	.134	.050	62.6	1960.1	5823.0	[illegible]	1.000
14	5	129.0	.05161	.095	.050	47.5	4086.7	7547.8	[illegible]	1.000
15	5	139.0	.05335	.096	.050	48.1	4035.0	7547.8	[illegible]	1.000
16	5	149.0	.05514	.097	.050	48.7	3983.4	7547.8	[illegible]	1.000
17	5	159.0	.05649	.098	.050	49.1	3945.8	7547.8	[illegible]	1.000
18	5	169.5	.05746	.099	.050	49.4	3919.4	7547.8	[illegible]	1.000
19	5	180.5	.05926	.100	.050	49.9	3871.4	7547.8	[illegible]	1.000
20	5	191.0	.04769	.093	.050	46.1	5413.6	9706.8	[illegible]	1.000
21	5	201.0	.04921	.094	.050	46.7	5350.9	9706.8	[illegible]	1.000
22	5	211.0	.05077	.095	.050	47.2	5288.4	9706.8	[illegible]	1.000
23	5	221.0	.05228	.096	.050	47.7	5229.8	9706.8	[illegible]	1.000
24	5	231.0	.05369	.097	.050	48.2	5176.3	9706.8	[illegible]	1.000
25	5	240.5	.05493	.097	.050	48.6	5130.8	9706.8	[illegible]	1.000
26	5	249.5	.05602	.098	.050	48.9	5091.5	9706.8	[illegible]	1.000

27	4	258.5	.05518	.126	.050	60.4	3686.7	10043.5	-172.4	1.000
28	4	267.5	.05615	.127	.050	60.6	3652.9	10043.5	-174.9	1.000
29	4	276.5	.05694	.128	.050	60.8	3626.2	10043.5	-177.0	1.000
30	4	286.0	.05757	.128	.050	61.0	3604.9	10043.5	-178.6	1.000
31	4	296.0	.05806	.129	.050	61.1	3588.4	10043.5	-179.9	1.000
32	4	306.0	.05864	.129	.050	61.2	3569.4	10043.5	-181.4	1.000
33	4	316.0	.05970	.130	.050	61.5	3535.0	10043.5	-184.1	1.000
34	4	326.0	.06040	.130	.050	61.7	3512.4	10043.5	-185.9	1.000
35	4	336.0	.06106	.131	.050	61.8	3491.5	10043.5	-187.7	1.000
36	4	346.0	.06146	.131	.050	61.9	3479.0	10043.5	-188.7	1.000
37	4	356.0	.06222	.132	.050	62.1	3455.3	10043.5	-190.7	1.000
38	4	366.0	.06309	.132	.050	62.3	3428.3	10043.5	-193.0	1.000

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01772	.049	.060	-22.2	1135.0	1018.0	10.3	.734
2	6	16.5	.02574	.056	.067	-19.0	1885.5	1689.5	10.4	.686
3	6	25.0	.02687	.057	.067	-18.3	2573.6	2311.5	10.2	.682
4	6	34.5	.02547	.056	.068	-17.9	3485.3	3144.6	9.8	.682
5	6	43.5	.02136	.050	.069	-16.1	3344.1	3030.7	9.4	.667
6	6	52.5	.03054	.063	.072	-11.3	3225.7	2954.3	8.4	.650
7	5	61.5	.04438	.090	.095	-5.0	2821.9	2680.0	5.0	.544
8	5	70.5	.04900	.094	.097	-3.8	2721.2	2609.4	4.1	.529
9	4	79.5	.06047	.130	.122	6.2	2035.1	2229.3	-9.5	.383
10	4	89.0	.06846	.136	.126	7.5	1896.4	2139.6	-12.8	.367
11	4	99.0	.07724	.142	.129	9.0	1761.7	2065.3	-17.2	.355
12	4	109.0	.08542	.147	.132	10.2	1649.2	2007.1	-21.7	.345
13	4	119.0	.09451	.151	.134	11.7	1536.3	1960.1	-27.6	.337
14	5	129.0	.04725	.092	.095	-3.1	4224.1	4086.7	3.3	.541
15	5	139.0	.05046	.095	.096	-1.9	4121.7	4035.0	2.1	.535
16	5	149.0	.05350	.096	.097	-1.0	4030.5	3983.4	1.2	.528
17	5	159.0	.05623	.098	.098	-.2	3953.2	3945.8	.2	.523
18	5	169.5	.05980	.100	.099	1.3	3857.2	3919.4	-1.6	.519
19	5	180.5	.06366	.102	.100	2.3	3759.9	3871.4	-3.0	.513
20	5	191.0	.04836	.093	.093	.5	5385.5	5413.6	-.5	.558
21	5	201.0	.05182	.095	.094	1.3	5247.5	5350.9	-2.0	.551
22	5	211.0	.05523	.097	.095	2.4	5119.8	5288.4	-3.3	.545
23	5	221.0	.05850	.098	.096	3.7	5004.7	5229.6	-4.5	.539
24	5	231.0	.06154	.101	.097	4.4	4904.2	5176.3	-5.6	.533
25	5	240.5	.06419	.102	.097	4.9	4819.2	5130.8	-6.5	.529
26	5	249.5	.06649	.103	.098	5.4	4748.2	5091.5	-7.2	.525
27	4	258.5	.09443	.151	.126	16.6	2651.3	3686.7	-39.1	.367
28	4	267.5	.09781	.153	.127	17.0	2583.6	3652.9	-41.4	.364
29	4	276.5	.10214	.155	.128	17.6	2513.3	3626.2	-44.3	.361
30	4	286.0	.10690	.157	.128	18.3	2453.6	3604.9	-46.9	.359
31	4	296.0	.11142	.159	.129	18.9	2399.4	3588.4	-49.6	.357
32	4	306.0	.11549	.160	.129	19.4	2352.4	3569.4	-51.7	.355
33	4	316.0	.11968	.162	.130	19.6	2305.8	3535.0	-53.3	.352
34	4	326.0	.12313	.163	.130	19.9	2268.6	3512.4	-54.8	.350
35	4	336.0	.12646	.164	.131	20.1	2233.6	3491.5	-56.3	.348
36	4	346.0	.12969	.165	.131	20.4	2200.6	3479.0	-58.1	.346
37	4	356.0	.13394	.166	.132	20.7	2158.4	3455.3	-60.1	.344
38	4	366.0	.13870	.168	.132	21.0	2112.7	3428.3	-62.3	.341

ACCELEROGRAM - tabas.sar
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ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.01114	.040	.049	-21.7	1227.5	1135.0	7.5	.819
2	6	16.5	.01635	.047	.056	-18.0	2046.4	1885.5	7.9	.765
3	6	25.0	.01750	.049	.057	-16.5	2782.6	2573.6	7.5	.759
4	6	34.5	.01736	.049	.056	-14.6	3735.9	3485.3	6.7	.767
5	6	43.5	.02226	.053	.060	-12.1	3573.4	3344.1	6.4	.735
6	6	52.5	.02724	.057	.063	-10.9	3441.4	3225.7	6.3	.709
7	5	61.5	.03538	.083	.090	-8.0	3052.1	2821.9	7.5	.573
8	5	70.5	.04104	.088	.094	-6.5	2901.3	2721.2	6.2	.552
9	4	79.5	.05986	.130	.130	-.4	2046.4	2035.1	.5	.349
10	4	89.0	.07052	.138	.136	1.0	1863.3	1896.4	-1.8	.326
11	4	99.0	.08411	.146	.142	2.7	1666.5	1761.7	-5.7	.303
12	4	109.0	.09870	.153	.147	4.4	1487.8	1649.2	-10.6	.283
13	4	119.0	.11466	.160	.151	5.2	1369.3	1536.3	-12.2	.264
14	5	129.0	.04432	.090	.092	-2.3	4323.6	4224.1	2.3	.560
15	5	139.0	.04829	.093	.095	-1.5	4190.0	4121.7	1.6	.546
16	5	149.0	.05258	.096	.096	-.4	4057.6	4030.5	.7	.534
17	5	159.0	.05705	.099	.098	.5	3930.6	3953.2	-.6	.524
18	5	169.5	.06205	.101	.100	1.2	3799.8	3857.2	-1.5	.511
19	5	180.5	.06725	.104	.102	1.7	3674.6	3759.9	-2.3	.498
20	5	191.0	.04885	.093	.093	.3	5369.5	5385.5	-.4	.555
21	5	201.0	.05214	.096	.095	.2	5235.1	5247.5	-.2	.541
22	5	211.0	.05538	.098	.097	.1	5114.3	5119.8	-.1	.527
23	5	221.0	.05849	.099	.098	.0	5005.1	5004.7	.0	.516
24	5	231.0	.06153	.101	.101	.0	4903.5	4903.2	.0	.505
25	5	240.5	.06439	.102	.102	.1	4812.6	4819.2	-.1	.496
26	5	249.5	.06716	.104	.103	.1	4728.1	4748.2	-.4	.488
27	4	258.5	.12570	.164	.151	7.9	2241.5	2651.3	-18.3	.364
28	4	267.5	.13367	.166	.153	8.0	2161.0	2583.6	-19.6	.357
29	4	276.5	.14225	.169	.155	8.2	2079.5	2513.3	-20.8	.350
30	4	286.0	.15049	.171	.157	8.4	2005.8	2453.6	-22.3	.344
31	4	296.0	.15831	.173	.159	8.6	1939.5	2399.4	-23.7	.339
32	4	306.0	.16506	.175	.160	8.6	1884.9	2352.4	-24.8	.334
33	4	316.0	.17111	.177	.162	8.5	1837.7	2305.8	-25.5	.330
34	4	326.0	.17603	.178	.162	8.4	1800.6	2268.6	-26.0	.326
35	4	336.0	.18065	.179	.164	8.4	1766.0	2233.6	-26.4	.322
36	4	346.0	.18530	.180	.165	8.3	1733.4	2200.6	-27.0	.319
37	4	356.0	.19130	.181	.166	8.3	1691.7	2158.4	-27.6	.315
38	4	366.0	.19808	.183	.168	8.2	1646.0	2112.7	-28.3	.310

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.00889	.037	.040	-9.9	1259.2	1227.5	2.5	.885
2	6	16.5	.01330	.044	.047	-8.9	2119.6	2046.4	3.5	.830
3	6	25.0	.01453	.045	.048	-7.7	2873.4	2782.6	3.2	.820
4	6	34.5	.01461	.045	.049	-7.2	3846.8	3735.9	2.9	.822
5	6	43.5	.01890	.050	.053	-6.1	3680.4	3573.4	2.9	.786
6	6	52.5	.02325	.054	.057	-5.5	3545.0	3441.4	2.9	.757
7	5	61.5	.02985	.078	.083	-7.1	3206.8	3052.1	4.8	.619
8	5	70.5	.03537	.083	.088	-5.8	3052.6	2901.3	4.9	.589
9	4	79.5	.05463	.126	.130	-3.4	2147.6	2046.4	4.7	.351
10	4	89.0	.06688	.135	.138	-1.8	1922.6	1863.3	3.1	.320
11	4	99.0	.08331	.145	.146	-.3	1677.2	1666.5	.6	.286
12	4	109.0	.10244	.155	.153	1.0	1454.9	1487.9	-2.2	.256
13	4	119.0	.12062	.162	.160	1.3	1330.9	1369.3	-2.8	.235
14	5	129.0	.04114	.088	.090	-2.7	4439.6	4323.6	2.6	.573
15	5	139.0	.04541	.091	.093	-2.2	4285.7	4190.0	2.2	.555
16	5	149.0	.05021	.094	.096	-1.6	4129.4	4057.6	1.7	.538
17	5	159.0	.05522	.097	.099	-1.1	3981.3	3930.6	1.3	.521
18	5	169.5	.06061	.100	.101	-.8	3836.2	3799.8	.9	.503

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19	5	180.5	.06618	.103	.104	-.5	3699.5	3674.6	.7	.487
20	5	191.0	.04721	.092	.093	-1.2	5433.7	5365.5	1.3	.553
21	5	201.0	.05031	.094	.096	-1.2	5306.5	5235.1	1.3	.539
22	5	211.0	.05329	.096	.098	-1.3	5191.3	5114.3	1.5	.527
23	5	221.0	.05618	.098	.099	-1.3	5085.5	5005.1	1.6	.516
24	5	231.0	.05896	.100	.101	-1.4	4988.8	4903.5	1.7	.505
25	5	240.5	.06162	.101	.102	-1.4	4900.6	4812.6	1.8	.496
26	5	249.5	.06419	.102	.104	-1.4	4818.8	4728.1	1.9	.487
27	4	258.5	.13964	.168	.164	2.6	2103.8	2241.5	-6.5	.223
28	4	267.5	.14878	.171	.166	2.6	2020.8	2161.0	-6.9	.215
29	4	276.5	.15882	.173	.169	2.7	1935.3	2079.5	-7.5	.207
30	4	286.0	.16904	.176	.171	2.8	1853.6	2000.8	-8.2	.200
31	4	296.0	.17887	.179	.173	2.9	1779.6	1939.5	-9.0	.193
32	4	306.0	.18714	.180	.175	2.9	1720.4	1894.9	-9.6	.188
33	4	316.0	.19393	.182	.177	2.9	1673.8	1837.7	-9.8	.183
34	4	326.0	.19897	.183	.178	2.8	1640.2	1800.6	-9.8	.179
35	4	336.0	.20366	.184	.179	2.7	1609.7	1766.6	-9.8	.176
36	4	346.0	.20853	.185	.180	2.7	1578.7	1733.4	-9.8	.173
37	4	356.0	.21535	.186	.181	2.7	1536.6	1691.7	-10.1	.168
38	4	366.0	.22309	.188	.183	2.7	1490.3	1646.0	-10.4	.164

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.00829	.036	.037	-2.7	1265.3	1259.3	.5	.908
2	6	16.5	.01227	.042	.044	-3.6	2148.1	2119.6	1.3	.860
3	6	25.0	.01346	.044	.045	-3.3	2910.7	2873.4	1.3	.847
4	6	34.5	.01360	.044	.045	-3.1	3895.8	3848.8	1.2	.846
5	6	43.5	.01759	.049	.050	-2.8	3727.6	3680.4	1.3	.809
6	6	52.5	.02187	.053	.054	-2.5	3580.9	3545.0	1.3	.780
7	5	61.5	.02730	.075	.078	-3.4	3274.1	3206.8	2.1	.651
8	5	70.5	.03231	.080	.083	-3.7	3144.5	3052.6	2.9	.619
9	4	79.5	.05003	.122	.126	-3.4	2246.8	2147.6	4.4	.369
10	4	89.0	.06252	.132	.135	-2.4	1997.9	1922.6	3.8	.330
11	4	99.0	.07979	.143	.145	-1.4	1725.4	1677.2	2.8	.288
12	4	109.0	.10097	.154	.155	-.4	1465.9	1454.9	.7	.250
13	4	119.0	.11999	.162	.162	-.1	1334.9	1330.9	.3	.229
14	5	129.0	.03891	.086	.088	-2.1	4526.3	4439.6	1.9	.588
15	5	139.0	.04321	.090	.091	-1.8	4362.9	4285.7	1.8	.568
16	5	149.0	.04805	.093	.094	-1.5	4197.8	4129.4	1.6	.547
17	5	159.0	.05311	.096	.097	-1.3	4041.9	3981.3	1.5	.527
18	5	169.5	.05851	.099	.100	-1.2	3891.3	3836.2	1.4	.508
19	5	180.5	.06407	.102	.103	-1.0	3749.9	3699.5	1.3	.490
20	5	191.0	.04552	.091	.092	-1.3	5506.8	5433.7	1.3	.560
21	5	201.0	.04847	.093	.094	-1.3	5381.2	5306.5	1.4	.547
22	5	211.0	.05127	.095	.096	-1.3	5268.8	5191.3	1.5	.535
23	5	221.0	.05401	.097	.098	-1.3	5164.6	5085.5	1.5	.524
24	5	231.0	.05659	.098	.100	-1.4	5071.1	4988.8	1.6	.514
25	5	240.5	.05903	.100	.101	-1.4	4986.7	4900.6	1.7	.505
26	5	249.5	.06133	.101	.102	-1.5	4910.1	4818.8	1.9	.496
27	4	258.5	.14411	.169	.168	.8	2062.5	2103.8	-2.0	.209
28	4	267.5	.15349	.172	.171	.8	1980.0	2020.8	-2.1	.201
29	4	276.5	.16398	.175	.173	.8	1893.4	1935.3	-2.2	.193
30	4	286.0	.17532	.178	.176	.9	1805.9	1853.6	-2.6	.185
31	4	296.0	.18643	.180	.178	1.0	1725.4	1779.6	-3.1	.177
32	4	306.0	.19561	.182	.180	1.0	1662.4	1720.4	-3.5	.171
33	4	316.0	.20256	.184	.182	1.0	1616.7	1673.8	-3.5	.167
34	4	326.0	.20711	.185	.183	.9	1587.7	1640.2	-3.3	.163
35	4	336.0	.21126	.185	.184	.8	1561.7	1609.7	-3.1	.160
36	4	346.0	.21590	.186	.185	.8	1533.2	1578.7	-3.0	.157
37	4	356.0	.22281	.188	.186	.8	1492.0	1536.6	-3.0	.153
38	4	366.0	.23097	.189	.188	.8	1444.9	1490.3	-3.1	.148

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.00814	.035	.036	-.7	1266.8	1265.3	.1	.913
2	6	16.5	.01196	.042	.042	-1.2	2157.3	2148.1	.4	.872
3	6	25.0	.01312	.043	.044	-1.1	2923.0	2910.7	.4	.858
4	6	34.5	.01327	.043	.044	-1.1	3911.5	3895.8	.4	.857
5	6	43.5	.01714	.048	.049	-1.0	3744.3	3727.6	.4	.820
6	6	52.5	.02112	.052	.053	-.9	3607.8	3580.9	.5	.790
7	5	61.5	.02639	.074	.075	-1.3	3299.7	3274.1	.8	.664
8	5	70.5	.03095	.079	.080	-1.8	3179.5	3144.5	1.1	.638
9	4	79.5	.04716	.119	.122	-2.3	2312.9	2246.8	2.9	.386
10	4	89.0	.05920	.129	.132	-2.0	2058.9	1997.9	3.0	.343
11	4	99.0	.07632	.141	.143	-1.5	1775.1	1725.4	2.6	.296
12	4	109.0	.09863	.153	.154	-.7	1483.7	1465.9	1.5	.252
13	4	119.0	.11796	.161	.162	-.4	1347.8	1334.9	1.0	.229
14	5	129.0	.03768	.085	.086	-1.2	4576.2	4526.3	1.1	.600
15	5	139.0	.04192	.089	.090	-1.1	4410.2	4362.9	1.1	.578
16	5	149.0	.04670	.092	.093	-1.0	4242.1	4197.8	1.0	.556
17	5	159.0	.05171	.095	.096	-.9	4083.5	4041.9	1.0	.536
18	5	169.5	.05705	.099	.099	-.8	3930.6	3891.3	1.0	.516
19	5	180.5	.06257	.102	.102	-.8	3786.8	3749.9	1.0	.497
20	5	191.0	.04450	.090	.091	-.8	5552.4	5506.8	.8	.567
21	5	201.0	.04738	.093	.093	-.8	5426.6	5381.2	.8	.554
22	5	211.0	.05012	.094	.095	-.8	5314.1	5268.8	.9	.543
23	5	221.0	.05275	.096	.097	-.8	5211.9	5164.6	.9	.532
24	5	231.0	.05525	.097	.098	-.8	5119.0	5071.1	.9	.522
25	5	240.5	.05753	.099	.100	-.8	5038.1	4986.7	1.0	.514
26	5	249.5	.05969	.100	.101	-.9	4964.2	4910.1	1.1	.506
27	4	258.5	.14546	.170	.169	.2	2050.4	2062.5	-.6	.205
28	4	267.5	.15463	.172	.172	.2	1969.6	1980.0	-.5	.197
29	4	276.5	.16546	.175	.175	.2	1881.6	1893.4	-.6	.189
30	4	286.0	.17737	.178	.178	.3	1790.7	1805.9	-.9	.180
31	4	296.0	.18946	.181	.180	.4	1704.3	1725.4	-1.2	.172
32	4	306.0	.19939	.183	.182	.4	1637.4	1662.4	-1.5	.166
33	4	316.0	.20645	.184	.184	.4	1581.9	1616.7	-1.6	.161
34	4	326.0	.21045	.185	.185	.4	1566.7	1587.7	-1.3	.158
35	4	336.0	.21382	.186	.185	.3	1545.9	1561.7	-1.0	.155
36	4	346.0	.21788	.187	.186	.2	1521.3	1533.2	-.8	.153
37	4	356.0	.22455	.189	.188	.2	1481.8	1492.0	-.7	.149
38	4	366.0	.23299	.190	.189	.2	1433.5	1444.9	-.8	.144

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	6.5	.00811	.035	.035	-.1	1267.2	1266.8	.0	.914
2	6	16.5	.01188	.041	.042	-.3	2159.7	2157.3	.1	.875
3	6	25.0	.01303	.043	.043	-.3	2926.6	2923.0	.1	.862
4	6	34.5	.01317	.043	.043	-.3	3916.6	3911.5	.1	.860
5	6	43.5	.01700	.048	.048	-.3	3749.7	3744.3	.1	.823
6	6	52.5	.02094	.052	.052	-.3	3613.4	3607.8	.1	.793
7	5	61.5	.02608	.074	.074	-.5	3308.6	3299.7	.3	.669
8	5	70.5	.03047	.078	.079	-.6	3191.2	3179.5	.4	.645
9	4	79.5	.04559	.117	.119	-1.3	2350.5	2312.9	1.6	.397
10	4	89.0	.05702	.128	.129	-1.4	2100.8	2058.9	2.0	.354

11	4	99.0	.07366	.140	.141	-1.2	1814.7	1775.1	2.2	.305
12	4	109.0	.09643	.152	.153	-.7	1513.9	1488.7	1.7	.254
13	4	119.0	.11599	.160	.161	-.4	1360.6	1347.8	.9	.231
14	5	129.0	.03706	.085	.085	-.6	4602.0	4576.2	.6	.606
15	5	139.0	.04124	.088	.089	-.6	4435.9	4410.2	.6	.584
16	5	149.0	.04595	.092	.092	-.6	4267.3	4242.1	.6	.562
17	5	159.0	.05092	.095	.095	-.5	4107.5	4083.5	.6	.541
18	5	169.5	.05621	.098	.099	-.5	3953.6	3930.6	.6	.521
19	5	180.5	.06170	.101	.102	-.4	3808.5	3786.8	.6	.502
20	5	191.0	.04398	.090	.090	-.4	5575.8	5552.4	.4	.572
21	5	201.0	.04684	.092	.093	-.4	5449.4	5426.6	.4	.559
22	5	211.0	.04956	.094	.094	-.4	5336.6	5314.1	.4	.547
23	5	221.0	.05214	.096	.096	-.4	5234.9	5211.9	.4	.537
24	5	231.0	.05462	.097	.097	-.4	5142.0	5119.0	.4	.527
25	5	240.5	.05681	.098	.099	-.4	5063.2	5038.1	.5	.519
26	5	249.5	.05891	.100	.100	-.4	4990.5	4964.2	.5	.511
27	4	258.5	.14597	.170	.170	.1	2045.8	2050.4	-.2	.204
28	4	267.5	.15519	.172	.172	.1	1965.6	1968.6	-.2	.196
29	4	276.5	.16587	.175	.175	.1	1878.4	1881.6	-.2	.187
30	4	286.0	.17818	.178	.178	.1	1784.7	1790.7	-.3	.178
31	4	296.0	.19100	.181	.181	.2	1693.7	1704.3	-.6	.170
32	4	306.0	.20158	.183	.183	.3	1623.1	1637.4	-.9	.163
33	4	316.0	.20877	.185	.184	.3	1577.2	1591.9	-.9	.158
34	4	326.0	.21229	.186	.185	.2	1555.3	1566.7	-.7	.156
35	4	336.0	.21484	.186	.186	.1	1539.7	1545.9	-.4	.154
36	4	346.0	.21824	.187	.187	.0	1519.2	1521.3	-.1	.151
37	4	356.0	.22455	.188	.188	.0	1481.8	1481.8	.0	.146
38	4	366.0	.23317	.190	.190	.0	1432.5	1433.5	-.1	.143

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	13.0	6.5	.01229	155.69	.19316	12.89
2	6	7.0	16.5	.01799	388.17	.18972	12.89
3	6	10.0	25.0	.01974	577.06	.18703	12.90
4	6	9.0	34.5	.01986	780.68	.18436	12.90
5	6	9.0	43.5	.02576	964.59	.18119	12.90
6	6	9.0	52.5	.03173	1144.83	.17853	12.91
7	5	9.0	61.5	.03951	1303.83	.17391	12.92
8	5	9.0	70.5	.04617	1467.94	.17115	12.93
9	4	9.0	79.5	.06908	1597.83	.16546	12.95
10	4	10.0	89.0	.08639	1778.68	.16474	13.01
11	4	10.0	99.0	.11161	1981.08	.16513	13.01
12	4	10.0	109.0	.14610	2174.98	.16481	13.02
13	4	10.0	119.0	.17575	2368.77	.16453	13.09
14	5	10.0	129.0	.05616	2569.77	.16455	13.01
15	5	10.0	139.0	.06248	2755.43	.16346	13.03
16	5	10.0	149.0	.06963	2953.57	.16321	13.05
17	5	10.0	159.0	.07715	3150.40	.16292	13.05
18	5	11.0	169.5	.08517	3347.69	.16220	13.05
19	5	11.0	180.5	.09349	3540.12	.16089	13.05
20	5	10.0	191.0	.06663	3699.70	.15868	13.04
21	5	10.0	201.0	.07098	3851.53	.15673	13.04
22	5	10.0	211.0	.07509	3990.51	.15446	13.04
23	5	10.0	221.0	.07900	4117.58	.15197	13.03
24	5	10.0	231.0	.08275	4236.18	.14940	13.03
25	5	9.0	240.5	.08608	4336.72	.14675	13.02
26	5	9.0	249.5	.08926	4431.12	.14440	13.02
27	4	9.0	258.5	.22117	4534.65	.14173	13.03
28	4	9.0	267.5	.23513	4628.83	.13825	13.01
29	4	9.0	276.5	.25132	4728.84	.13524	13.00
30	4	10.0	286.0	.26997	4834.20	.13232	12.99
31	4	10.0	296.0	.28939	4932.14	.12917	12.97
32	4	10.0	306.0	.30543	5001.17	.12555	12.96
33	4	10.0	316.0	.31632	5035.34	.12138	12.95
34	4	10.0	326.0	.32166	5039.51	.11684	12.94
35	4	10.0	336.0	.32551	5032.21	.11237	12.92
36	4	10.0	346.0	.33066	5030.31	.10833	12.90
37	4	10.0	356.0	.34023	5041.67	.10485	12.89

38	4	10.0	366.0	.35329	5064.42	.10183	12.87

PERIOD = 1.782 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 832.6 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 3.70
FOR FREQUENCY (f) = .49 c/sec
FOR PERIOD (1 / f) = 2.05 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - tabas.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.19763	12.89	1.24	.003	512
WITHIN	13.0	.19162	12.89	1.13	.003	0
WITHIN	20.0	.18720	12.90	1.06	.003	0
WITHIN	30.0	.18178	12.91	.99	.003	0
WITHIN	35.0	.17905	12.92	.94	.003	0
WITHIN	46.0	.17460	12.93	.91	.003	0
WITHIN	57.0	.17237	12.95	.90	.003	0
WITHIN	66.0	.17342	12.98	.90	.003	0
WITHIN	75.0	.17553	12.99	.92	.003	0
WITHIN	84.0	.17719	12.99	.96	.003	0
WITHIN	94.0	.17604	12.99	1.03	.003	0
WITHIN	104.0	.16989	12.99	1.09	.003	0
WITHIN	114.0	.15840	13.01	1.17	.003	0
WITHIN	124.0	.15874	13.05	1.27	.003	0
WITHIN	134.0	.15772	13.05	1.27	.003	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - tabas.sar
D E P O S I T - Paducah U Landfill - fee-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	196.0	.12940	12.88	1.23	.004	0
WITHIN	371.0	.33980	10.95	3.93	.000	0
OUTCR.	371.0	.36000	10.95	3.94	.000	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 21

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 21
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 21

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APPENDIX E

SITE RESPONSE ANALYSIS—LANDFILL

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* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85     : IBM-PC version of SHAKE                  *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88     : New modulus reduction curves for clays   *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 26, 1989                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; input now is either *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91     : General cleanup and finalization of input / *
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake98     : Routine for direct calculation of average *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing. The following   *
*             modulus reduction and damping curves are   *
*             added: Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SMR sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1992 - May 1998                     *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

*******************
MATERIAL TYPE NO. 1
*******************

CURVE NO.  1:      #1 Modulus for Oil Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for Oil Waste (Matasovic & Kavazanjian, 1998
```

CURVE No. 1		CURVE No. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


```
*******************
MATERIAL TYPE NO. 4
*******************

CURVE NO.  7:      #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:      #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
*******************
MATERIAL TYPE NO. 5
*******************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.895	.0010	2.58
.0030	.836	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
*******************
MATERIAL TYPE NO. 6
*******************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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SOIL PROFILE NO. 1 Paducah 0 Landfill - fee-field prof

NUMBER OF LAYERS 47
DEPTH TO BEDROCK 441.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	5.00	2.50	300.00	2507.	5.00	120.00	820.2
2	1	10.00	10.00	969.50	745.	5.00	73.90	569.6
3	1	10.00	20.00	1730.00	855.	5.00	78.20	593.2
4	1	10.00	30.00	2528.50	963.	5.00	81.50	616.8
5	1	10.00	40.00	3356.50	1071.	5.00	84.10	640.4
6	1	10.00	50.00	4206.50	1176.	5.00	85.90	664.0
7	1	10.00	60.00	5071.50	1279.	5.00	87.10	687.7
8	6	5.00	67.50	5832.00	2715.	5.00	130.00	820.0
9	6	13.00	76.50	6963.00	1386.	5.00	124.00	600.0
10	6	7.00	86.50	8203.00	2465.	5.00	124.00	800.0
11	6	10.00	95.00	9242.00	3391.	5.00	121.00	950.0
12	6	9.00	104.50	10391.50	4547.	5.00	121.00	1100.0
13	6	9.00	113.50	11480.50	4547.	5.00	121.00	1100.0
14	6	9.00	122.50	12569.50	4547.	5.00	121.00	1100.0
15	5	9.00	131.50	13654.00	4928.	5.00	120.00	1150.0
16	5	9.00	140.50	14734.00	4928.	5.00	120.00	1150.0
17	4	9.00	149.50	15814.00	5823.	5.00	120.00	1250.0
18	4	10.00	159.00	16954.00	5823.	5.00	120.00	1250.0
19	4	10.00	169.00	18154.00	5823.	5.00	120.00	1250.0
20	4	10.00	179.00	19354.00	5823.	5.00	120.00	1250.0
21	4	10.00	189.00	20554.00	5823.	5.00	120.00	1250.0
22	5	10.00	199.00	21774.00	7548.	5.00	124.00	1400.0
23	5	10.00	209.00	23014.00	7548.	5.00	124.00	1400.0
24	5	10.00	219.00	24254.00	7548.	5.00	124.00	1400.0
25	5	10.00	229.00	25494.00	7548.	5.00	124.00	1400.0
26	5	11.00	239.50	26796.00	7548.	5.00	124.00	1400.0
27	5	11.00	250.50	28160.00	7548.	5.00	124.00	1400.0
28	5	10.00	261.00	29472.00	9707.	5.00	126.00	1575.0
29	5	10.00	271.00	30732.00	9707.	5.00	126.00	1575.0
30	5	10.00	281.00	31992.00	9707.	5.00	126.00	1575.0
31	5	10.00	291.00	33252.00	9707.	5.00	126.00	1575.0
32	5	10.00	301.00	34512.00	9707.	5.00	126.00	1575.0
33	5	9.00	310.50	35709.00	9707.	5.00	126.00	1575.0
34	5	9.00	319.50	36843.00	9707.	5.00	126.00	1575.0
35	4	9.00	328.50	38152.50	10043.	5.00	165.00	1400.0
36	4	9.00	337.50	39637.50	10043.	5.00	165.00	1400.0
37	4	9.00	346.50	41122.50	10043.	5.00	165.00	1400.0
38	4	10.00	356.00	42680.00	10043.	5.00	165.00	1400.0
39	4	10.00	366.00	44340.00	10043.	5.00	165.00	1400.0
40	4	10.00	376.00	45990.00	10043.	5.00	165.00	1400.0
41	4	10.00	386.00	47640.00	10043.	5.00	165.00	1400.0
42	4	10.00	396.00	49290.00	10043.	5.00	165.00	1400.0
43	4	10.00	406.00	50940.01	10043.	5.00	165.00	1400.0
44	4	10.00	416.00	52590.01	10043.	5.00	165.00	1400.0
45	4	10.00	426.00	54240.01	10043.	5.00	165.00	1400.0
46	4	10.00	436.00	55890.01	10043.	5.00	165.00	1400.0
47	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.446 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1220.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 16.07
FOR FREQUENCY (f) = .87 c/sec
FOR PERIOD (1 / f) = 1.15 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = t56-ac2b.sar
NO. OF INPUT ACCEL. POINTS = 2248
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 3
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200

FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

Time history matched to spectrum:dwr-tar.dat / WCC for El Sobrante
Max in file = 0.636577 g Ds = 25.8 s
2248 pts @ 0.02 s

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	.000525	.000548	.000616	.000729	.000866	.001030	.001169	.001291
2	.001324	.001299	.001149	.000959	.000688	.000405	.000059	-.000288
3	-.000617	-.000891	-.001129	-.001236	-.001257	-.001101	-.000812	-.000337
4	.000187	.000753	.001613	.003606	.004803	.003955	.002017	.006526
5	.009613	.005528	-.011607	.001042	.041819	.037028	-.025987	-.053567

..... INPUT MOTION READ NOT ECHOED.....

277	-.000568	-.000614	-.000644	-.000686	-.000714	-.000753	-.000778	-.000813
278	-.000836	-.000866	-.000886	-.000914	-.000931	-.000954	-.000969	-.000989
279	-.001001	-.001018	-.001027	-.001040	-.001047	-.001057	-.001062	-.001069
280	-.001071	-.001075	-.001075	-.001076	-.001074	-.001073	-.001069	-.001065
281	-.001058	-.001053	-.001046	-.001038	-.001029	-.001019	-.001009	-.000998

MAXIMUM ACCELERATION = .636577
AT TIME = 3.62 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .56552470
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.42 c/sec
MAXIMUM ACCELERATION = .359987 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 47 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah 0 Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00794	.035	.050	-42.8	2294.9	2507.1	-9.2	1.000
2	1	10.0	.08591	.124	.050	59.6	663.7	744.6	-12.2	1.000
3	1	20.0	.13004	.140	.050	64.3	708.8	854.6	-20.6	1.000
4	1	30.0	.16134	.149	.050	66.4	757.9	962.9	-27.1	1.000
5	1	40.0	.18561	.154	.050	67.6	813.5	1071.1	-31.7	1.000
6	1	50.0	.20082	.158	.050	68.3	875.1	1176.2	-34.4	1.000
7	1	60.0	.20737	.159	.050	68.6	943.8	1279.3	-35.5	1.000
8	6	67.5	.10576	.089	.050	43.8	1432.0	2714.7	-89.6	1.000
9	6	76.5	.22742	.114	.050	56.0	532.3	1386.3	-180.5	1.000
10	6	86.5	.13805	.098	.050	48.8	1177.0	2464.6	-109.4	1.000
11	6	95.0	.10629	.089	.050	43.9	1785.8	3391.4	-89.9	1.000
12	6	104.5	.08476	.083	.050	40.0	2574.2	4546.9	-76.6	1.000
13	6	113.5	.08962	.085	.050	41.0	2529.3	4546.9	-79.8	1.000
14	6	122.5	.09448	.086	.050	41.8	2490.2	4546.9	-82.6	1.000
15	5	131.5	.09167	.114	.050	56.1	2084.5	4928.6	-136.4	1.000
16	5	140.5	.09533	.115	.050	56.6	2044.7	4928.6	-141.0	1.000
17	4	149.5	.08308	.145	.050	65.6	1680.3	5823.0	-246.5	1.000
18	4	159.0	.08497	.146	.050	65.8	1655.2	5823.0	-251.8	1.000
19	4	169.0	.08740	.148	.050	66.1	1623.7	5823.0	-258.6	1.000
20	4	179.0	.08912	.149	.050	66.4	1601.9	5823.0	-263.5	1.000

21	4	189.0	.09012	.149	.050	66.5	1589.5	5823.0	-266.4	1.000
22	5	199.0	.07053	.105	.050	52.6	3600.4	7547.8	-109.6	1.000
23	5	209.0	.07143	.106	.050	52.7	3560.7	7547.8	-110.6	1.000
24	5	219.0	.07186	.106	.050	52.8	3571.3	7547.8	-111.5	1.000
25	5	229.0	.07223	.106	.050	52.9	3563.2	7547.8	-111.8	1.000
26	5	239.5	.07274	.106	.050	53.0	3552.4	7547.8	-112.5	1.000
27	5	250.5	.07265	.106	.050	53.0	3554.2	7547.8	-112.4	1.000
28	5	261.0	.05682	.098	.050	49.2	5063.1	9706.8	-91.7	1.000
29	5	271.0	.05717	.099	.050	49.3	5050.6	9706.8	-92.2	1.000
30	5	281.0	.05772	.099	.050	49.4	5031.3	9706.8	-92.9	1.000
31	5	291.0	.05880	.099	.050	49.7	4994.4	9706.8	-94.4	1.000
32	5	301.0	.05945	.100	.050	49.9	4972.2	9706.8	-95.2	1.000
33	5	310.5	.05970	.100	.050	50.0	4963.8	9706.8	-95.6	1.000
34	5	319.5	.05962	.100	.050	50.0	4966.6	9706.8	-95.4	1.000
35	4	328.5	.05742	.128	.050	61.0	3609.9	10043.5	-176.2	1.000
36	4	337.5	.05739	.128	.050	60.9	3610.8	10043.5	-176.2	1.000
37	4	346.5	.05864	.129	.050	61.2	3569.4	10043.5	-181.4	1.000
38	4	356.0	.06097	.131	.050	61.8	3494.4	10043.5	-187.4	1.000
39	4	366.0	.06312	.132	.050	62.3	3427.6	10043.5	-193.0	1.000
40	4	376.0	.06487	.134	.050	62.6	3375.0	10043.5	-197.6	1.000
41	4	386.0	.06613	.135	.050	62.9	3337.8	10043.5	-200.9	1.000
42	4	396.0	.06687	.135	.050	63.0	3316.3	10043.5	-202.5	1.000
43	4	406.0	.06708	.135	.050	63.1	3310.2	10043.5	-203.4	1.000
44	4	416.0	.06673	.135	.050	63.0	3320.3	10043.5	-202.5	1.000
45	4	426.0	.06602	.135	.050	62.8	3341.0	10043.5	-200.6	1.000
46	4	436.0	.06514	.134	.050	62.7	3366.8	10043.5	-198.3	1.000

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00410	.026	.035	-34.5	2398.2	2294.9	4.3	.915
2	1	10.0	.04529	.102	.124	-21.5	695.9	663.7	4.6	.891
3	1	20.0	.07371	.119	.140	-17.9	770.5	708.8	8.0	.829
4	1	30.0	.09694	.128	.149	-16.1	850.4	757.9	10.9	.787
5	1	40.0	.11385	.134	.154	-14.9	916.4	813.5	11.2	.760
6	1	50.0	.12437	.138	.158	-14.2	985.8	875.1	11.2	.744
7	1	60.0	.12879	.139	.159	-14.0	1063.5	943.8	11.3	.738
8	6	67.5	.09348	.086	.089	-4.0	1491.6	1432.0	4.0	.527
9	6	76.5	.26895	.119	.114	4.5	488.7	532.3	-8.9	.384
10	6	86.5	.12701	.095	.098	-2.9	1215.5	1177.0	3.2	.478
11	6	95.0	.08508	.083	.089	-7.0	1917.9	1785.8	6.9	.527
12	6	104.5	.06089	.075	.083	-10.5	2830.3	2574.2	9.0	.566
13	6	113.5	.06681	.078	.085	-9.1	2758.5	2529.3	8.3	.556
14	6	122.5	.07252	.080	.086	-7.9	2695.0	2490.2	7.6	.548
15	5	131.5	.09292	.114	.114	.4	2070.7	2084.5	-.7	.623
16	5	140.5	.09988	.117	.115	1.1	1997.3	2044.7	-2.4	.615
17	4	149.5	.12895	.165	.145	11.7	1280.2	1680.3	-31.3	.289
18	4	159.0	.13721	.167	.146	12.5	1233.1	1655.2	-34.2	.284
19	4	169.0	.14627	.170	.148	13.1	1184.5	1623.7	-37.1	.279
20	4	179.0	.15410	.172	.149	13.7	1144.9	1601.9	-39.9	.275
21	4	189.0	.16102	.174	.149	14.3	1111.6	1589.5	-41.0	.273
22	5	199.0	.07168	.106	.105	.5	3575.1	3600.4	-.7	.477
23	5	209.0	.07424	.107	.106	1.2	3520.5	3580.7	-1.7	.474
24	5	219.0	.07649	.108	.106	1.9	3474.1	3571.3	-2.8	.473
25	5	229.0	.07872	.109	.106	2.4	3429.4	3563.2	-3.9	.472
26	5	239.5	.08086	.110	.106	3.1	3387.5	3552.4	-4.9	.471
27	5	250.5	.08294	.111	.106	3.9	3348.1	3554.2	-6.2	.471
28	5	261.0	.05927	.100	.098	1.4	4978.4	5063.1	-1.7	.522
29	5	271.0	.06088	.101	.099	2.0	4924.9	5050.6	-2.6	.520
30	5	281.0	.06244	.101	.099	2.5	4874.0	5031.3	-3.2	.518
31	5	291.0	.06415	.102	.099	2.8	4820.0	4994.4	-3.6	.515
32	5	301.0	.06580	.103	.100	3.2	4769.2	4972.2	-4.1	.512
33	5	310.5	.06702	.104	.100	3.6	4732.5	4963.8	-4.9	.511

34	5	319.5	.06792	.104	.100	4.1	4705.8	4966.6	-5.5	.512
35	4	328.5	.09614	.152	.128	15.9	2616.8	3609.9	-38.0	.359
36	4	337.5	.09795	.153	.128	16.3	2580.9	3610.8	-39.5	.360
37	4	346.5	.10079	.154	.129	16.4	2530.7	3569.4	-41.0	.355
38	4	356.0	.10502	.156	.131	16.2	2476.9	3494.4	-41.1	.346
39	4	366.0	.10896	.158	.132	15.9	2428.7	3427.6	-41.1	.341
40	4	376.0	.11264	.159	.134	15.9	2385.1	3375.0	-41.5	.336
41	4	386.0	.11559	.160	.135	15.9	2351.3	3337.8	-42.0	.332
42	4	396.0	.11798	.161	.135	16.0	2324.5	3316.3	-42.7	.330
43	4	406.0	.11983	.162	.135	16.3	2304.1	3310.2	-43.7	.330
44	4	416.0	.12069	.162	.135	16.6	2294.7	3320.3	-44.7	.331
45	4	426.0	.12156	.162	.135	17.0	2285.4	3341.0	-46.2	.333
46	4	436.0	.12140	.162	.134	17.4	2287.1	3366.8	-47.2	.335

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00281	.021	.026	-22.2	2450.5	2398.2	2.1	.957
2	1	10.0	.03091	.089	.102	-14.5	714.4	695.9	2.6	.935
3	1	20.0	.04839	.104	.119	-13.8	794.9	770.5	3.1	.902
4	1	30.0	.06146	.112	.128	-13.9	880.1	850.4	3.4	.883
5	1	40.0	.07175	.118	.134	-14.2	967.7	916.4	5.2	.856
6	1	50.0	.07835	.121	.138	-14.3	1055.6	985.8	6.6	.838
7	1	60.0	.08125	.122	.139	-14.3	1145.0	1063.5	7.1	.831
8	6	67.5	.06420	.077	.086	-11.7	1665.3	1491.6	10.4	.545
9	6	76.5	.21201	.111	.119	-6.6	550.5	488.7	11.2	.352
10	6	86.5	.09628	.086	.095	-9.6	1341.8	1215.5	9.4	.493
11	6	95.0	.06663	.078	.083	-7.3	2059.0	1917.9	6.5	.566
12	6	104.5	.04921	.070	.075	-7.2	2995.2	2830.3	5.5	.622
13	6	113.5	.05446	.073	.078	-6.7	2916.7	2758.5	5.4	.607
14	6	122.5	.05975	.075	.080	-6.2	2844.9	2695.0	5.3	.593
15	5	131.5	.08361	.111	.114	-3.1	2178.1	2070.7	4.9	.620
16	5	140.5	.09167	.114	.117	-2.4	2084.5	1997.3	4.2	.605
17	4	149.5	.15302	.172	.165	4.2	1150.3	1280.2	-11.0	.220
18	4	159.0	.16668	.175	.167	4.7	1085.4	1233.1	-13.6	.212
19	4	169.0	.18097	.179	.170	5.0	1022.9	1184.5	-15.8	.203
20	4	179.0	.19431	.182	.172	5.4	968.9	1144.9	-18.2	.197
21	4	189.0	.20589	.184	.174	5.6	925.0	1111.6	-20.6	.191
22	5	199.0	.06429	.102	.106	-3.4	3744.4	3575.1	4.5	.474
23	5	209.0	.06695	.104	.107	-3.2	3681.5	3520.5	4.4	.466
24	5	219.0	.06949	.105	.108	-3.0	3623.5	3474.1	4.2	.460
25	5	229.0	.07202	.106	.109	-2.7	3567.8	3429.4	3.9	.454
26	5	239.5	.07439	.107	.110	-2.5	3517.5	3387.5	3.9	.449
27	5	250.5	.07703	.108	.111	-2.2	3463.0	3348.1	3.3	.444
28	5	261.0	.05271	.096	.100	-4.0	5213.4	4978.4	4.5	.513
29	5	271.0	.05441	.097	.101	-3.8	5148.9	4924.9	4.4	.507
30	5	281.0	.05607	.098	.101	-3.6	5089.6	4874.0	4.3	.502
31	5	291.0	.05791	.099	.102	-3.3	5025.0	4820.0	4.1	.497
32	5	301.0	.05956	.100	.103	-3.2	4968.5	4769.2	4.0	.491
33	5	310.5	.06105	.101	.104	-3.0	4919.1	4732.5	3.8	.488
34	5	319.5	.06239	.101	.104	-2.7	4875.8	4705.8	3.6	.485
35	4	328.5	.11492	.160	.152	4.8	2358.9	2616.8	-10.9	.261
36	4	337.5	.11819	.161	.153	5.0	2322.2	2580.9	-11.1	.257
37	4	346.5	.12278	.163	.154	5.1	2272.3	2530.7	-11.4	.252
38	4	356.0	.12740	.164	.156	4.9	2224.0	2476.9	-11.4	.247
39	4	366.0	.13202	.166	.158	4.9	2177.2	2428.7	-11.5	.242
40	4	376.0	.13641	.167	.159	4.8	2134.4	2385.1	-11.7	.237
41	4	386.0	.13961	.168	.160	4.7	2104.1	2351.3	-11.4	.334
42	4	396.0	.14293	.169	.161	4.8	2073.3	2324.5	-10.1	.231
43	4	406.0	.14541	.170	.162	4.8	2050.8	2304.1	-10.4	.229
44	4	416.0	.14656	.170	.162	4.8	2040.4	2294.7	-10.5	.226
45	4	426.0	.14830	.171	.162	4.9	2025.1	2285.4	-10.5	.226
46	4	436.0	.14865	.171	.162	5.0	2021.9	2287.1	-10.1	.226

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MAR 08 2012
Division of Waste Management
Solid Waste Branch

ACCELEROGRAM - t56-ac2b.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00231	.020	.021	-5.6	2458.8	2450.5	.3	.977
2	1	10.0	.02626	.085	.089	-5.1	717.0	714.4	.4	.959
3	1	20.0	.00088	.099	.104	-5.9	804.6	794.9	1.2	.930
4	1	30.0	.05175	.107	.112	-5.5	891.3	880.1	1.3	.914
5	1	40.0	.05923	.111	.118	-5.9	981.7	967.7	1.4	.903
6	1	50.0	.06364	.114	.121	-6.2	1072.0	1055.6	1.5	.898
7	1	60.0	.06593	.115	.122	-6.2	1163.1	1145.0	1.6	.895
8	6	67.5	.04598	.071	.077	-8.5	1781.0	1665.3	6.5	.613
9	6	76.5	.17711	.106	.111	-5.5	587.3	550.5	7.8	.397
10	6	86.5	.08231	.083	.086	-4.5	1407.6	1341.8	4.7	.544
11	6	95.0	.05873	.075	.078	-4.0	2131.9	2059.0	3.4	.607
12	6	104.5	.04414	.068	.070	-3.3	3079.4	2995.2	2.7	.659
13	6	113.5	.04903	.070	.073	-3.8	2898.0	2816.7	2.7	.641
14	6	122.5	.05395	.072	.075	-3.4	2924.1	2844.9	2.7	.626
15	5	131.5	.07579	.108	.111	-2.9	2277.8	2178.1	4.4	.442
16	5	140.5	.08391	.111	.114	-2.6	2174.4	2084.5	4.1	.423
17	4	149.5	.16319	.175	.172	1.5	1101.4	1150.3	-4.4	.198
18	4	159.0	.18150	.179	.175	2.0	1020.7	1085.4	-6.3	.186
19	4	169.0	.20075	.183	.179	2.4	944.2	1022.9	-8.3	.176
20	4	179.0	.21956	.187	.182	2.7	876.2	968.9	-10.6	.166
21	4	189.0	.23568	.190	.184	3.0	822.4	925.0	-12.5	.159
22	5	199.0	.05836	.099	.102	-3.2	3895.2	3744.4	3.9	.496
23	5	209.0	.06076	.101	.104	-3.1	3832.4	3681.5	3.9	.488
24	5	219.0	.06312	.102	.105	-3.1	3773.1	3623.5	4.0	.480
25	5	229.0	.06535	.103	.108	-3.1	3719.1	3567.8	4.1	.473
26	5	239.5	.06773	.104	.107	-2.9	3663.3	3517.5	4.0	.466
27	5	250.5	.07010	.105	.108	-2.9	3609.8	3463.0	4.1	.459
28	5	261.0	.04741	.093	.096	-3.7	5425.5	5213.4	3.9	.537
29	5	271.0	.04898	.094	.097	-3.6	5360.1	5149.9	3.9	.531
30	5	281.0	.05060	.095	.098	-3.5	5294.9	5089.6	3.9	.524
31	5	291.0	.05221	.096	.099	-3.5	5232.2	5025.0	4.0	.518
32	5	301.0	.05397	.097	.100	-3.3	5167.8	4968.5	3.9	.512
33	5	310.5	.05538	.098	.101	-3.2	5114.4	4919.1	3.8	.507
34	5	319.5	.05671	.098	.101	-3.1	5066.9	4875.8	3.8	.502
35	4	328.5	.11982	.162	.160	1.1	2304.2	2358.9	-2.4	.235
36	4	337.5	.12394	.163	.161	1.2	2260.0	2322.2	-2.8	.231
37	4	346.5	.12840	.164	.163	1.1	2213.7	2272.3	-2.6	.226
38	4	356.0	.13353	.166	.164	1.2	2162.4	2224.0	-2.8	.221
39	4	366.0	.13851	.168	.166	1.2	2114.4	2177.2	-3.0	.217
40	4	376.0	.14278	.169	.167	1.1	2074.7	2134.4	-2.9	.213
41	4	386.0	.14666	.170	.168	1.2	2039.6	2104.1	-3.2	.209
42	4	396.0	.14999	.171	.169	1.2	2010.2	2073.3	-3.1	.206
43	4	406.0	.15219	.172	.170	1.1	1991.1	2050.8	-3.0	.204
44	4	416.0	.15402	.172	.170	1.2	1975.4	2040.4	-3.3	.203
45	4	426.0	.15562	.173	.171	1.2	1961.9	2025.1	-3.2	.202
46	4	436.0	.15568	.173	.171	1.1	1961.4	2021.9	-3.1	.201

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P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00227	.020	.020	-2.1	2461.9	2458.8	.1	.981

2	1	10.0	.02480	.083	.085	-2.8	717.8	717.0	.1	.963
3	1	20.0	.03827	.096	.099	-2.3	808.5	804.6	.5	.942
4	1	30.0	.04838	.104	.107	-2.2	895.7	891.3	.5	.926
5	1	40.0	.05524	.109	.111	-2.2	986.7	981.7	.5	.916
6	1	50.0	.05940	.111	.114	-2.2	1077.7	1072.0	.5	.911
7	1	60.0	.06172	.113	.115	-2.0	1168.8	1163.1	.5	.909
8	6	67.5	.04509	.068	.071	-3.6	1828.7	1781.0	2.6	.656
9	6	76.5	.15926	.102	.106	-3.3	624.9	587.3	4.4	.431
10	6	86.5	.07672	.081	.083	-2.1	1437.2	1407.6	2.1	.571
11	6	95.0	.05558	.073	.075	-1.8	2163.7	2131.9	1.5	.629
12	6	104.5	.04209	.067	.068	-1.7	3116.3	3079.4	1.2	.677
13	6	113.5	.04681	.069	.070	-1.6	3033.9	2898.0	1.2	.659
14	6	122.5	.05157	.071	.072	-1.5	2959.0	2924.1	1.2	.643
15	5	131.5	.07128	.106	.108	-1.9	2340.2	2277.8	2.7	.462
16	5	140.5	.07919	.109	.111	-1.7	2233.2	2174.4	2.6	.441
17	4	149.5	.16799	.176	.175	.7	1079.4	1101.4	-2.0	.189
18	4	159.0	.19048	.181	.179	1.1	984.1	1020.7	-3.7	.175
19	4	169.0	.21479	.186	.183	1.5	892.8	944.2	-5.7	.162
20	4	179.0	.23920	.191	.187	1.9	811.1	876.2	-8.0	.150
21	4	189.0	.26108	.194	.190	2.2	744.7	822.4	-10.4	.141
22	5	199.0	.05514	.097	.099	-1.9	3983.5	3895.2	2.2	.516
23	5	209.0	.05725	.099	.101	-2.0	3925.2	3832.4	2.4	.508
24	5	219.0	.05944	.100	.102	-1.9	3866.6	3773.1	2.4	.500
25	5	229.0	.06137	.101	.103	-2.0	3816.8	3719.1	2.6	.493
26	5	239.5	.06367	.102	.104	-2.0	3759.6	3663.3	2.6	.485
27	5	250.5	.06578	.103	.105	-2.0	3708.9	3609.8	2.7	.478
28	5	261.0	.04458	.091	.092	-2.2	5548.5	5425.5	2.2	.559
29	5	271.0	.04603	.092	.094	-2.2	5484.7	5360.1	2.3	.552
30	5	281.0	.04761	.093	.095	-2.1	5417.1	5294.9	2.3	.545
31	5	291.0	.04908	.094	.096	-2.1	5356.2	5232.2	2.3	.539
32	5	301.0	.05078	.095	.097	-2.0	5287.9	5167.8	2.3	.532
33	5	310.5	.05213	.096	.098	-2.0	5231.6	5114.4	2.2	.527
34	5	319.5	.05350	.096	.098	-2.0	5183.4	5066.9	2.3	.522
35	4	328.5	.12047	.162	.162	.1	2297.1	2304.2	-.3	.229
36	4	337.5	.12499	.163	.163	.2	2248.9	2260.0	-.5	.225
37	4	346.5	.12946	.165	.164	.2	2202.9	2213.7	-.5	.220
38	4	356.0	.13497	.167	.166	.3	2148.4	2162.4	-.7	.215
39	4	366.0	.14012	.168	.168	.3	2099.3	2114.4	-.7	.211
40	4	376.0	.14458	.169	.169	.3	2058.3	2074.7	-.8	.207
41	4	386.0	.14879	.171	.170	.4	2020.8	2039.6	-.9	.203
42	4	396.0	.15197	.172	.171	.3	1993.0	2010.2	-.9	.200
43	4	406.0	.15414	.172	.172	.3	1974.5	1991.1	-.8	.198
44	4	416.0	.15632	.173	.172	.4	1956.1	1975.4	-1.0	.197
45	4	426.0	.15765	.173	.173	.3	1945.0	1961.9	-.9	.195
46	4	436.0	.15735	.173	.173	.3	1947.5	1961.4	-.7	.195

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ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00223	.020	.020	-1.3	2463.7	2461.9	.1	.982
2	1	10.0	.02396	.082	.083	-1.1	718.4	717.8	.1	.964
3	1	20.0	.03683	.095	.096	-1.4	810.7	808.5	.3	.946
4	1	30.0	.04652	.103	.104	-1.3	898.2	895.7	.2	.930
5	1	40.0	.05307	.107	.108	-1.3	989.6	986.7	.3	.921
6	1	50.0	.05702	.110	.111	-1.3	1080.9	1077.7	.3	.916
7	1	60.0	.05858	.112	.113	-.6	1170.4	1168.8	.1	.914
8	6	67.5	.04336	.067	.068	-1.4	1846.8	1828.7	.1	.674
9	6	76.5	.15024	.100	.102	-1.9	640.0	624.9	2.4	.451
10	6	86.5	.07425	.080	.081	-1.0	1450.9	1437.2	.9	.583
11	6	95.0	.05418	.073	.073	-.8	2178.5	2163.7	.7	.638
12	6	104.5	.04119	.066	.067	-.8	3132.9	3116.3	.5	.685
13	6	113.5	.04560	.069	.069	-.8	3050.7	3033.9	.6	.667
14	6	122.5	.05048	.071	.071	-.7	2975.5	2959.0	.6	.651

15	5	131.5	.06877	.105	.106	-1.1	2376.6	2340.2	1.5	.475
16	5	140.5	.07646	.108	.109	-1.1	2268.9	2233.2	1.6	.453
17	4	149.5	.17007	.176	.176	.3	1070.1	1079.4	-.9	.185
18	4	159.0	.19616	.182	.181	.7	961.7	984.1	-2.3	.169
19	4	169.0	.22570	.188	.186	1.1	855.2	892.8	-4.4	.153
20	4	179.0	.25625	.194	.191	1.5	758.9	811.1	-6.9	.139
21	4	189.0	.28598	.198	.194	1.9	675.5	744.7	-10.2	.128
22	5	199.0	.05340	.096	.097	-1.1	4033.6	3983.5	1.2	.528
23	5	209.0	.05526	.098	.099	-1.2	3979.5	3925.2	1.4	.520
24	5	219.0	.05734	.099	.100	-1.2	3922.6	3866.6	1.4	.512
25	5	229.0	.05910	.100	.101	-1.2	3875.7	3816.8	1.5	.506
26	5	239.5	.06128	.101	.102	-1.2	3819.2	3759.6	1.6	.498
27	5	250.5	.06322	.102	.103	-1.3	3770.7	3708.9	1.6	.491
28	5	261.0	.04304	.089	.091	-1.2	5618.8	5548.5	1.3	.572
29	5	271.0	.04442	.090	.092	-1.3	5555.9	5484.7	1.3	.565
30	5	281.0	.04596	.092	.093	-1.2	5487.5	5417.1	1.3	.558
31	5	291.0	.04738	.093	.094	-1.2	5426.7	5356.2	1.3	.552
32	5	301.0	.04907	.094	.095	-1.2	5356.6	5287.9	1.3	.545
33	5	310.5	.05050	.095	.096	-1.2	5298.8	5231.6	1.3	.539
34	5	319.5	.05177	.095	.096	-1.1	5249.4	5183.4	1.3	.534
35	4	328.5	.11968	.162	.162	-.2	2305.7	2297.1	.4	.229
36	4	337.5	.12405	.163	.163	-.1	2254.6	2248.9	.3	.224
37	4	346.5	.12900	.165	.165	-.1	2207.5	2202.9	.2	.219
38	4	356.0	.13480	.167	.167	.0	2150.0	2148.4	.1	.214
39	4	366.0	.14013	.168	.168	.0	2099.3	2099.3	.0	.209
40	4	376.0	.14480	.170	.169	.0	2056.3	2058.3	-.1	.205
41	4	386.0	.14925	.171	.171	.1	2016.6	2020.8	-.2	.201
42	4	396.0	.15239	.172	.172	.1	1989.4	1993.0	-.2	.198
43	4	406.0	.15459	.172	.172	.1	1970.6	1974.5	-.2	.197
44	4	416.0	.15700	.173	.173	.1	1950.4	1956.1	-.3	.195
45	4	426.0	.15815	.173	.173	.1	1940.8	1945.0	-.2	.194
46	4	436.0	.15759	.173	.173	.0	1945.5	1947.5	-.1	.194

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ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	----> ERROR	G/Go RATIO
1	6	2.5	.00215	.019	.020	-1.0	2465.1	2463.7	.1	.983
2	1	10.0	.02330	.082	.082	-.9	718.8	718.4	.1	.965
3	1	20.0	.03572	.094	.095	-1.1	812.4	810.7	.2	.949
4	1	30.0	.04511	.102	.103	-1.0	900.2	898.2	.2	.933
5	1	40.0	.05143	.106	.107	-1.0	991.9	989.6	.2	.924
6	1	50.0	.05525	.109	.110	-1.0	1083.5	1080.9	.2	.919
7	1	60.0	.05993	.112	.112	-.3	1171.4	1170.4	.1	.915
8	6	67.5	.04257	.067	.067	-.7	1855.2	1846.8	.5	.680
9	6	76.5	.16534	.099	.100	-1.1	648.6	640.0	1.3	.462
10	6	86.5	.07290	.080	.080	-.5	1458.6	1450.9	.5	.589
11	6	95.0	.05339	.072	.073	-.5	2186.9	2178.5	.4	.642
12	6	104.5	.04069	.066	.066	-.4	3142.3	3132.9	.3	.689
13	6	113.5	.04526	.068	.069	-.4	3060.0	3050.7	.3	.671
14	6	122.5	.04987	.071	.071	-.4	2984.9	2975.5	.3	.654
15	5	131.5	.06726	.104	.105	-.7	2399.2	2376.6	.9	.482
16	5	140.5	.07477	.107	.108	-.7	2291.6	2268.9	1.0	.460
17	4	149.5	.17071	.176	.176	.1	1067.2	1070.1	-.3	.184
18	4	159.0	.19949	.183	.182	.4	946.9	961.7	-1.3	.165
19	4	169.0	.23436	.190	.188	.8	826.7	855.2	-3.5	.147
20	4	179.0	.27247	.196	.194	1.3	712.3	758.9	-6.5	.130
21	4	189.0	.31309	.202	.198	1.9	606.8	675.5	-11.3	.116
22	5	199.0	.05232	.096	.096	-.7	4065.3	4033.6	.8	.534
23	5	209.0	.05404	.097	.098	-.8	4014.9	3979.5	.9	.527
24	5	219.0	.05599	.098	.099	-.8	3959.6	3922.6	.9	.520
25	5	229.0	.05763	.099	.100	-.8	3914.9	3875.7	1.0	.513
26	5	239.5	.05971	.100	.101	-.8	3859.5	3819.2	1.0	.506
27	5	250.5	.06153	.101	.102	-.9	3812.8	3770.7	1.1	.500

28	5	261.0	.04206	.089	.089	-.8	5665.0	5618.8	.6	.579
29	5	271.0	.04340	.090	.090	-.8	5602.3	5555.9	.8	.572
30	5	281.0	.04491	.091	.092	-.8	5533.7	5487.5	.8	.565
31	5	291.0	.04632	.092	.093	-.8	5471.9	5426.7	.8	.559
32	5	301.0	.04799	.093	.094	-.8	5400.9	5356.6	.8	.552
33	5	310.5	.04942	.094	.095	-.7	5342.3	5298.8	.8	.546
34	5	319.5	.05070	.095	.095	-.7	5291.1	5249.4	.8	.541
35	4	328.5	.11830	.161	.162	-.3	2321.0	2305.7	.7	.230
36	4	337.5	.12327	.163	.163	-.2	2267.1	2254.6	.6	.224
37	4	346.5	.12786	.164	.165	-.2	2218.9	2207.5	.5	.220
38	4	356.0	.13393	.166	.167	-.2	2158.5	2150.0	.4	.214
39	4	366.0	.13947	.168	.168	-.1	2105.4	2099.3	.3	.209
40	4	376.0	.14433	.169	.170	-.1	2060.5	2056.3	.2	.205
41	4	386.0	.14904	.171	.171	.0	2018.5	2016.6	.1	.201
42	4	396.0	.15221	.172	.172	.0	1991.0	1989.4	.1	.198
43	4	406.0	.15447	.172	.172	.0	1971.6	1970.6	.1	.196
44	4	416.0	.15709	.173	.173	.0	1949.6	1950.4	.0	.194
45	4	426.0	.15816	.173	.173	.0	1940.8	1940.8	.0	.193
46	4	436.0	.15745	.173	.173	.0	1946.7	1945.5	.1	.194

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	5.0	2.5	.00326	80.36	.26788	4.22
2	1	10.0	10.0	.03530	253.57	.26155	4.22
3	1	10.0	20.0	.05412	438.78	.25363	4.22
4	1	10.0	30.0	.06834	613.87	.24278	4.22
5	1	10.0	40.0	.07793	771.21	.22976	4.22
6	1	10.0	50.0	.08371	904.82	.21510	4.22
7	1	10.0	60.0	.09090	1062.76	.20955	3.80
8	6	5.0	67.5	.06450	1191.17	.20425	3.80
9	6	13.0	76.5	.22022	1409.47	.20242	3.80
10	6	7.0	86.5	.11046	1602.69	.19538	3.78
11	6	10.0	95.0	.08090	1762.30	.19068	3.78
12	6	9.0	104.5	.06165	1931.55	.18580	3.78
13	6	9.0	113.5	.06857	2091.98	.18222	3.78
14	6	9.0	122.5	.07556	2248.23	.17886	3.78
15	5	9.0	131.5	.10191	2421.94	.17738	3.78
16	5	9.0	140.5	.11329	2570.49	.17446	3.78
17	4	9.0	149.5	.25865	2767.75	.17502	3.82
18	4	10.0	159.0	.30226	2906.99	.17146	3.80
19	4	10.0	169.0	.35509	3036.82	.16728	3.80
20	4	10.0	179.0	.41284	3132.99	.16188	3.80
21	4	10.0	189.0	.47438	3204.64	.15591	3.78
22	5	10.0	199.0	.07927	3197.47	.14685	3.74
23	5	10.0	209.0	.08188	3258.47	.14159	3.72
24	5	10.0	219.0	.08484	3327.90	.13721	3.72
25	5	10.0	229.0	.08731	3383.95	.13274	3.72
26	5	11.0	239.5	.09048	3455.41	.12895	3.70
27	5	11.0	250.5	.09323	3515.57	.12464	3.70
28	5	10.0	261.0	.06373	3560.94	.12150	3.66
29	5	10.0	271.0	.06576	3653.41	.11868	3.66
30	5	10.0	281.0	.06805	3734.26	.11672	3.66
31	5	10.0	291.0	.07018	3808.67	.11454	3.64
32	5	10.0	301.0	.07272	3895.17	.11286	3.64
33	5	9.0	310.5	.07468	3967.58	.11111	3.64
34	5	9.0	319.5	.07682	4032.49	.10945	3.62
35	4	9.0	328.5	.17934	4132.72	.10832	3.64
36	4	9.0	337.5	.18677	4210.65	.10603	3.62
37	4	9.0	346.5	.19377	4277.44	.10402	3.62
38	4	10.0	356.0	.20292	4362.87	.10220	3.60
39	4	10.0	366.0	.21132	4436.23	.10005	3.56
40	4	10.0	376.0	.21869	4496.88	.09778	3.54
41	4	10.0	386.0	.22582	4553.95	.09559	3.56
42	4	10.0	396.0	.23062	4587.93	.09308	3.54
43	4	10.0	406.0	.23405	4612.18	.09051	3.54
44	4	10.0	416.0	.23800	4642.24	.08827	3.52
45	4	10.0	426.0	.23963	4650.81	.08574	3.50
46	4	10.0	436.0	.23855	4641.04	.08304	3.48

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```
PERIOD = 2.289 sec  FROM AVERAGE SHEAR WAVE VELOCITY OF  770.7 ft/sec


FREQUENCY  AMPLITUDE:
MAXIMUM AMPLIFICATION =   4.45
FOR FREQUENCY  (f)    =    .45 c/sec
FOR PERIOD (1 / f)    =   2.20 sec

******   OPTION  5  ***  COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM  -                t56-ac2b.sar
D E P O S I T -  Paducah U Landfill - free-field prof

LAYER          DEPTH     MAX. ACC.       TIME     MN.SQ.FR.    ACC. RATIO  TH SAVED
                (ft)        (g)          (sec)     (c/sec)     QUIET ZONE  ACC.REC.
WITHIN           .0       .26859         4.22       1.01          .000         0
WITHIN          5.0       .26785         4.22       1.00          .000         0
WITHIN         15.0       .25294         4.20        .94          .000         0
WITHIN         25.0       .23254         4.20        .86          .000         0
WITHIN         35.0       .20572         4.20        .80          .000         0
WITHIN         45.0       .19509         3.78        .76          .000         0
WITHIN         55.0       .18864         3.78        .75          .000         0
WITHIN         65.0       .18265         3.76        .74          .000         0
WITHIN         70.0       .18035         3.76        .74          .000         0
WITHIN         83.0       .16254         3.72        .76          .000         0
WITHIN         90.0       .15795         3.72        .75          .000         0
WITHIN        100.0       .15263         3.72        .78          .000         0
WITHIN        109.0       .14910         3.70        .75          .000         0
WITHIN        118.0       .14545         3.70        .77          .000         0
WITHIN        127.0       .14167         3.68        .76          .000         0

******   OPTION  6  ***  COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM  -                t56-ac2b.sar
D E P O S I T -  Paducah U Landfill - free-field prof

LAYER          DEPTH     MAX. ACC.       TIME     MN.SQ.FR.    ACC. RATIO  TH SAVED
                (ft)        (g)          (sec)     (c/sec)     QUIET ZONE  ACC.REC.
WITHIN         136.0       .13740         3.68        .75          .000         0
WITHIN         441.0       .13726         3.42       3.44          .000         0
BUTCH.         441.0       .16000         3.62       3.42          .000         0

******   OPTION  7  ***  COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    6
SCALE FOR PLOTTING      .0000
IDENTIFICATION -  -- stress in layer  2

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    6
SCALE FOR PLOTTING      .0000
IDENTIFICATION -  -- strain in layer  3
```

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85  : IBM-PC version of SHAKE                     *
*            by: S.S. (Willie) Lai, January 1985         *
* ------------------------------------------------------ *
* Shake88  : New modulus reduction curves for clays      *
*            added using results from Sun et al. (1988)  *
*            by: J. I. Sun & Ramin Golesorkhi            *
*            February 26, 1988                           *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; Input now is either *
*            Gmax or max Vs; up to 13 material types can *
*            be specified by user; up to 50 layers can   *
*            be specified; object motion can be read in  *
*            from a separate file and can have user      *
*            specified format; Different periods for     *
*            response spectral calculations; options     *
*            are renumbered; and general cleanup         *
*            by: J. I. Sun, I. M. Idriss & P. Dirrim     *
*            June 1990 - February 1991                   *
* ------------------------------------------------------ *
* Shake91  : General cleanup and finalization of input / *
*            output format ... etc                       *
*            by: I. M. Idriss                            *
*            December 1991                               *
* ------------------------------------------------------ *
* Shake98  : Routine for direct calculation of average   *
*            acceleration is added to the program. Out-  *
*            put format is modified to enable the two -  *
*            - page landscape printing. The following    *
*            modulus reduction and damping curves are    *
*            added: Matasovic & Kavazanjian (1998) for   *
*            municipal solid waste; Matasovic & Vucetic  *
*            (1993) for SMB sand; and Vucetic and Dobry  *
*            (1991) for clays of various plasticities.   *
*            by: Neven Matasovic                         *
*            August 1993 - May 1998                      *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.57
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.82
3.1600	.130	3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30)  Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30)  Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 47
DEPTH TO BEDROCK 441.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	5.00	2.50	300.00	2507.	5.00	120.00	820.2
2	1	10.00	10.00	969.50	745.	5.00	73.90	569.6
3	1	10.00	20.00	1730.00	855.	5.00	78.20	593.2
4	1	10.00	30.00	2528.50	963.	5.00	81.50	616.8
5	1	10.00	40.00	3356.50	1071.	5.00	84.10	640.4
6	1	10.00	50.00	4206.50	1176.	5.00	85.90	664.0
7	1	10.00	60.00	5071.50	1279.	5.00	87.10	687.7
8	6	5.00	67.50	5832.00	2715.	5.00	130.00	820.0
9	6	13.00	76.50	6963.00	1386.	5.00	124.00	600.0
10	6	7.00	86.50	8203.00	2465.	5.00	124.00	800.0
11	6	10.00	95.00	9242.00	3391.	5.00	121.00	950.0
12	6	9.00	104.50	10391.50	4547.	5.00	121.00	1100.0
13	6	9.00	113.50	11480.50	4547.	5.00	121.00	1100.0
14	6	9.00	122.50	12569.50	4547.	5.00	121.00	1100.0
15	5	9.00	131.50	13654.00	4929.	5.00	120.00	1150.0
16	5	9.00	140.50	14734.00	4929.	5.00	120.00	1150.0
17	4	9.00	149.50	15814.00	5823.	5.00	120.00	1250.0
18	4	10.00	159.00	16954.00	5823.	5.00	120.00	1250.0
19	4	10.00	169.00	18154.00	5823.	5.00	120.00	1250.0
20	4	10.00	179.00	19354.00	5823.	5.00	120.00	1250.0
21	4	10.00	189.00	20554.00	5823.	5.00	120.00	1250.0
22	5	10.00	199.00	21774.00	7548.	5.00	124.00	1400.0
23	5	10.00	209.00	23014.00	7548.	5.00	124.00	1400.0
24	5	10.00	219.00	24254.00	7548.	5.00	124.00	1400.0
25	5	10.00	229.00	25494.00	7548.	5.00	124.00	1400.0
26	5	11.00	239.50	26796.00	7548.	5.00	124.00	1400.0
27	5	11.00	250.50	28160.00	7548.	5.00	124.00	1400.0
28	5	10.00	261.00	29472.00	9707.	5.00	126.00	1575.0
29	5	10.00	271.00	30732.00	9707.	5.00	126.00	1575.0
30	5	10.00	281.00	31992.00	9707.	5.00	126.00	1575.0
31	5	10.00	291.00	33252.00	9707.	5.00	126.00	1575.0
32	5	10.00	301.00	34512.00	9707.	5.00	126.00	1575.0
33	5	9.00	310.50	35709.00	9707.	5.00	126.00	1575.0
34	5	9.00	319.50	36843.00	9707.	5.00	126.00	1575.0
35	4	9.00	328.50	38152.50	10043.	5.00	165.00	1400.0
36	4	9.00	337.50	39637.50	10043.	5.00	165.00	1400.0
37	4	9.00	346.50	41122.50	10043.	5.00	165.00	1400.0
38	4	10.00	356.00	42690.00	10043.	5.00	165.00	1400.0
39	4	10.00	366.00	44340.00	10043.	5.00	165.00	1400.0
40	4	10.00	376.00	45990.00	10043.	5.00	165.00	1400.0
41	4	10.00	386.00	47640.00	10043.	5.00	165.00	1400.0
42	4	10.00	396.00	49290.00	10043.	5.00	165.00	1400.0
43	4	10.00	406.00	50940.01	10043.	5.00	165.00	1400.0
44	4	10.00	416.00	52590.01	10043.	5.00	165.00	1400.0
45	4	10.00	426.00	54240.01	10043.	5.00	165.00	1400.0
46	4	10.00	436.00	55890.01	10043.	5.00	165.00	1400.0
47	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.446 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1220.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 16.07
FOR FREQUENCY (f) = .87 c/sec
FOR PERIOD (1 / f) = 1.15 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = HBS-wcc.ser
NO. OF INPUT ACCEL. POINTS = 3784
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 6
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0100

FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

HBS-WCC Synthetic Accelerogram for very large earthquakes in near-field;
orig. generated by late Prof. H.B. Seed for Mw 7.5+ eq. on Hayward Fault
This accelerogram was used by USBR for Bradbury Dam, Santa Barbara, 1995
where there is MW 7.25 @ Santa Inez & MW 6.75 @ Bind Thrust / near-field
Max. in file 0.75 g; Ds = 19.2 sec
473*8 = 3784 pts. @ 0.01 sec

** FIRST 4 LAST 5 LINES OF INPUT MOTION *****

1	-.000666	.004702	.007918	.012539	.015394	.002460	-.015849	-.033831
2	-.010565	.006040	.021866	.003959	-.025189	-.037765	-.004636	.021600
3	.036423	.015382	-.030232	-.033526	.008350	.046008	.051941	.004820
4	-.025389	-.013775	.011079	.030145	.027728	.018684	-.006837	-.021263
5	-.018395	-.011703	.009715	.015248	.012747	.004127	-.008467	-.012041
..... INPUT MOTION READ NOT ECHOED.....								
468	-.021416	-.012910	-.004403	.004102	.012610	.021116	.029622	.038128
470	.036687	.035245	.033804	.032362	.030522	.029478	.028039	.026599
471	.015415	.004232	-.006948	-.018128	-.014140	-.010151	-.006166	-.002176
472	.001812	.005801	.009789	.013777	.017767	.021755	.013475	.005193
473	-.003085	-.011367	-.019647	-.027927	-.036208	-.044487	-.040335	.000000

MAXIMUM ACCELERATION = .750000
AT TIME = 7.75 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .48000000
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.96 c/sec
MAXIMUM ACCELERATION = .361911 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - HBS-wcc.ser
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<----- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00464	.028	.050	-80.4	2378.9	2507.1	-5.1	1.000
2	1	10.0	.04940	.105	.050	52.4	691.6	744.6	-7.1	1.000
3	1	20.0	.06904	.116	.050	57.1	774.3	854.6	-10.4	1.000
4	1	30.0	.07449	.119	.050	58.0	867.5	962.9	-11.0	1.000
5	1	40.0	.07000	.117	.050	57.2	969.5	1071.1	-10.5	1.000
6	1	50.0	.06779	.116	.050	56.8	1087.2	1176.2	-10.1	1.000
7	1	60.0	.07709	.120	.050	58.4	1149.6	1279.3	-11.1	1.000
8	6	67.5	.04205	.067	.050	24.8	1861.0	2714.7	-45.8	1.000
9	6	76.5	.09525	.086	.050	41.9	757.3	1386.3	-83.1	1.000
10	6	86.5	.05776	.074	.050	32.5	1556.3	2464.6	-58.4	1.000
11	6	95.0	.04417	.068	.050	26.2	2296.4	3391.4	-47.7	1.000
12	6	104.5	.03608	.063	.050	20.5	3235.6	4546.9	-40.5	1.000
13	6	113.5	.03880	.065	.050	22.6	3179.3	4546.9	-43.6	1.000
14	6	122.5	.04128	.066	.050	24.3	3131.2	4546.9	-45.1	1.000
15	5	131.5	.04019	.087	.050	42.6	2922.7	4928.6	-68.6	1.000
16	5	140.5	.04212	.089	.050	43.6	2875.0	4928.6	-71.4	1.000
17	4	149.5	.03714	.108	.050	53.6	2579.7	5823.0	-125.7	1.000

18	4	159.0	.03657	.109	.050	54.3	2537.4	5823.0	-129.5	1.000
19	4	169.0	.03996	.111	.050	55.0	2497.8	5823.0	-133.1	1.000
20	4	179.0	.04133	.113	.050	55.6	2460.2	5823.0	-136.7	1.000
21	4	189.0	.04269	.114	.050	56.2	2424.2	5823.0	-140.2	1.000
22	5	199.0	.03394	.082	.050	38.8	4738.9	7547.8	-59.3	1.000
23	5	209.0	.03488	.083	.050	39.5	4696.3	7547.8	-60.7	1.000
24	5	219.0	.03573	.083	.050	40.0	4659.0	7547.8	-62.0	1.000
25	5	229.0	.03646	.084	.050	40.5	4627.3	7547.8	-63.1	1.000
26	5	239.5	.03714	.085	.050	40.9	4598.8	7547.8	-64.1	1.000
27	5	250.5	.03774	.085	.050	41.3	4573.8	7547.8	-65.0	1.000
28	5	261.0	.02977	.077	.050	35.5	6319.6	9706.8	-53.6	1.000
29	5	271.0	.03041	.078	.050	36.0	6288.1	9706.8	-54.4	1.000
30	5	281.0	.03094	.079	.050	36.5	6262.3	9706.8	-55.0	1.000
31	5	291.0	.03143	.079	.050	36.9	6239.2	9706.8	-55.6	1.000
32	5	301.0	.03184	.080	.050	37.2	6219.9	9706.8	-56.1	1.000
33	5	310.5	.03221	.080	.050	37.5	6199.1	9706.8	-56.6	1.000
34	5	319.5	.03256	.080	.050	37.8	6177.8	9706.8	-57.1	1.000
35	4	328.5	.03192	.101	.050	50.3	4741.3	10043.5	-111.8	1.000
36	4	337.5	.03248	.101	.050	50.7	4707.5	10043.5	-113.4	1.000
37	4	346.5	.03308	.102	.050	51.1	4672.5	10043.5	-115.0	1.000
38	4	356.0	.03372	.103	.050	51.5	4635.4	10043.5	-116.7	1.000
39	4	366.0	.03437	.104	.050	51.9	4598.7	10043.5	-118.4	1.000
40	4	376.0	.03490	.105	.050	52.3	4569.4	10043.5	-119.8	1.000
41	4	386.0	.03534	.105	.050	52.5	4545.1	10043.5	-121.0	1.000
42	4	396.0	.03562	.106	.050	52.7	4529.9	10043.5	-121.7	1.000
43	4	406.0	.03584	.106	.050	52.8	4517.9	10043.5	-122.3	1.000
44	4	416.0	.03640	.107	.050	53.1	4488.2	10043.5	-123.8	1.000
45	4	426.0	.03689	.107	.050	53.4	4462.4	10043.5	-125.1	1.000
46	4	436.0	.03729	.108	.050	53.6	4441.6	10043.5	-126.1	1.000

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00226	.020	.028	-40.9	2462.5	2378.9	3.4	.949
2	1	10.0	.02320	.081	.105	-28.9	718.9	691.6	3.8	.929
3	1	20.0	.03559	.094	.116	-24.2	812.7	774.3	4.7	.906
4	1	30.0	.04535	.102	.119	-16.6	899.9	867.5	3.6	.901
5	1	40.0	.05247	.107	.117	-9.2	990.4	969.5	2.1	.905
6	1	50.0	.05828	.111	.116	-4.7	1079.2	1067.2	1.1	.907
7	1	60.0	.06373	.114	.120	-5.7	1166.1	1149.6	1.4	.899
8	6	67.5	.04490	.068	.067	2.3	1830.6	1861.0	-1.7	.686
9	6	76.5	.12777	.095	.086	9.5	682.1	757.3	-11.0	.546
10	6	86.5	.07028	.079	.074	5.9	1474.0	1556.3	-5.6	.631
11	6	95.0	.05168	.071	.068	5.3	2205.7	2296.4	-4.1	.677
12	6	104.5	.03962	.065	.063	3.4	3163.1	3235.6	-2.3	.712
13	6	113.5	.04289	.067	.065	3.6	3101.5	3179.3	-2.5	.699
14	6	122.5	.04605	.069	.066	3.8	3046.6	3131.2	-2.8	.689
15	5	131.5	.05161	.095	.087	8.5	2668.4	2822.7	-9.5	.593
16	5	140.5	.05490	.097	.089	8.8	2605.5	2875.0	-10.3	.583
17	4	149.5	.06339	.133	.108	18.9	1962.4	2579.7	-30.1	.443
18	4	159.0	.06679	.135	.109	19.0	1924.0	2537.4	-31.9	.436
19	4	169.0	.07002	.137	.111	19.1	1871.3	2497.8	-33.5	.429
20	4	179.0	.07335	.139	.113	19.2	1819.5	2460.2	-35.2	.422
21	4	189.0	.07652	.141	.114	19.3	1772.2	2424.2	-36.8	.416
22	5	199.0	.04018	.087	.082	6.3	4476.2	4738.9	-5.9	.628
23	5	209.0	.04134	.088	.083	6.2	4431.9	4696.3	-6.0	.622
24	5	219.0	.04228	.089	.083	6.1	4397.1	4659.0	-6.0	.617
25	5	229.0	.04300	.089	.084	6.0	4370.6	4627.3	-5.9	.613
26	5	239.5	.04358	.090	.085	5.8	4349.9	4598.8	-5.7	.609
27	5	250.5	.04428	.090	.085	5.7	4325.0	4573.8	-5.8	.606
28	5	261.0	.03259	.080	.077	3.6	6175.5	6319.6	-2.3	.651
29	5	271.0	.03338	.081	.078	3.7	6127.6	6288.1	-2.6	.648
30	5	281.0	.03409	.082	.079	3.8	6085.8	6262.3	-2.9	.645

31	5	291.0	.03474	.082	.079	3.9	6047.7	6239.2	-3.2	.643
32	5	301.0	.03538	.083	.080	4.1	6011.5	6219.9	-3.5	.641
33	5	310.5	.03601	.084	.080	4.3	5976.1	6199.1	-3.7	.639
34	5	319.5	.03664	.084	.080	4.5	5941.4	6177.8	-4.0	.636
35	4	328.5	.04890	.121	.101	16.6	3919.6	4741.3	-21.0	.472
36	4	337.5	.05005	.122	.101	16.6	3874.6	4707.5	-21.5	.469
37	4	346.5	.05111	.123	.102	16.6	3834.3	4672.5	-21.9	.465
38	4	356.0	.05215	.124	.103	16.5	3795.5	4635.4	-22.1	.462
39	4	366.0	.05309	.124	.104	16.4	3761.1	4598.7	-22.3	.458
40	4	376.0	.05387	.125	.105	16.2	3733.0	4569.4	-22.4	.455
41	4	386.0	.05455	.126	.105	16.2	3708.8	4545.1	-22.5	.453
42	4	396.0	.05509	.126	.106	16.2	3689.6	4529.9	-22.8	.451
43	4	406.0	.05560	.127	.106	16.2	3672.1	4517.9	-23.0	.450
44	4	416.0	.05631	.127	.107	16.1	3647.5	4488.2	-23.0	.447
45	4	426.0	.05697	.128	.107	15.9	3625.1	4462.4	-23.1	.444
46	4	436.0	.05758	.128	.108	15.9	3604.6	4441.6	-23.2	.442

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00181	.018	.020	-9.2	2474.7	2482.5	.5	.882
2	1	10.0	.02012	.078	.081	-4.9	721.1	718.9	.3	.965
3	1	20.0	.03138	.090	.094	-4.8	819.7	812.7	.9	.951
4	1	30.0	.04056	.098	.102	-3.9	907.2	899.9	.8	.935
5	1	40.0	.04763	.104	.107	-3.2	997.5	990.4	.7	.925
6	1	50.0	.05334	.108	.111	-2.8	1086.3	1079.2	.6	.918
7	1	60.0	.05800	.110	.114	-2.9	1174.2	1166.1	.7	.912
8	6	67.5	.04207	.067	.068	-2.3	1860.7	1830.6	1.6	.674
9	6	76.5	.12996	.096	.095	.6	677.7	682.1	-.7	.492
10	6	86.5	.06805	.078	.079	-1.0	1487.5	1474.0	.9	.596
11	6	95.0	.04932	.070	.071	-1.6	2232.8	2205.7	1.2	.650
12	6	104.5	.03717	.064	.065	-2.4	3212.4	3163.1	1.5	.696
13	6	113.5	.04035	.066	.067	-2.2	3148.8	3101.5	1.5	.682
14	6	122.5	.04348	.067	.068	-2.0	3091.0	3046.6	1.4	.670
15	5	131.5	.05187	.095	.095	.2	2663.2	2668.4	-.2	.541
16	5	140.5	.05556	.098	.097	.4	2593.4	2605.5	-.5	.529
17	4	149.5	.07519	.141	.133	5.7	1791.7	1962.4	-10.4	.340
18	4	159.0	.08044	.144	.135	6.0	1716.4	1924.0	-12.1	.330
19	4	169.0	.08573	.147	.137	6.4	1645.3	1871.3	-13.7	.321
20	4	179.0	.09062	.149	.139	6.6	1583.2	1819.5	-15.6	.312
21	4	189.0	.09480	.152	.141	6.6	1532.9	1772.2	-15.6	.304
22	5	199.0	.03854	.086	.087	-1.6	4541.3	4476.2	1.4	.593
23	5	209.0	.03933	.086	.088	-1.9	4509.6	4431.9	1.7	.587
24	5	219.0	.03989	.087	.089	-2.2	4487.3	4397.1	2.0	.583
25	5	229.0	.04045	.087	.089	-2.3	4465.8	4370.6	2.1	.579
26	5	239.5	.04172	.088	.090	-1.6	4417.7	4349.9	1.5	.576
27	5	250.5	.04294	.089	.090	-1.1	4372.9	4325.0	1.1	.573
28	5	261.0	.03050	.078	.080	-2.8	6283.8	6175.5	1.7	.636
29	5	271.0	.03127	.079	.081	-2.7	6246.8	6127.6	1.9	.631
30	5	281.0	.03195	.080	.082	-2.6	6214.7	6085.8	2.1	.627
31	5	291.0	.03259	.080	.082	-2.6	6175.6	6047.7	2.1	.623
32	5	301.0	.03324	.081	.083	-2.5	6136.2	6011.5	2.0	.619
33	5	310.5	.03390	.082	.084	-2.4	6096.8	5976.1	2.0	.616
34	5	319.5	.03455	.082	.084	-2.3	6058.9	5941.4	1.9	.612
35	4	328.5	.05396	.125	.121	3.7	3729.7	3919.6	-5.1	.390
36	4	337.5	.05545	.126	.122	3.8	3677.2	3874.6	-5.4	.386
37	4	346.5	.05679	.128	.123	3.9	3631.3	3834.3	-5.6	.382
38	4	356.0	.05799	.129	.124	3.9	3591.0	3795.5	-5.7	.378
39	4	366.0	.05906	.129	.124	3.9	3555.5	3761.1	-5.6	.374
40	4	376.0	.05998	.130	.125	3.9	3525.8	3733.0	-5.6	.372
41	4	386.0	.06083	.131	.126	3.9	3498.8	3708.8	-5.6	.369
42	4	396.0	.06162	.131	.126	4.0	3473.7	3689.6	-5.2	.367
43	4	406.0	.06245	.132	.127	4.1	3448.0	3672.1	-4.9	.366

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44	4	416.0	.06342	.133	.127	4.5	3416.3	3647.5	-6.7	.343
45	4	426.0	.06437	.133	.128	4.3	3389.7	3625.1	-6.5	.341
46	4	436.0	.06536	.134	.128	4.4	3360.4	3604.6	-7.3	.339

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00175	.018	.018	-1.2	2476.3	2474.7	.1	.987
2	1	10.0	.01959	.077	.078	-.9	721.5	721.1	.1	.968
3	1	20.0	.03036	.089	.090	-1.0	820.3	819.7	.1	.959
4	1	30.0	.03922	.097	.098	-1.2	909.4	907.2	.2	.942
5	1	40.0	.04611	.103	.104	-1.1	999.8	997.5	.2	.931
6	1	50.0	.05160	.106	.108	-1.1	1088.9	1086.3	.2	.924
7	1	60.0	.05601	.109	.110	-1.1	1177.2	1174.2	.3	.918
8	6	67.5	.04020	.065	.067	-1.7	1881.7	1860.7	1.1	.685
9	6	76.5	.12691	.095	.096	-.8	683.9	677.7	.9	.489
10	6	86.5	.06547	.077	.078	-1.2	1503.7	1487.5	1.1	.604
11	6	95.0	.04737	.069	.070	-1.4	2256.1	2232.8	1.0	.658
12	6	104.5	.03561	.063	.064	-1.6	3245.6	3212.4	1.0	.706
13	6	113.5	.03870	.065	.066	-1.5	3181.1	3148.8	1.0	.693
14	6	122.5	.04176	.066	.067	-1.5	3122.3	3091.0	1.0	.680
15	5	131.5	.05065	.095	.095	-.8	2687.6	2663.2	.9	.540
16	5	140.5	.05443	.097	.098	-.7	2614.3	2593.4	.8	.526
17	4	149.5	.08105	.144	.141	2.4	1707.9	1791.7	-4.9	.308
18	4	159.0	.08804	.148	.144	2.9	1615.5	1716.4	-6.2	.295
19	4	169.0	.09511	.152	.147	3.2	1529.2	1645.3	-7.6	.283
20	4	179.0	.10131	.155	.149	3.3	1463.4	1583.2	-8.2	.272
21	4	189.0	.10623	.157	.152	3.2	1427.4	1532.9	-7.4	.263
22	5	199.0	.03688	.084	.086	-1.7	4609.5	4541.3	1.5	.602
23	5	209.0	.03741	.085	.086	-1.9	4587.6	4509.6	1.7	.597
24	5	219.0	.03772	.085	.087	-2.1	4574.5	4487.3	1.9	.595
25	5	229.0	.03851	.086	.087	-1.9	4542.4	4465.9	1.7	.592
26	5	239.5	.03996	.087	.088	-1.8	4484.6	4417.7	1.5	.585
27	5	250.5	.04131	.088	.089	-1.4	4433.3	4372.9	1.4	.579
28	5	261.0	.02913	.077	.078	-1.8	6351.8	6283.8	1.1	.647
29	5	271.0	.02980	.078	.079	-2.0	6318.2	6246.8	1.1	.644
30	5	281.0	.03039	.078	.080	-2.1	6288.9	6214.7	1.2	.640
31	5	291.0	.03098	.079	.080	-2.1	6260.6	6175.6	1.4	.636
32	5	301.0	.03158	.079	.081	-2.1	6231.9	6136.2	1.5	.632
33	5	310.5	.03222	.080	.082	-2.1	6198.9	6096.8	1.6	.628
34	5	319.5	.03285	.081	.082	-2.0	6159.9	6058.9	1.6	.624
35	4	328.5	.05514	.126	.125	.8	3687.8	3729.7	-1.1	.371
36	4	337.5	.05605	.128	.126	.9	3629.1	3677.2	-1.3	.366
37	4	346.5	.05638	.129	.128	1.0	3578.1	3631.3	-1.5	.362
38	4	356.0	.05972	.130	.129	1.1	3534.3	3591.0	-1.6	.358
39	4	366.0	.06090	.131	.129	1.1	3496.6	3555.5	-1.7	.354
40	4	376.0	.06192	.132	.130	1.1	3464.5	3525.8	-1.8	.351
41	4	386.0	.06288	.132	.131	1.2	3434.9	3498.8	-1.9	.348
42	4	396.0	.06386	.133	.132	1.3	3405.1	3473.7	-2.0	.346
43	4	406.0	.06495	.134	.132	1.4	3372.5	3448.0	-2.2	.343
44	4	416.0	.06614	.135	.133	1.5	3337.5	3418.3	-2.4	.340
45	4	426.0	.06734	.135	.133	1.6	3302.9	3389.7	-2.6	.337
46	4	436.0	.06860	.136	.134	1.7	3267.1	3360.4	-2.9	.335

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO TYPE DEPTH UNIFRM. <---- DAMPING ----> <---- SHEAR MODULUS -----> G/Go

		(ft)	STRAIN	NEW	USED	ERROR	NEW	USED	ERROR	RATIO
1	6	2.5	.00174	.018	.018	-.4	2476.8	2476.3	.0	.988
2	1	10.0	.01938	.077	.077	-.4	721.7	721.5	.0	.969
3	1	20.0	.03003	.088	.089	-.3	820.5	820.3	.0	.960
4	1	30.0	.03872	.097	.097	-.4	910.2	909.4	.1	.944
5	1	40.0	.04549	.102	.102	-.5	1000.8	999.8	.1	.933
6	1	50.0	.05086	.106	.106	-.5	1090.1	1088.9	.1	.926
7	1	60.0	.05518	.109	.108	-.5	1178.5	1177.2	.1	.920
8	6	67.5	.03929	.065	.065	-.8	1892.3	1881.7	.6	.693
9	6	76.5	.12415	.094	.095	-.7	689.6	683.9	.8	.493
10	6	86.5	.06399	.077	.077	-.7	1513.3	1503.7	.6	.610
11	6	95.0	.04632	.069	.069	-.8	2269.0	2256.1	.6	.665
12	6	104.5	.03486	.062	.063	-.8	3262.2	3245.6	.5	.714
13	6	113.5	.03792	.064	.065	-.8	3197.0	3181.1	.5	.700
14	6	122.5	.04094	.066	.066	-.7	3137.6	3122.3	.5	.687
15	5	131.5	.04872	.094	.095	-.6	2706.3	2697.6	.7	.545
16	5	140.5	.05352	.096	.097	-.6	2631.6	2614.3	.7	.530
17	4	149.5	.08429	.146	.144	1.3	1664.1	1707.9	-2.6	.293
18	4	159.0	.09276	.150	.148	1.6	1557.2	1615.5	-3.7	.277
19	4	169.0	.10144	.155	.152	1.9	1462.4	1529.2	-4.6	.263
20	4	179.0	.10858	.157	.155	1.8	1410.7	1463.4	-3.7	.251
21	4	189.0	.11271	.159	.157	1.6	1382.4	1427.4	-3.3	.245
22	5	199.0	.03596	.084	.084	-1.0	4648.9	4609.5	.8	.611
23	5	209.0	.03632	.084	.085	-1.1	4633.5	4587.6	1.0	.605
24	5	219.0	.03651	.084	.085	-1.3	4625.2	4574.5	1.1	.606
25	5	229.0	.03745	.085	.086	-1.1	4585.9	4542.4	.9	.602
26	5	239.5	.03894	.086	.087	-1.0	4525.0	4484.6	.9	.594
27	5	250.5	.04030	.087	.088	-.9	4471.6	4433.3	.9	.587
28	5	261.0	.02851	.076	.077	-.8	6384.0	6351.8	.5	.654
29	5	271.0	.02914	.077	.078	-.8	6351.6	6318.2	.5	.651
30	5	281.0	.02970	.077	.078	-.9	6323.3	6288.9	.5	.648
31	5	291.0	.03020	.078	.079	-1.1	6296.3	6260.6	.4	.645
32	5	301.0	.03072	.078	.079	-1.1	6273.0	6231.9	.7	.642
33	5	310.5	.03129	.079	.080	-1.2	6245.5	6198.9	.7	.639
34	5	319.5	.03191	.080	.081	-1.2	6216.3	6159.9	.6	.635
35	4	328.5	.05516	.126	.126	.0	3687.2	3687.8	.2	.367
36	4	337.5	.05700	.128	.126	.1	3624.0	3629.1	-.1	.361
37	4	346.5	.05866	.129	.128	.2	3568.6	3578.1	-.3	.356
38	4	356.0	.06011	.130	.130	.2	3521.6	3534.3	-.4	.352
39	4	366.0	.06138	.131	.131	.3	3481.4	3496.6	-.4	.348
40	4	376.0	.06248	.132	.132	.3	3447.1	3464.5	-.5	.345
41	4	386.0	.06352	.133	.132	.4	3415.4	3434.9	-.6	.342
42	4	396.0	.06462	.134	.133	.4	3382.2	3405.1	-.7	.339
43	4	406.0	.06590	.134	.134	.5	3344.6	3372.5	-.8	.336
44	4	416.0	.06725	.135	.135	.6	3305.5	3337.5	-1.0	.332
45	4	426.0	.06863	.136	.135	.7	3266.3	3302.9	-1.1	.329
46	4	436.0	.07009	.137	.136	.7	3225.6	3267.1	-1.3	.325

ACCELEROGRAM - HBS-wcc.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00173	.016	.018	-.2	2477.0	2476.8	.0	.988
2	1	10.0	.01929	.076	.077	-.2	721.7	721.7	.0	.969
3	1	20.0	.02989	.088	.088	-.1	820.5	820.5	.0	.960
4	1	30.0	.03851	.096	.097	-.2	910.5	910.2	.0	.945
5	1	40.0	.04521	.102	.102	-.2	1001.2	1000.8	.0	.934
6	1	50.0	.05055	.106	.106	-.2	1090.5	1090.1	.0	.927
7	1	60.0	.05483	.109	.109	-.2	1179.1	1178.5	.0	.921
8	6	67.5	.03885	.065	.065	-.4	1897.5	1892.3	.3	.697
9	6	76.5	.12242	.094	.094	-.5	683.3	689.6	.5	.497
10	6	86.5	.06324	.076	.077	-.4	1516.3	1513.3	.2	.614
11	6	95.0	.04582	.069	.069	-.4	2275.2	2269.0	.3	.669

12	6	104.5	.03451	.062	.062	-.4	3270.0	3262.2	.2	.717
13	6	113.5	.03757	.064	.064	-.3	3204.2	3197.0	.2	.703
14	4	122.5	.04058	.066	.066	-.3	3144.5	3137.6	.2	.690
15	5	131.5	.04919	.094	.094	-.4	2717.3	2706.3	.4	.549
16	5	140.5	.05298	.096	.096	-.3	2641.7	2631.6	.4	.534
17	4	149.5	.08622	.147	.146	.7	1638.8	1664.1	-1.5	.286
18	4	159.0	.09598	.152	.150	1.1	1519.0	1557.2	-2.5	.267
19	4	169.0	.10570	.156	.155	1.1	1431.1	1462.4	-2.2	.251
20	4	179.0	.11218	.159	.157	.9	1386.0	1410.7	-1.8	.242
21	4	189.0	.11582	.160	.159	.7	1361.7	1382.4	-1.5	.237
22	5	199.0	.03551	.083	.084	-.5	4668.7	4649.9	.4	.616
23	5	209.0	.03577	.083	.084	-.4	4657.2	4633.5	.5	.614
24	5	219.0	.03590	.084	.084	-.7	4651.4	4625.2	.6	.613
25	5	229.0	.03692	.084	.085	-.5	4608.0	4585.9	.5	.608
26	5	239.5	.03841	.086	.086	-.5	4546.3	4525.0	.5	.600
27	5	250.5	.03976	.087	.087	-.5	4492.4	4471.6	.5	.592
28	5	261.0	.02823	.076	.076	-.4	6398.5	6384.0	.2	.658
29	5	271.0	.02885	.077	.077	-.4	6366.3	6351.6	.2	.654
30	5	281.0	.02940	.077	.077	-.4	6338.4	6323.3	.2	.651
31	5	291.0	.02987	.078	.078	-.4	6314.5	6298.3	.3	.649
32	5	301.0	.03036	.078	.078	-.5	6290.5	6273.0	.3	.646
33	5	310.5	.03090	.079	.079	-.5	6264.5	6245.5	.3	.643
34	5	319.5	.03146	.079	.080	-.6	6237.6	6216.3	.3	.640
35	4	328.5	.05491	.126	.126	-.2	3695.9	3687.2	.2	.367
36	4	337.5	.05683	.128	.128	-.1	3629.7	3624.0	.2	.361
37	4	346.5	.05859	.129	.129	.0	3571.0	3568.6	.1	.355
38	4	356.0	.06011	.130	.130	.0	3521.7	3521.6	.0	.351
39	4	366.0	.06145	.131	.131	.0	3479.2	3481.4	-.1	.347
40	4	376.0	.06261	.132	.132	.1	3443.2	3447.1	-.1	.343
41	4	386.0	.06370	.133	.133	.1	3409.9	3415.4	-.2	.340
42	4	396.0	.06489	.134	.134	.1	3374.4	3382.2	-.2	.337
43	4	406.0	.06628	.135	.134	.2	3333.5	3344.6	-.3	.333
44	4	416.0	.06774	.136	.135	.3	3291.3	3305.5	-.4	.329
45	4	426.0	.06925	.137	.136	.3	3248.9	3266.3	-.5	.325
46	4	436.0	.07086	.138	.137	.4	3204.7	3225.6	-.7	.321

ACCELEROGRAM - HBS-wcn.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00173	.018	.018	-.1	2477.1	2477.0	.0	.988
2	1	10.0	.01925	.076	.076	-.1	721.8	721.7	.0	.969
3	1	20.0	.02982	.088	.088	-.1	820.6	820.5	.0	.960
4	1	30.0	.03841	.096	.096	-.1	910.7	910.5	.0	.946
5	1	40.0	.04509	.102	.102	-.1	1001.4	1001.2	.0	.935
6	1	50.0	.05041	.106	.106	-.1	1090.8	1090.5	.0	.927
7	1	60.0	.05466	.108	.109	-.1	1179.3	1179.1	.0	.922
8	6	67.5	.03865	.065	.065	-.2	1899.9	1897.5	.1	.699
9	6	76.5	.12145	.093	.094	-.3	695.3	693.3	.3	.500
10	6	86.5	.06287	.076	.076	-.2	1520.7	1518.3	.2	.616
11	6	95.0	.04559	.068	.069	-.2	2278.1	2275.2	.1	.671
12	6	104.5	.03435	.062	.062	-.2	3273.4	3270.0	.1	.719
13	6	113.5	.03741	.064	.064	-.2	3207.4	3204.2	.1	.705
14	6	122.5	.04042	.066	.066	-.1	3147.5	3144.5	.1	.692
15	5	131.5	.04891	.094	.094	-.2	2723.0	2717.3	.2	.551
16	5	140.5	.05272	.096	.096	-.2	2646.8	2641.7	.2	.536
17	4	149.5	.08746	.148	.147	.5	1622.9	1638.8	-1.0	.281
18	4	159.0	.09829	.153	.152	.7	1492.4	1519.0	-1.8	.261
19	4	169.0	.10789	.157	.156	.5	1415.5	1431.1	-1.1	.246
20	4	179.0	.11399	.159	.159	.4	1373.8	1386.0	-.9	.238
21	4	189.0	.11735	.161	.160	.3	1351.7	1361.7	-.7	.234
22	5	199.0	.03529	.083	.083	-.2	4678.2	4668.7	.2	.619
23	5	209.0	.03550	.083	.083	-.3	4668.8	4657.2	.2	.617
24	5	219.0	.03561	.083	.084	-.3	4664.3	4651.4	.3	.616

25	5	229.0	.03667	.084	.084	-.3	4618.7	4606.0	.2	.611
26	5	239.5	.03815	.085	.086	-.3	4557.0	4546.3	.2	.602
27	5	250.5	.03949	.087	.087	-.3	4503.0	4492.4	.2	.595
28	5	261.0	.02811	.076	.076	-.2	6404.9	6398.5	.1	.659
29	5	271.0	.02872	.076	.077	-.2	6372.8	6366.3	.1	.656
30	5	281.0	.02927	.077	.077	-.2	6345.1	6338.4	.1	.653
31	5	291.0	.02973	.077	.078	-.2	6321.5	6314.5	.1	.651
32	5	301.0	.03021	.078	.078	-.2	6297.9	6290.5	.1	.648
33	5	310.5	.03072	.078	.078	-.2	6272.4	6264.5	.1	.645
34	5	319.5	.03128	.079	.079	-.2	6246.0	6237.6	.1	.643
35	4	328.5	.05467	.126	.126	-.2	3704.5	3695.9	.2	.368
36	4	337.5	.05664	.127	.128	-.1	3636.3	3629.7	.2	.361
37	4	346.5	.05845	.129	.129	-.1	3575.5	3571.0	.1	.356
38	4	356.0	.06002	.130	.130	-.1	3524.5	3521.7	.1	.351
39	4	366.0	.06141	.131	.131	.0	3480.4	3479.2	.0	.346
40	4	376.0	.06261	.132	.132	.0	3443.0	3443.2	.0	.343
41	4	386.0	.06374	.133	.133	.0	3408.6	3409.9	.0	.340
42	4	396.0	.06498	.134	.134	.0	3371.6	3374.4	-.1	.336
43	4	406.0	.06645	.135	.135	.1	3328.6	3333.5	-.1	.332
44	4	416.0	.06799	.136	.136	.1	3284.3	3291.3	-.2	.328
45	4	426.0	.06959	.137	.137	.2	3239.5	3248.9	-.3	.323
46	4	436.0	.07130	.138	.138	.2	3192.9	3204.7	-.4	.319

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME sec)
1	6	5.0	2.5	.00262	64.86	.21620	3.75
2	1	10.0	10.0	.02917	210.55	.21717	3.76
3	1	10.0	20.0	.04518	370.70	.21428	3.76
4	1	10.0	30.0	.05820	529.96	.20959	3.76
5	1	10.0	40.0	.06831	683.98	.20378	3.75
6	1	10.0	50.0	.07638	832.91	.19800	3.75
7	1	10.0	60.0	.08282	976.57	.19256	3.74
8	6	5.0	67.5	.05856	1111.18	.19053	3.72
9	6	13.0	76.5	.18402	1275.73	.18322	3.72
10	6	7.0	86.5	.09526	1446.24	.17621	3.71
11	6	10.0	95.0	.06908	1571.67	.17006	3.71
12	6	9.0	104.5	.05205	1702.12	.16380	3.71
13	6	9.0	113.5	.05668	1816.30	.15821	3.71
14	6	9.0	122.5	.06124	1925.75	.15321	3.71
15	5	9.0	131.5	.07411	2013.74	.14748	3.72
16	5	9.0	140.5	.07988	2110.26	.14322	3.73
17	4	9.0	149.5	.13251	2171.60	.13732	3.76
18	4	10.0	159.0	.14893	2262.27	.13344	3.76
19	4	10.0	169.0	.16348	2339.52	.12887	3.76
20	4	10.0	179.0	.17271	2393.68	.12369	3.75
21	4	10.0	189.0	.17781	2421.21	.11780	3.75
22	5	10.0	199.0	.05347	2496.41	.11465	3.72
23	5	10.0	209.0	.05379	2505.32	.10886	3.71
24	5	10.0	219.0	.05395	2509.53	.10347	3.71
25	5	10.0	229.0	.05556	2559.98	.10041	3.13
26	5	11.0	239.5	.05780	2627.93	.09807	3.13
27	5	11.0	250.5	.05984	2688.31	.09547	3.13
28	5	10.0	261.0	.04259	2725.14	.09247	3.12
29	5	10.0	271.0	.04352	2770.68	.09016	3.11
30	5	10.0	281.0	.04434	2810.54	.08785	3.11
31	5	10.0	291.0	.04505	2844.65	.08555	3.10
32	5	10.0	301.0	.04577	2879.16	.08342	3.09
33	5	9.0	310.5	.04656	2916.95	.08169	3.05
34	5	9.0	319.5	.04740	2956.48	.08025	3.07
35	4	9.0	328.5	.08283	3061.38	.08024	3.08
36	4	9.0	337.5	.08561	3114.80	.07858	3.07
37	4	9.0	346.5	.08857	3162.79	.07691	3.06
38	4	10.0	356.0	.09094	3202.65	.07502	3.06
39	4	10.0	366.0	.09305	3237.29	.07301	3.05
40	4	10.0	376.0	.09487	3266.54	.07103	3.04
41	4	10.0	386.0	.09658	3293.24	.06913	3.03
42	4	10.0	396.0	.09845	3322.17	.06740	3.01
43	4	10.0	406.0	.10068	3356.06	.06588	3.00

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44	4	10.0	416.0	.10302	3380.57	.06047	2.89
45	4	10.0	426.0	.10544	3425.56	.06316	2.97
46	4	10.0	436.0	.10802	3461.81	.06194	2.97

PERIOD = 2.034 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 867.5 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 6.03
FOR FREQUENCY (f) = .56 c/sec
FOR PERIOD (1 / f) = 1.78 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - HBS-wcc.sai
D E P O S I T - Paducah U Landfill - few-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.21556	3.75	1.88	.120	0
WITHIN	5.0	.21521	3.75	1.87	.120	0
WITHIN	15.0	.20808	3.74	1.65	.116	0
WITHIN	25.0	.20092	3.72	1.45	.122	0
WITHIN	35.0	.19732	3.70	1.38	.117	0
WITHIN	45.0	.19337	3.69	1.44	.107	0
WITHIN	55.0	.18841	3.69	1.56	.097	0
WITHIN	65.0	.18067	3.68	1.66	.092	0
WITHIN	70.0	.17680	3.68	1.66	.091	0
WITHIN	83.0	.14158	3.85	1.76	.111	0
WITHIN	90.0	.13009	3.85	1.81	.124	0
WITHIN	100.0	.11988	3.83	1.80	.134	0
WITHIN	109.0	.11236	3.83	1.77	.138	0
WITHIN	118.0	.11403	8.44	1.74	.127	0
WITHIN	127.0	.11644	8.43	1.74	.113	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM - HBS-wcc.sai
D E P O S I T - Paducah U Landfill - few-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	136.0	.11543	8.42	1.80	.113	0
WITHIN	441.0	.35483	7.24	7.15	.110	0
OUTCR.	441.0	.38764	7.64	7.19	.109	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 8
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 8

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 8
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 8

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
*********************************************************
* Shake85     : IBM-PC version of SHAKE                  *
*             by: S.S. (Willie) Lai, January 1985        *
*********************************************************
* Shake88     : New modulus reduction curves for clays   *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 26, 1989                          *
*********************************************************
* Shake90/91: Adjust last iteration; Input now is either *
*             GmaX or max Vs; up to 13 material types can *
*             be specified by user; up to 50 layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim    *
*             June 1990 - February 1991                  *
*********************************************************
* Shake91     : General cleanup and finalization of input /
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
*********************************************************
* Shake98     : Routine for direct calculation of average *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing. The following   *
*             modulus reduction and damping curves are   *
*             added: Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SWE sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Kevin Matasovic                        *
*             August 1993 - May 1998                     *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 47
DEPTH TO BEDROCK 441.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	5.00	2.50	300.00	2507.	5.00	120.00	820.2
2	1	10.00	10.00	969.50	745.	5.00	73.90	569.6
3	1	10.00	20.00	1730.00	855.	5.00	78.20	593.2
4	1	10.00	30.00	2528.50	963.	5.00	81.50	616.8
5	1	10.00	40.00	3356.50	1071.	5.00	84.10	640.4
6	1	10.00	50.00	4206.50	1176.	5.00	85.90	664.0
7	1	10.00	60.00	5071.50	1279.	5.00	87.10	687.7
8	6	5.00	67.50	5832.00	2715.	5.00	130.00	820.0
9	6	13.00	76.50	6963.00	1386.	5.00	124.00	600.0
10	6	7.00	86.50	8203.00	2465.	5.00	124.00	800.0
11	6	10.00	95.00	9242.00	3391.	5.00	121.00	950.0
12	6	9.00	104.50	10391.50	4547.	5.00	121.00	1100.0
13	6	9.00	113.50	11480.50	4547.	5.00	121.00	1100.0
14	6	9.00	122.50	12569.50	4547.	5.00	121.00	1100.0
15	5	9.00	131.50	13654.00	4928.	5.00	120.00	1150.0
16	5	9.00	140.50	14734.00	4928.	5.00	120.00	1150.0
17	4	9.00	149.50	15814.00	5823.	5.00	120.00	1250.0
18	4	10.00	159.00	16954.00	5823.	5.00	120.00	1250.0
19	4	10.00	169.00	18154.00	5823.	5.00	120.00	1250.0
20	4	10.00	179.00	19354.00	5823.	5.00	120.00	1250.0
21	4	10.00	189.00	20554.00	5823.	5.00	120.00	1250.0
22	5	10.00	199.00	21774.00	7548.	5.00	124.00	1400.0
23	5	10.00	209.00	23014.00	7548.	5.00	124.00	1400.0
24	5	10.00	219.00	24254.00	7548.	5.00	124.00	1400.0
25	5	10.00	229.00	25494.00	7548.	5.00	124.00	1400.0
26	5	11.00	239.50	26796.00	7548.	5.00	124.00	1400.0
27	5	11.00	250.50	28166.00	7548.	5.00	124.00	1400.0
28	5	10.00	261.00	29472.00	9707.	5.00	126.00	1575.0
29	5	10.00	271.00	30732.00	9707.	5.00	126.00	1575.0
30	5	10.00	281.00	31992.00	9707.	5.00	126.00	1575.0
31	5	10.00	291.00	33252.00	9707.	5.00	126.00	1575.0
32	5	10.00	301.00	34512.00	9707.	5.00	126.00	1575.0
33	5	9.00	310.50	35709.00	9707.	5.00	126.00	1575.0
34	5	9.00	319.50	36843.00	9707.	5.00	126.00	1575.0
35	4	9.00	328.50	38152.50	10043.	5.00	165.00	1400.0
36	4	9.00	337.50	39637.50	10043.	5.00	165.00	1400.0
37	4	9.00	346.50	41122.50	10043.	5.00	165.00	1400.0
38	4	10.00	356.00	42690.00	10043.	5.00	165.00	1400.0
39	4	10.00	366.00	44340.00	10043.	5.00	165.00	1400.0
40	4	10.00	376.00	45990.00	10043.	5.00	165.00	1400.0
41	4	10.00	386.00	47640.00	10043.	5.00	165.00	1400.0
42	4	10.00	396.00	49290.00	10043.	5.00	165.00	1400.0
43	4	10.00	406.00	50940.01	10043.	5.00	165.00	1400.0
44	4	10.00	416.00	52590.01	10043.	5.00	165.00	1400.0
45	4	10.00	426.00	54240.01	10043.	5.00	165.00	1400.0
46	4	10.00	436.00	55890.01	10043.	5.00	165.00	1400.0
47	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.446 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1220.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 16.07
FOR FREQUENCY (f) = .87 c/sec
FOR PERIOD (1 / f) = 1.15 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = magBeq.sar
NO. OF INPUT ACCEL. POINTS = 3760
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 3
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200

FORMAT FOR OF TIME HISTORY = (8F8.4)

***** A C C E L E R O G R A M H E A D E R *****

Seed and Idriss (1968) M 8.25 Eq.(for rock sites approx. 70 mi. from S.A
Max. in file = 0.60 g @ 25.92 sec (originally 0.42 g): Mean Sq. Freq = 3
8 * 470 = 3760 pts. @ 0.02 sec

** FIRST 4 LAST 5 LINES OF INPUT MOTION *****

1	.082761	.073796	.074938	.075873	.062602	.052252	.051858	.044955
2	.031522	.027570	.023298	.023945	.022443	.021225	.012130	.003501
3	.001423	-.017185	-.026398	-.031722	-.038444	-.049085	-.061570	-.073038
4	-.084124	-.092176	-.100385	-.082172	-.062311	-.025014	-.017026	-.011280
5	-.017032	-.018943	-.021842	-.029682	-.035054	-.033638	-.028899	-.036261

..... INPUT MOTION READ NOT ECHOED.....

466	-.031961	-.008844	-.002331	.003973	.052467	.056858	.060505	.062610
467	.053975	.065884	.067351	.069606	.070892	.072492	.070844	.065096
468	.060221	.057258	.054201	.051875	.049411	.043016	.034124	.029108
469	.024519	.010956	-.004150	-.024819	-.030046	-.034114	-.036601	-.037012
470	-.034063	-.029237	-.018126	.001685	.002426	.002465	.000067	-.002264

MAXIMUM ACCELERATION = .600000
AT TIME = 25.92 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .60000000
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.12 c/sec
MAXIMUM ACCELERATION = .360000 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - magBeq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00514	.029	.050	-71.7	2362.7	2507.1	[illegible]	1.000
2	1	10.0	.05510	.109	.050	54.0	666.0	744.6	[illegible]	1.000
3	1	20.0	.08032	.122	.050	58.9	765.6	854.6	[illegible]	1.000
4	1	30.0	.09524	.127	.050	60.8	851.5	962.9	[illegible]	1.000
5	1	40.0	.10148	.130	.050	61.5	940.6	1071.1	[illegible]	1.000
6	1	50.0	.10094	.129	.050	61.4	1034.1	1176.2	[illegible]	1.000
7	1	60.0	.09554	.128	.050	60.8	1131.0	1279.3	[illegible]	1.000
8	6	67.5	.04667	.069	.050	27.6	1812.7	2714.7	[illegible]	1.000
9	6	76.5	.09726	.087	.050	42.2	752.4	1366.3	[illegible]	1.000
10	6	86.5	.05692	.074	.050	32.2	1562.6	2464.6	[illegible]	1.000
11	6	95.0	.04395	.068	.050	26.0	2299.4	3391.4	[illegible]	1.000
12	6	104.5	.03484	.062	.050	19.4	3262.5	4546.9	[illegible]	1.000
13	6	113.5	.03645	.063	.050	20.8	3226.7	4546.5	[illegible]	1.000
14	6	122.5	.03784	.064	.050	21.9	3198.5	4546.5	[illegible]	1.000
15	5	131.5	.03589	.064	.050	40.1	3037.7	4928.6	[illegible]	1.000
16	5	140.5	.02661	.084	.050	40.6	3017.4	4928.6	[illegible]	1.000
17	4	149.5	.03141	.100	.050	49.9	2767.3	5823.0	[illegible]	1.000
18	4	159.0	.03166	.100	.050	50.1	2757.3	5823.0	[illegible]	1.000
19	4	169.0	.03229	.101	.050	50.6	2735.9	5823.0	[illegible]	1.000
20	4	179.0	.03278	.102	.050	50.9	2720.0	5823.0	[illegible]	1.000

21	4	189.0	.03343	.103	.050	51.3	2697.1	5823.0	-115.9	1.000
22	5	199.0	.02684	.075	.050	32.9	5033.8	7547.8	-49.9	1.000
23	5	209.0	.02829	.076	.050	34.2	4972.8	7547.8	-51.8	1.000
24	5	219.0	.02987	.078	.050	35.5	4910.1	7547.8	-53.7	1.000
25	5	229.0	.03132	.079	.050	36.8	4855.5	7547.8	-55.4	1.000
26	5	239.5	.03267	.080	.050	37.9	4798.2	7547.8	-57.3	1.000
27	5	250.5	.03390	.082	.050	38.8	4740.9	7547.8	-59.2	1.000
28	5	261.0	.02713	.075	.050	33.2	6457.6	9706.8	-50.3	1.000
29	5	271.0	.02788	.076	.050	33.9	6417.0	9706.8	-51.3	1.000
30	5	281.0	.02858	.076	.050	34.5	6380.3	9706.8	-52.1	1.000
31	5	291.0	.02917	.077	.050	35.0	6350.1	9706.8	-52.9	1.000
32	5	301.0	.02964	.077	.050	35.4	6326.1	9706.8	-53.4	1.000
33	5	310.5	.02998	.078	.050	35.6	6309.3	9706.8	-53.8	1.000
34	5	319.5	.03020	.078	.050	35.8	6298.5	9706.8	-54.1	1.000
35	4	328.5	.02940	.097	.050	48.6	4910.7	10043.5	-104.5	1.000
36	4	337.5	.02967	.098	.050	48.8	4891.6	10043.5	-105.3	1.000
37	4	346.5	.02982	.098	.050	48.9	4880.7	10043.5	-105.8	1.000
38	4	356.0	.02987	.098	.050	48.9	4877.8	10043.5	-105.9	1.000
39	4	366.0	.02981	.098	.050	48.9	4881.7	10043.5	-105.7	1.000
40	4	376.0	.02989	.098	.050	48.9	4876.9	10043.5	-105.9	1.000
41	4	386.0	.02981	.098	.050	48.9	4881.5	10043.5	-105.7	1.000
42	4	396.0	.02963	.098	.050	48.7	4894.7	10043.5	-105.2	1.000
43	4	406.0	.03016	.098	.050	49.1	4857.5	10043.5	-106.8	1.000
44	4	416.0	.03059	.099	.050	49.4	4828.2	10043.5	-108.0	1.000
45	4	426.0	.03127	.100	.050	49.8	4782.4	10043.5	-110.0	1.000
46	4	436.0	.03175	.100	.050	50.2	4751.6	10043.5	-111.4	1.000

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ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00271	.021	.029	-38.5	2452.5	2362.7	3.7	.942
2	1	10.0	.02808	.087	.109	-24.3	715.4	686.0	4.1	.921
3	1	20.0	.04358	.101	.122	-20.8	800.9	765.6	4.4	.896
4	1	30.0	.05413	.108	.127	-17.9	888.4	851.5	4.1	.884
5	1	40.0	.06181	.113	.130	-15.1	978.6	940.6	3.9	.878
6	1	50.0	.06592	.115	.129	-12.7	1069.4	1034.1	3.3	.879
7	1	60.0	.06745	.116	.128	-10.3	1161.1	1131.0	2.6	.884
8	6	67.5	.04440	.068	.069	-1.0	1835.8	1812.7	1.3	.668
9	6	76.5	.11469	.092	.087	5.5	710.2	752.4	-5.9	.543
10	6	86.5	.05991	.075	.074	1.6	1540.9	1562.4	-1.4	.634
11	6	95.0	.04260	.067	.068	-1.1	2317.3	2299.4	.8	.678
12	6	104.5	.03109	.059	.062	-4.3	3350.6	3262.5	2.6	.718
13	6	113.5	.03326	.061	.063	-3.6	3297.9	3226.7	2.2	.710
14	6	122.5	.03532	.062	.064	-2.6	3251.9	3198.5	1.6	.703
15	5	131.5	.03854	.087	.084	3.6	2939.2	3037.7	-3.4	.616
16	5	140.5	.04182	.088	.084	4.9	2882.1	3017.4	-4.7	.612
17	4	149.5	.04812	.120	.100	16.6	2290.3	2767.3	-20.8	.475
18	4	159.0	.05080	.122	.100	18.1	2229.7	2757.3	-23.7	.474
19	4	169.0	.05391	.125	.101	19.2	2163.3	2735.9	-26.5	.470
20	4	179.0	.05669	.127	.102	20.1	2107.2	2720.0	-29.1	.467
21	4	189.0	.05909	.129	.103	20.6	2060.9	2697.1	-30.9	.463
22	5	199.0	.03272	.081	.075	7.4	4796.0	5033.8	-5.0	.667
23	5	209.0	.03385	.082	.076	6.8	4743.0	4972.8	-4.8	.659
24	5	219.0	.03496	.083	.078	6.1	4693.1	4910.1	-4.6	.651
25	5	229.0	.03593	.084	.079	5.3	4650.2	4855.5	-4.4	.643
26	5	239.5	.03686	.084	.080	4.5	4618.1	4798.2	-3.9	.636
27	5	250.5	.03712	.085	.082	3.5	4599.5	4740.9	-3.1	.628
28	5	261.0	.02716	.075	.075	.0	6456.1	6457.6	.0	.665
29	5	271.0	.02786	.076	.076	.0	6418.0	6417.0	.0	.661
30	5	281.0	.02855	.077	.076	.4	6364.2	6380.3	-.3	.657
31	5	291.0	.02967	.077	.077	.8	6324.5	6350.1	-.4	.654
32	5	301.0	.03044	.078	.077	1.0	6286.6	6326.1	-.6	.652
33	5	310.5	.03111	.079	.078	1.5	6254.5	6309.3	-.9	.650

34	5	319.5	.03153	.079	.078	1.8	6234.3	6298.5	-1.0	.649
35	4	328.5	.04073	.112	.097	13.1	4271.8	4910.7	-15.0	.489
36	4	337.5	.04134	.113	.098	13.4	4243.2	4891.6	-15.3	.487
37	4	346.5	.04171	.113	.098	13.5	4225.9	4880.7	-15.5	.486
38	4	356.0	.04168	.113	.098	13.4	4227.4	4877.8	-15.4	.486
39	4	366.0	.04187	.113	.098	13.6	4218.6	4881.7	-15.7	.486
40	4	376.0	.04170	.113	.098	13.4	4226.2	4876.9	-15.4	.486
41	4	386.0	.04176	.113	.098	13.6	4223.5	4881.5	-15.6	.486
42	4	396.0	.04134	.113	.098	13.4	4242.9	4894.7	-15.4	.487
43	4	406.0	.04123	.113	.098	12.7	4248.1	4857.5	-14.3	.484
44	4	416.0	.04090	.112	.099	11.9	4263.5	4828.2	-13.2	.481
45	4	426.0	.04019	.111	.100	10.5	4297.2	4782.4	-11.3	.476
46	4	436.0	.03973	.111	.100	9.5	4319.4	4751.6	-10.0	.473

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ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00229	.020	.021	-6.2	2461.6	2452.5	.4	.978
2	1	10.0	.02501	.082	.087	-4.8	717.7	715.4	.3	.961
3	1	20.0	.03767	.096	.101	-5.2	809.4	800.9	1.0	.937
4	1	30.0	.04726	.103	.108	-4.5	897.2	888.4	1.0	.923
5	1	40.0	.05418	.108	.113	-4.2	988.1	978.6	1.0	.914
6	1	50.0	.05820	.111	.115	-3.9	1079.3	1069.4	.9	.909
7	1	60.0	.05932	.111	.116	-3.9	1172.3	1161.1	.9	.908
8	6	67.5	.04013	.065	.068	-3.7	1882.5	1835.8	2.5	.676
9	6	76.5	.11517	.092	.092	.1	709.1	710.2	-.2	.512
10	6	86.5	.05668	.074	.075	-1.6	1564.2	1540.9	1.5	.625
11	6	95.0	.03960	.065	.067	-2.7	2359.5	2317.3	1.8	.683
12	6	104.5	.02875	.058	.059	-2.5	3406.3	3350.6	1.6	.737
13	6	113.5	.03076	.059	.061	-2.6	3358.8	3297.9	1.8	.725
14	6	122.5	.03286	.061	.062	-2.4	3307.9	3251.9	1.7	.715
15	5	131.5	.03850	.086	.087	-1.0	2966.3	2939.2	.9	.596
16	5	140.5	.04109	.088	.088	-.6	2900.0	2882.1	.6	.585
17	4	149.5	.05453	.126	.120	4.7	2150.6	2290.3	-6.5	.398
18	4	159.0	.05855	.129	.122	5.1	2071.2	2229.7	-7.6	.383
19	4	169.0	.06326	.133	.125	5.6	1984.7	2163.3	-9.0	.372
20	4	179.0	.06735	.136	.127	5.9	1914.8	2107.2	-10.0	.362
21	4	189.0	.07095	.138	.129	6.2	1856.7	2060.9	-11.0	.354
22	5	199.0	.03115	.079	.081	-2.0	4861.8	4796.0	1.4	.635
23	5	209.0	.03212	.080	.082	-2.1	4824.6	4743.0	1.7	.626
24	5	219.0	.03296	.081	.083	-2.5	4789.3	4693.1	2.0	.622
25	5	229.0	.03331	.081	.084	-3.0	4768.0	4650.2	2.5	.616
26	5	239.5	.03368	.081	.084	-3.4	4750.9	4618.1	2.8	.612
27	5	250.5	.03459	.082	.085	-2.8	4709.2	4599.5	2.3	.609
28	5	261.0	.02551	.073	.075	-2.4	6549.3	6456.1	1.4	.665
29	5	271.0	.02648	.074	.076	-2.0	6493.5	6418.0	1.2	.661
30	5	281.0	.02751	.075	.077	-1.8	6436.8	6364.2	1.1	.656
31	5	291.0	.02828	.076	.077	-1.8	6396.0	6324.5	1.1	.652
32	5	301.0	.02884	.077	.078	-2.1	6367.0	6286.6	1.3	.648
33	5	310.5	.02939	.077	.079	-2.3	6338.5	6254.5	1.3	.641
34	5	319.5	.02983	.078	.079	-2.3	6316.7	6234.3	1.3	.642
35	4	328.5	.04356	.115	.112	2.7	4142.1	4271.8	-3.1	.425
36	4	337.5	.04383	.115	.113	2.4	4130.3	4243.2	-2.7	.422
37	4	346.5	.04406	.116	.113	2.2	4120.3	4225.9	-2.6	.421
38	4	356.0	.04383	.115	.113	2.0	4130.2	4227.4	-2.4	.421
39	4	366.0	.04368	.115	.113	1.7	4136.6	4218.6	-2.0	.420
40	4	376.0	.04326	.115	.113	1.5	4155.5	4226.2	-1.7	.421
41	4	386.0	.04300	.115	.113	1.2	4167.2	4223.5	-1.4	.421
42	4	396.0	.04222	.114	.113	.9	4202.2	4242.9	-1.0	.422
43	4	406.0	.04137	.113	.113	.1	4241.6	4248.1	-.2	.423
44	4	416.0	.04031	.111	.112	-.6	4291.7	4263.5	.7	.425
45	4	426.0	.03931	.110	.111	-.9	4339.8	4297.2	1.0	.428
46	4	436.0	.03931	.110	.111	-.5	4340.2	4319.4	.5	.430

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Solid Waste Branch

ACCELEROGRAM - magSeq.sar
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ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00222	.020	.020	-1.2	2463.3	2461.6	.1	.982
2	1	10.0	.02435	.083	.083	-.9	718.1	717.7	.1	.964
3	1	20.0	.03641	.095	.096	-1.2	811.3	809.4	.2	.947
4	1	30.0	.04577	.102	.103	-1.1	898.3	897.2	.2	.932
5	1	40.0	.05247	.107	.108	-1.0	990.4	988.1	.2	.922
6	1	50.0	.05642	.110	.111	-1.0	1081.8	1079.3	.2	.918
7	1	60.0	.05757	.110	.111	-.9	1174.9	1172.3	.2	.916
8	6	67.5	.03827	.064	.065	-1.8	1904.5	1882.5	1.2	.693
9	6	76.5	.11456	.092	.093	-.2	710.5	709.1	.2	.512
10	6	86.5	.05561	.073	.074	-.6	1572.2	1569.2	.5	.635
11	6	95.0	.03866	.065	.065	-.9	2373.4	2359.5	.6	.696
12	6	104.5	.02806	.058	.058	-.8	3422.1	3406.3	.5	.749
13	6	113.5	.03002	.059	.059	-.8	3377.7	3358.9	.6	.739
14	6	122.5	.03201	.060	.061	-1.0	3328.2	3307.9	.6	.728
15	5	131.5	.03782	.085	.086	-.7	2984.4	2966.3	.6	.602
16	5	140.5	.04044	.087	.088	-.6	2916.3	2900.0	.6	.588
17	4	149.5	.05735	.128	.126	1.8	2094.3	2150.6	-2.7	.369
18	4	159.0	.06235	.132	.129	2.2	2000.9	2071.2	-3.5	.356
19	4	169.0	.06781	.136	.133	2.4	1907.1	1984.7	-4.1	.341
20	4	179.0	.07292	.139	.136	2.7	1826.0	1914.8	-4.9	.329
21	4	189.0	.07690	.142	.138	2.7	1766.7	1856.7	-5.1	.319
22	5	199.0	.03004	.078	.079	-1.5	4903.8	4861.8	.9	.644
23	5	209.0	.03077	.079	.080	-1.8	4876.0	4823.6	1.1	.639
24	5	219.0	.03132	.079	.081	-2.0	4855.2	4789.3	1.4	.635
25	5	229.0	.03156	.079	.081	-2.2	4846.6	4768.0	1.6	.632
26	5	239.5	.03176	.080	.082	-2.4	4839.5	4750.9	1.8	.629
27	5	250.5	.03366	.081	.082	-1.1	4752.0	4709.2	.9	.624
28	5	261.0	.02504	.073	.073	-.7	6576.6	6549.3	.4	.675
29	5	271.0	.02604	.074	.074	-.6	6518.3	6493.5	.4	.669
30	5	281.0	.02705	.075	.075	-.6	6461.9	6436.8	.4	.663
31	5	291.0	.02779	.076	.076	-.7	6421.7	6396.0	.4	.659
32	5	301.0	.02828	.076	.077	-.7	6395.7	6367.0	.4	.656
33	5	310.5	.02874	.076	.077	-.8	6371.9	6338.5	.5	.653
34	5	319.5	.02916	.077	.078	-.8	6350.4	6316.7	.5	.651
35	4	328.5	.04439	.116	.115	.8	4105.9	4142.1	-.9	.412
36	4	337.5	.04447	.116	.115	.6	4102.2	4130.3	-.7	.411
37	4	346.5	.04447	.116	.116	.4	4102.4	4120.3	-.4	.410
38	4	356.0	.04412	.116	.115	.3	4117.5	4130.2	-.3	.411
39	4	366.0	.04372	.115	.115	.0	4135.1	4136.6	.0	.412
40	4	376.0	.04316	.115	.115	-.1	4159.9	4155.5	.1	.414
41	4	386.0	.04273	.114	.115	-.3	4179.1	4167.2	.3	.415
42	4	396.0	.04179	.113	.114	-.4	4222.3	4202.2	.5	.418
43	4	406.0	.04063	.112	.113	-.8	4276.3	4241.6	.8	.422
44	4	416.0	.03925	.110	.111	-1.1	4343.0	4291.7	1.2	.427
45	4	426.0	.03852	.109	.110	-.9	4379.1	4339.9	.9	.432
46	4	436.0	.03865	.110	.110	-.7	4372.5	4340.2	.7	.432

ACCELEROGRAM - magSeq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00219	.019	.020	-.5	2464.1	2463.3	.0	.983

2	1	10.0	.02408	.082	.083	-.4	718.3	718.1	.0	.964
3	1	20.0	.03593	.094	.095	-.5	812.1	811.3	.1	.949
4	1	30.0	.04524	.102	.102	-.4	900.0	899.3	.1	.934
5	1	40.0	.05186	.107	.107	-.4	991.3	990.4	.1	.925
6	1	50.0	.05577	.109	.110	-.4	1082.7	1081.8	.1	.920
7	1	60.0	.05695	.110	.110	-.3	1175.8	1174.9	.1	.918
8	6	67.5	.03746	.064	.064	-.6	1914.3	1904.5	.5	.702
9	6	76.5	.11418	.091	.092	-.1	711.4	710.5	.1	.513
10	6	86.5	.05534	.073	.073	-.2	1574.2	1572.2	.1	.638
11	6	95.0	.03841	.064	.065	-.2	2377.1	2373.4	.2	.700
12	6	104.5	.02790	.057	.058	-.2	3425.9	3422.1	.1	.753
13	6	113.5	.02985	.059	.059	-.2	3381.7	3377.7	.1	.743
14	6	122.5	.03176	.060	.060	-.3	3334.3	3328.2	.2	.732
15	5	131.5	.03753	.085	.085	-.3	2992.4	2984.4	.3	.606
16	5	140.5	.04018	.087	.087	-.3	2922.9	2916.3	.2	.592
17	4	149.5	.05873	.129	.128	.4	2067.8	2094.3	-1.3	.360
18	4	159.0	.06433	.133	.132	1.1	1966.0	2000.9	-1.8	.344
19	4	169.0	.07012	.137	.136	1.3	1869.7	1907.1	-2.0	.328
20	4	179.0	.07589	.141	.139	1.4	1779.9	1826.0	-2.6	.314
21	4	189.0	.08020	.144	.142	1.4	1719.7	1766.7	-2.7	.303
22	5	199.0	.02953	.077	.078	-.6	4923.3	4903.8	.4	.650
23	5	209.0	.03012	.078	.079	-.4	4900.5	4876.0	.5	.646
24	5	219.0	.03055	.078	.079	-1.0	4884.2	4855.2	.6	.643
25	5	229.0	.03068	.078	.079	-1.2	4879.4	4846.6	.7	.642
26	5	239.5	.03118	.079	.080	-.7	4860.6	4839.5	.4	.641
27	5	250.5	.03341	.081	.081	-.3	4763.4	4752.0	.2	.630
28	5	261.0	.02498	.072	.073	-.1	6580.3	6576.6	.1	.678
29	5	271.0	.02598	.074	.074	-.1	6522.2	6518.3	.1	.672
30	5	281.0	.02697	.075	.075	-.1	6466.3	6461.9	.1	.666
31	5	291.0	.02770	.075	.076	-.1	6426.8	6421.7	.1	.662
32	5	301.0	.02816	.076	.076	-.2	6402.1	6395.7	.1	.659
33	5	310.5	.02856	.076	.076	-.2	6381.3	6371.9	.1	.656
34	5	319.5	.02897	.077	.077	-.2	6360.3	6350.4	.2	.654
35	4	328.5	.04467	.116	.116	.3	4093.6	4105.9	-.3	.409
36	4	337.5	.04466	.116	.116	.2	4094.3	4102.2	-.2	.408
37	4	346.5	.04448	.116	.116	.0	4101.8	4102.4	.0	.408
38	4	356.0	.04407	.116	.116	.2	4119.8	4117.5	.1	.410
39	4	366.0	.04352	.115	.115	-.2	4143.9	4135.1	.2	.412
40	4	376.0	.04290	.114	.115	-.2	4171.6	4159.9	.2	.414
41	4	386.0	.04241	.114	.114	-.3	4193.8	4179.1	.4	.416
42	4	396.0	.04140	.113	.113	-.4	4240.4	4222.3	.4	.420
43	4	406.0	.04014	.111	.112	-.5	4299.9	4276.3	.5	.426
44	4	416.0	.03864	.110	.110	-.7	4373.2	4343.0	.7	.432
45	4	426.0	.03810	.109	.109	-.5	4400.1	4379.1	.5	.436
46	4	436.0	.03827	.109	.110	-.4	4391.4	4372.5	.4	.435

ACCELEROGRAM - magSeq.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00218	.019	.019	-.3	2464.5	2464.1	.0	.983
2	1	10.0	.02394	.082	.082	-.2	718.4	718.3	.0	.965
3	1	20.0	.03568	.094	.094	-.2	812.5	812.1	.0	.950
4	1	30.0	.04499	.102	.102	-.2	900.0	900.0	.0	.935
5	1	40.0	.05156	.106	.107	-.2	991.7	991.3	.0	.925
6	1	50.0	.05546	.109	.109	-.2	1083.2	1082.7	.0	.921
7	1	60.0	.05665	.110	.110	-.2	1176.3	1175.8	.0	.919
8	6	67.5	.03711	.063	.064	-.4	1918.6	1914.3	.2	.705
9	6	76.5	.11400	.091	.091	-.1	711.8	711.4	.1	.515
10	6	86.5	.05531	.073	.073	.0	1574.5	1574.2	.0	.639
11	6	95.0	.03836	.064	.064	-.1	2377.8	2377.1	.0	.701
12	6	104.5	.02787	.057	.057	.0	3426.4	3425.9	.0	.753
13	6	113.5	.02982	.059	.059	.0	3382.3	3381.7	.0	.744
14	6	122.5	.03169	.060	.060	-.1	3336.3	3334.3	.1	.733

15	5	131.5	.03740	.085	.085	-.1	2995.8	2992.4	.1	.607
16	5	140.5	.04008	.087	.087	-.1	2925.5	2922.9	.1	.593
17	4	149.5	.05847	.130	.129	.5	2053.7	2067.8	-.7	.355
18	4	159.0	.06536	.134	.133	.6	1948.2	1966.0	-.9	.338
19	4	169.0	.07125	.138	.137	.6	1851.2	1869.7	-1.0	.321
20	4	179.0	.07776	.142	.141	.7	1755.0	1779.9	-1.4	.306
21	4	189.0	.08211	.145	.144	.8	1693.4	1719.7	-1.6	.295
22	5	199.0	.02909	.077	.077	-.3	4932.8	4923.3	.2	.652
23	5	209.0	.02981	.078	.078	-.4	4912.7	4900.5	.2	.649
24	5	219.0	.03019	.078	.078	-.5	4897.9	4884.2	.3	.647
25	5	229.0	.03028	.078	.078	-.5	4894.5	4879.4	.3	.646
26	5	239.5	.03111	.079	.079	-.1	4863.3	4860.6	.1	.644
27	5	250.5	.03339	.081	.081	.0	4764.2	4763.4	.0	.631
28	5	261.0	.02501	.072	.072	.0	6578.5	6580.3	.0	.678
29	5	271.0	.02600	.074	.074	.0	6521.0	6522.2	.0	.672
30	5	281.0	.02698	.075	.075	.0	6465.6	6466.3	.0	.666
31	5	291.0	.02770	.075	.075	.0	6426.6	6426.8	.0	.662
32	5	301.0	.02816	.076	.076	.0	6402.4	6402.1	.0	.660
33	5	310.5	.02852	.076	.076	-.1	6383.3	6381.3	.0	.657
34	5	319.5	.02892	.077	.077	-.1	6362.7	6360.3	.0	.655
35	4	328.5	.04477	.116	.116	.1	4089.2	4093.6	-.1	.408
36	4	337.5	.04471	.116	.116	.0	4092.1	4094.3	-.1	.408
37	4	346.5	.04443	.116	.116	-.1	4104.3	4101.8	.1	.408
38	4	356.0	.04398	.116	.116	-.1	4123.9	4119.8	.1	.410
39	4	366.0	.04335	.115	.115	-.2	4151.5	4143.9	.2	.413
40	4	376.0	.04270	.114	.114	-.2	4180.5	4171.6	.2	.415
41	4	386.0	.04218	.114	.114	-.2	4204.0	4193.8	.2	.418
42	4	396.0	.04115	.112	.113	-.2	4251.7	4240.4	.3	.422
43	4	406.0	.03985	.111	.111	-.2	4313.5	4299.9	.3	.428
44	4	416.0	.03832	.109	.110	-.4	4389.1	4373.2	.4	.435
45	4	426.0	.03791	.109	.109	-.2	4405.9	4400.1	.2	.438
46	4	436.0	.03809	.109	.109	-.2	4400.8	4391.4	.2	.437

ACCELEROGRAM - magBeq.ser
P R O F I L E - Paducah U Landfill - free-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ------> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00217	.019	.019	-.1	2464.6	2464.5	.0	.983
2	1	10.0	.02305	.082	.082	-.1	718.4	718.4	.0	.965
3	1	20.0	.03555	.094	.094	-.1	812.7	812.5	.0	.951
4	1	30.0	.04485	.102	.102	-.1	900.6	900.4	.0	.935
5	1	40.0	.05140	.106	.106	-.1	991.9	991.7	.0	.926
6	1	50.0	.05529	.109	.109	-.1	1083.4	1083.2	.0	.921
7	1	60.0	.05650	.110	.110	-.1	1176.5	1176.3	.0	.919
8	6	67.5	.03702	.063	.064	-.1	1919.8	1918.6	.1	.707
9	6	76.5	.11391	.091	.091	.0	712.0	711.8	.0	.513
10	6	86.5	.05533	.073	.073	.0	1574.3	1574.5	.0	.639
11	6	95.0	.03835	.064	.064	.0	2377.9	2377.8	.0	.701
12	6	104.5	.02789	.057	.057	.0	3426.0	3426.4	.0	.754
13	6	113.5	.02982	.059	.059	.0	3382.2	3382.3	.0	.744
14	6	122.5	.03166	.060	.060	.0	3336.7	3336.3	.0	.734
15	5	131.5	.03735	.085	.085	-.1	2997.3	2995.8	.1	.608
16	5	140.5	.04004	.087	.087	.0	2926.5	2925.5	.0	.594
17	4	149.5	.05987	.130	.130	.2	2046.3	2053.7	-.4	.353
18	4	159.0	.06589	.134	.134	.3	1939.2	1948.2	-.5	.335
19	4	169.0	.07195	.138	.138	.3	1841.0	1851.2	-.6	.318
20	4	179.0	.07866	.143	.142	.4	1741.3	1755.0	-.8	.301
21	4	189.0	.08323	.145	.145	.4	1678.3	1693.4	-.9	.291
22	5	199.0	.02917	.077	.077	-.2	4937.6	4932.8	.1	.654
23	5	209.0	.02964	.077	.078	-.2	4919.1	4912.7	.1	.651
24	5	219.0	.03000	.078	.078	-.3	4905.0	4897.9	.1	.649
25	5	229.0	.03008	.078	.078	-.3	4902.0	4894.5	.2	.648
26	5	239.5	.03113	.079	.079	.0	4862.4	4863.3	.0	.644
27	5	250.5	.03343	.081	.081	.0	4762.5	4764.2	.0	.631

28	5	261.0	.02505	.073	.073	.1	6576.2	6578.5	.0	.678
29	5	271.0	.02603	.074	.074	.0	6519.3	6521.0	.0	.672
30	5	281.0	.02701	.075	.075	.0	6464.2	6465.6	.0	.666
31	5	291.0	.02772	.075	.075	.0	6425.5	6426.6	.0	.662
32	5	301.0	.02817	.076	.076	.0	6401.6	6402.4	.0	.660
33	5	310.5	.02852	.076	.076	.0	6383.5	6383.3	.0	.658
34	5	319.5	.02891	.077	.077	.0	6363.2	6362.7	.0	.655
35	4	328.5	.04481	.116	.116	.0	4087.5	4089.2	.0	.407
36	4	337.5	.04472	.116	.116	.0	4091.6	4092.1	.0	.407
37	4	346.5	.04437	.116	.116	.0	4106.5	4104.3	.1	.409
38	4	356.0	.04390	.115	.116	-.1	4127.1	4123.9	.1	.411
39	4	366.0	.04324	.115	.115	-.1	4156.6	4151.5	.1	.413
40	4	376.0	.04258	.114	.114	-.1	4186.2	4180.5	.1	.416
41	4	386.0	.04205	.113	.114	-.1	4210.1	4204.0	.1	.419
42	4	396.0	.04101	.112	.112	-.1	4258.2	4251.7	.1	.423
43	4	406.0	.03970	.111	.111	-.2	4320.9	4313.5	.2	.429
44	4	416.0	.03816	.109	.109	-.2	4397.2	4389.1	.2	.437
45	4	426.0	.03782	.109	.109	-.1	4414.2	4409.9	.1	.439
46	4	436.0	.03800	.109	.109	-.1	4405.1	4400.8	.1	.438

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	5.0	2.5	.00329	81.04	.27012	26.36
2	1	10.0	10.0	.03616	358.75	.26782	26.36
3	1	10.0	20.0	.05386	437.64	.25297	26.36
4	1	10.0	30.0	.06795	611.85	.24198	21.10
5	1	10.0	40.0	.07788	772.33	.23010	21.10
6	1	10.0	50.0	.08378	907.44	.21572	21.10
7	1	10.0	60.0	.08560	1006.90	.19854	21.10
8	6	5.0	67.5	.05609	1076.24	.18454	31.34
9	6	13.0	76.5	.17260	1228.53	.17644	31.34
10	6	7.0	86.5	.08383	1319.94	.16091	31.34
11	6	10.0	95.0	.05811	1381.83	.14552	31.32
12	6	9.0	104.5	.04226	1447.92	.13834	31.32
13	6	9.0	113.5	.04516	1526.24	.13312	31.30
14	6	9.0	122.5	.04797	1600.32	.12732	31.30
15	5	9.0	131.5	.05658	1695.10	.12415	31.28
16	5	9.0	140.5	.06066	1774.72	.12045	31.26
17	4	9.0	149.5	.09071	1862.96	.11780	31.28
18	4	10.0	159.0	.09984	1945.06	.11473	31.26
19	4	10.0	169.0	.10901	2018.06	.11116	31.26
20	4	10.0	179.0	.11918	2091.68	.10807	31.24
21	4	10.0	189.0	.12610	2135.38	.10389	31.24
22	5	10.0	199.0	.04419	2180.02	.10012	31.22
23	5	10.0	209.0	.04491	2206.24	.09587	31.20
24	5	10.0	219.0	.04546	2226.69	.09181	31.20
25	5	10.0	229.0	.04558	2230.78	.08750	31.20
26	5	11.0	239.5	.04717	2293.94	.08561	24.28
27	5	11.0	250.5	.05065	2413.18	.08570	24.28
28	5	10.0	261.0	.03795	2496.56	.08471	24.28
29	5	10.0	271.0	.03943	2571.39	.08367	24.26
30	5	10.0	281.0	.04092	2645.94	.08271	24.26
31	5	10.0	291.0	.04200	2699.48	.08118	24.26
32	5	10.0	301.0	.04269	2732.87	.07919	24.26
33	5	9.0	310.5	.04321	2758.07	.07724	24.24
34	5	9.0	319.5	.04380	2787.13	.07565	24.24
35	4	9.0	328.5	.06790	2776.59	.07278	24.24
36	4	9.0	337.5	.06775	2772.55	.06995	24.24
37	4	9.0	346.5	.06723	2759.38	.06710	24.22
38	4	10.0	356.0	.06652	2743.19	.06426	24.22
39	4	10.0	366.0	.06551	2719.58	.06133	24.20
40	4	10.0	376.0	.06451	2696.85	.05864	24.20
41	4	10.0	386.0	.06371	2678.48	.05622	24.18
42	4	10.0	396.0	.06214	2642.10	.05360	24.18
43	4	10.0	406.0	.06015	2594.70	.05094	24.16
44	4	10.0	416.0	.05782	2537.64	.04825	24.16
45	4	10.0	426.0	.05731	2527.28	.04659	21.48
46	4	10.0	436.0	.05758	2534.04	.04534	21.46

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PERIOD = 1.937 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 910.6 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION - 7.10
FOR FREQUENCY (f) = .61 c/sec
FOR PERIOD (1 / f) = 1.64 sec

****** OPTION 5 *** COMPUTE MOTION IN MEM SUBLAYERS

ACCELEROGRAM - magEeq.aar
D E P O S I T - Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.27186	26.34	1.87	.185	0
WITHIN	5.0	.27024	26.34	1.86	.186	0
WITHIN	15.0	.24173	21.08	1.72	.203	0
WITHIN	25.0	.21678	21.08	1.60	.218	0
WITHIN	35.0	.18810	21.08	1.52	.228	0
WITHIN	45.0	.17889	31.66	1.48	.232	0
WITHIN	55.0	.17369	19.88	1.48	.217	0
WITHIN	65.0	.16564	19.88	1.56	.212	0
WITHIN	70.0	.16021	19.88	1.56	.217	0
WITHIN	83.0	.15638	21.30	1.87	.231	0
WITHIN	90.0	.14766	21.30	1.93	.207	0
WITHIN	100.0	.15527	21.28	1.94	.190	0
WITHIN	109.0	.15693	21.28	1.92	.194	0
WITHIN	118.0	.15343	21.28	1.90	.185	0
WITHIN	127.0	.14819	21.26	1.90	.186	0

****** OPTION 6 *** COMPUTE MOTION IN MEM SUBLAYERS

ACCELEROGRAM - magEeq.aar
D E P O S I T - Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	136.0	.14157	21.26	1.95	.192	0
WITHIN	441.0	.21817	25.84	4.21	.139	0
OUTCR.	441.0	.23949	25.84	4.26	.135	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 4
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- stress in layer 3

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 8
SCALE FOR PLOTTING .0000
IDENTIFICATION - -- strain in layer 3

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES     *
*             by: Per B. Schnabel & John Lysmer -- 1970  *
* ------------------------------------------------------ *
* Shake85   : IBM-PC version of SHAKE                    *
*             by: S.S. (Willie) Lai, January 1985        *
* ------------------------------------------------------ *
* Shake88   : New modulus reduction curves for clays     *
*             added using results from Sun et al. (1988) *
*             by: J. I. Sun & Ramin Golesorkhi           *
*             February 26, 1988                          *
* ------------------------------------------------------ *
* Shake90/91: Adjust last iteration; Input now is either *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can  *
*             be specified; object motion can be read in *
*             from a separate file and can have user     *
*             specified format; Different periods for    *
*             response spectral calculations; options    *
*             are renumbered; and general cleanup        *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim    *
*             June 1990 - February 1991                  *
* ------------------------------------------------------ *
* Shake91   : General cleanup and finalization of input / *
*             output format ... etc                      *
*             by: I. M. Idriss                           *
*             December 1991                              *
* ------------------------------------------------------ *
* Shake98   : Routine for direct calculation of average  *
*             acceleration is added to the program. Out- *
*             put format is modified to enable the two - *
*             - page landscape printing.  The following  *
*             modulus reduction and  damping curves are  *
*             added:  Matasovic & Kavazanjian (1998) for *
*             municipal solid waste; Matasovic & Vucetic *
*             (1993) for SME sand; and Vucetic and Dobry *
*             (1991) for clays of various plasticities.  *
*             by: Neven Matasovic                        *
*             August 1993 - May 1998                     *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:   #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:   #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.818	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0001	.85
.0010	1.000	.0010	1.26
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0300	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	14.56
3.0000	.048	3.1600	11.56

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
```


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SOIL PROFILE NO. 1 Paducah U Landfill - free-field prof

NUMBER OF LAYERS 47
DEPTH TO BEDROCK 441.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	5.00	2.50	300.00	2507.	5.00	120.00	820.2
2	1	10.00	10.00	969.50	745.	5.00	73.90	569.6
3	1	10.00	20.00	1730.00	855.	5.00	78.20	593.2
4	1	10.00	30.00	2528.50	963.	5.00	81.50	616.8
5	1	10.00	40.00	3356.50	1071.	5.00	84.10	640.4
6	1	10.00	50.00	4206.50	1176.	5.00	85.90	664.0
7	1	10.00	60.00	5071.50	1279.	5.00	87.10	687.7
8	6	5.00	67.50	5832.00	2715.	5.00	130.00	820.0
9	6	13.00	76.50	6963.00	1386.	5.00	124.00	600.0
10	6	7.00	86.50	8203.00	2465.	5.00	124.00	800.0
11	6	10.00	95.00	9242.00	3391.	5.00	121.00	950.0
12	6	9.00	104.50	10391.50	4547.	5.00	121.00	1100.0
13	6	9.00	113.50	11480.50	4547.	5.00	121.00	1100.0
14	6	9.00	122.50	12569.50	4547.	5.00	121.00	1100.0
15	5	9.00	131.50	13654.00	4929.	5.00	120.00	1150.0
16	5	9.00	140.50	14734.00	4929.	5.00	120.00	1150.0
17	4	9.00	149.50	15814.00	5823.	5.00	120.00	1250.0
18	4	10.00	159.00	16954.00	5823.	5.00	120.00	1250.0
19	4	10.00	169.00	18154.00	5823.	5.00	120.00	1250.0
20	4	10.00	179.00	19354.00	5823.	5.00	120.00	1250.0
21	4	10.00	189.00	20554.00	5823.	5.00	120.00	1250.0
22	5	10.00	199.00	21774.00	7548.	5.00	124.00	1400.0
23	5	10.00	209.00	23014.00	7548.	5.00	124.00	1400.0
24	5	10.00	219.00	24254.00	7548.	5.00	124.00	1400.0
25	5	10.00	229.00	25494.00	7548.	5.00	124.00	1400.0
26	5	11.00	239.50	26796.00	7548.	5.00	124.00	1400.0
27	5	11.00	250.50	28160.00	7548.	5.00	124.00	1400.0
28	5	10.00	261.00	29472.00	9707.	5.00	126.00	1575.0
29	5	10.00	271.00	30732.00	9707.	5.00	126.00	1575.0
30	5	10.00	281.00	31992.00	9707.	5.00	126.00	1575.0
31	5	10.00	291.00	33252.00	9707.	5.00	126.00	1575.0
32	5	10.00	301.00	34512.00	9707.	5.00	126.00	1575.0
33	5	9.00	310.50	35709.00	9707.	5.00	126.00	1575.0
34	5	9.00	319.50	36943.00	9707.	5.00	126.00	1575.0
35	4	9.00	328.50	38152.50	10043.	5.00	165.00	1400.0
36	4	9.00	337.50	39637.50	10043.	5.00	165.00	1400.0
37	4	9.00	346.50	41122.50	10043.	5.00	165.00	1400.0
38	4	10.00	356.00	42690.00	10043.	5.00	165.00	1400.0
39	4	10.00	366.00	44340.00	10043.	5.00	165.00	1400.0
40	4	10.00	376.00	45990.00	10043.	5.00	165.00	1400.0
41	4	10.00	386.00	47640.00	10043.	5.00	165.00	1400.0
42	4	10.00	396.00	49290.00	10043.	5.00	165.00	1400.0
43	4	10.00	406.00	50940.01	10043.	5.00	165.00	1400.0
44	4	10.00	416.00	52590.01	10043.	5.00	165.00	1400.0
45	4	10.00	426.00	54240.01	10043.	5.00	165.00	1400.0
46	4	10.00	436.00	55890.01	10043.	5.00	165.00	1400.0
47	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.446 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1220.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 16.07
FOR FREQUENCY (f) = .87 c/sec
FOR PERIOD (1 / f) = 1.15 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = riod1-hz.sar
NO. OF INPUT ACCEL. POINTS = 1800
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 6
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0200

FORMAT FOR OF TIME HISTORY - (8F9.4)

***** A C C E L E R O G R A M H E A D E R *****

CAPE MENDOCINO, CA EQ. 1992; Mw = 7.0 (6.1 J & B); Ms = 7.1
RIO DELL - 101/PAINTER ST. OVERPASS; CHAN 4: (270 deg) (free-field)
Thrust fault; H = 15 km; R = 24 km (Naeim) or 12.3 km (J & B)
Uncor. Max. = -0.78 g @ 5.575 sec; Max. in file = 0.385732 @ 5.58 sec
J & B Site Class B; Mean sq. freq. = 3.01 Hz; Ds = 15.4 s; To = 0.2371 s
225*8 = 1800 pts @ 0.02 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	-.002296	-.001777	.000569	.000731	-.003688	-.000583	.004051	.002788
2	.000964	-.002422	-.004550	-.004451	-.005423	-.008852	-.014746	-.015439
3	-.011380	-.006311	-.005492	-.008705	-.008035	-.006091	-.004255	-.001129
4	.002864	.006916	.010116	.005313	-.004705	-.003748	.003541	.005366
5	.000370	-.000956	.004616	.007193	.010419	.013203	.011285	.008016

..... INPUT MOTION READ NOT ECHOED.....

221	-.005527	-.003620	-.002145	-.002337	-.002461	-.004595	-.007641	-.008303
222	-.007946	-.006056	-.005096	-.005324	-.005166	-.005233	-.004698	-.004398
223	-.002852	-.002130	-.002072	-.002438	-.002967	-.001687	.001139	.004567
224	.006282	.006832	.006628	.006013	.009033	.007818	.006191	.003176
225	.000796	-.001591	-.001767	.000490	.000460	-.001572	.000280	.001179

MAXIMUM ACCELERATION = .385732
AT TIME = 5.58 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .93328050
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.02 c/sec
MAXIMUM ACCELERATION = .359996 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - riod1-hz.sar
P R O F I L E - Paducah U Landfill - free-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00446	.027	.050	-83.8	2384.8	2507.1	-5.1	1.000
2	1	10.0	.04837	.104	.050	52.0	692.6	744.6	-7.0	1.000
3	1	20.0	.07355	.119	.050	57.8	770.7	854.6	-11.9	1.000
4	1	30.0	.09146	.126	.050	60.3	851.2	962.9	-12.3	1.000
5	1	40.0	.10259	.130	.050	61.6	938.3	1071.1	-14.1	1.000
6	1	50.0	.11027	.133	.050	62.4	1013.6	1176.2	-14.1	1.000
7	1	60.0	.11560	.135	.050	63.0	1090.6	1279.3	-17.1	1.000
8	6	67.5	.06069	.075	.050	33.7	1689.8	2714.7	-62.8	1.000
9	6	76.5	.13604	.097	.050	48.5	665.8	1386.3	-128.2	1.000
10	6	86.5	.08511	.083	.050	40.0	1393.6	2464.6	-76.9	1.000
11	6	95.0	.06581	.077	.050	35.3	2066.2	3391.4	-64.2	1.000
12	6	104.5	.05166	.071	.050	30.0	2957.6	4546.9	-53.7	1.000
13	6	113.5	.05452	.073	.050	31.3	2915.8	4546.9	-55.9	1.000
14	6	122.5	.05696	.074	.050	32.2	2882.0	4546.9	-57.8	1.000
15	5	131.5	.05438	.097	.050	48.4	2615.3	4929.8	-88.4	1.000
16	5	140.5	.05670	.098	.050	49.1	2572.9	4929.6	-91.6	1.000
17	4	149.5	.04963	.121	.050	58.8	2255.8	5823.0	-158.1	1.000

18	4	159.0	.05166	.123	.050	59.4	2211.1	5823.0	-163.3	1.000
19	4	169.0	.05379	.125	.050	60.0	2165.9	5823.0	-168.8	1.000
20	4	179.0	.05552	.126	.050	60.5	2130.6	5823.0	-173.3	1.000
21	4	189.0	.05731	.128	.050	60.9	2095.1	5823.0	-177.9	1.000
22	5	199.0	.04532	.091	.050	45.1	4288.8	7547.8	-76.0	1.000
23	5	209.0	.04609	.092	.050	45.4	4262.6	7547.8	-77.1	1.000
24	5	219.0	.04654	.092	.050	45.6	4247.4	7547.8	-77.7	1.000
25	5	229.0	.04675	.092	.050	45.7	4240.6	7547.8	-78.0	1.000
26	5	239.5	.04678	.092	.050	45.7	4239.5	7547.8	-78.0	1.000
27	5	250.5	.04670	.092	.050	45.7	4242.0	7547.8	-77.9	1.000
28	5	261.0	.03641	.084	.050	40.5	5954.1	9706.8	-63.0	1.000
29	5	271.0	.03644	.084	.050	40.5	5952.5	9706.8	-63.1	1.000
30	5	281.0	.03641	.084	.050	40.5	5953.7	9706.8	-63.0	1.000
31	5	291.0	.03634	.084	.050	40.4	5957.6	9706.8	-62.9	1.000
32	5	301.0	.03622	.084	.050	40.3	5964.6	9706.8	-62.7	1.000
33	5	310.5	.03602	.084	.050	40.2	5975.4	9706.8	-62.4	1.000
34	5	319.5	.03575	.083	.050	40.0	5990.8	9706.8	-62.0	1.000
35	4	328.5	.03411	.104	.050	51.8	4613.1	10043.5	-117.7	1.000
36	4	337.5	.03481	.105	.050	52.2	4574.2	10043.5	-119.6	1.000
37	4	346.5	.03580	.106	.050	52.8	4520.2	10043.5	-122.2	1.000
38	4	356.0	.03696	.107	.050	53.5	4458.6	10043.5	-125.3	1.000
39	4	366.0	.03804	.109	.050	54.0	4403.3	10043.5	-128.1	1.000
40	4	376.0	.03883	.110	.050	54.4	4363.5	10043.5	-130.2	1.000
41	4	386.0	.03930	.110	.050	54.7	4340.4	10043.5	-131.4	1.000
42	4	396.0	.03945	.110	.050	54.7	4333.4	10043.5	-131.8	1.000
43	4	406.0	.03932	.110	.050	54.7	4339.5	10043.5	-131.4	1.000
44	4	416.0	.03930	.110	.050	54.7	4340.2	10043.5	-131.4	1.000
45	4	426.0	.03900	.110	.050	54.5	4355.3	10043.5	-130.6	1.000
46	4	436.0	.03846	.109	.050	54.3	4382.1	10043.5	-129.2	1.000

ACCELEROGRAM - riod1-hz.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00303	.022	.027	-23.9	2445.2	2384.8	2.5	.951
2	1	10.0	.03403	.092	.104	-13.0	710.3	692.6	2.5	.930
3	1	20.0	.05341	.108	.119	-10.2	789.2	770.7	2.3	.902
4	1	30.0	.06833	.116	.126	-8.6	873.2	854.2	2.2	.887
5	1	40.0	.07926	.121	.130	-7.4	960.5	938.3	2.3	.876
6	1	50.0	.08737	.124	.133	-6.9	1047.0	1013.6	3.2	.862
7	1	60.0	.09295	.127	.135	-6.7	1133.4	1090.6	3.8	.853
8	6	67.5	.06660	.078	.075	2.8	1648.4	1689.8	-2.5	.622
9	6	76.5	.18946	.108	.097	9.9	579.7	665.8	-14.5	.480
10	6	86.5	.09766	.087	.083	3.8	1335.9	1393.6	-4.3	.565
11	6	95.0	.06679	.078	.077	1.4	2040.6	2066.2	-1.3	.609
12	6	104.5	.05009	.071	.071	-1.0	2981.5	2957.6	.8	.650
13	6	113.5	.05265	.072	.073	-1.2	2942.9	2915.8	.9	.641
14	6	122.5	.05508	.073	.074	-1.1	2908.0	2882.0	.9	.634
15	5	131.5	.06180	.101	.097	4.1	2485.3	2615.3	-5.2	.531
16	5	140.5	.06459	.103	.098	4.1	2440.4	2572.9	-5.4	.522
17	4	149.5	.07421	.140	.121	13.4	1806.4	2255.8	-24.9	.387
18	4	159.0	.07715	.142	.123	13.2	1763.1	2211.1	-25.4	.380
19	4	169.0	.07992	.144	.125	12.9	1723.6	2165.9	-25.7	.372
20	4	179.0	.08190	.145	.126	12.6	1696.2	2130.6	-25.4	.366
21	4	189.0	.08396	.146	.128	12.3	1668.5	2095.1	-25.4	.360
22	5	199.0	.04177	.088	.091	-3.0	4415.9	4288.8	2.9	.568
23	5	209.0	.04371	.090	.092	-1.9	4345.1	4262.6	1.9	.565
24	5	219.0	.04531	.091	.092	-1.0	4289.2	4247.4	1.0	.563
25	5	229.0	.04642	.092	.092	-.2	4251.5	4240.6	.3	.562
26	5	239.5	.04760	.093	.092	.6	4212.4	4239.5	-.6	.562
27	5	250.5	.04826	.093	.092	1.1	4191.0	4242.0	-1.2	.562
28	5	261.0	.03442	.082	.084	-2.2	6066.4	5954.1	1.9	.613
29	5	271.0	.03459	.082	.084	-2.0	6056.6	5952.5	1.7	.613
30	5	281.0	.03459	.082	.084	-2.0	6056.6	5953.7	1.7	.613

31	5	291.0	.03432	.082	.084	-2.3	6072.2	5957.6	1.9	.614
32	5	301.0	.03383	.082	.084	-2.7	6100.9	5964.6	2.2	.614
33	5	310.5	.03342	.081	.084	-3.0	6125.6	5975.4	2.5	.616
34	5	319.5	.03278	.081	.083	-3.5	6163.3	5990.8	2.8	.617
35	4	328.5	.04147	.113	.104	8.1	4236.7	4613.1	-8.9	.459
36	4	337.5	.04042	.112	.105	6.3	4286.3	4574.2	-6.7	.455
37	4	346.5	.04111	.112	.106	5.8	4253.6	4520.2	-6.3	.450
38	4	356.0	.04353	.115	.107	6.6	4143.5	4458.6	-7.6	.444
39	4	366.0	.04576	.117	.108	7.4	4047.0	4403.3	-8.8	.438
40	4	376.0	.04796	.120	.110	8.3	3956.7	4363.5	-10.5	.434
41	4	386.0	.04937	.121	.110	8.8	3900.9	4340.4	-11.3	.432
42	4	396.0	.05034	.122	.110	9.4	3863.4	4333.4	-12.2	.431
43	4	406.0	.05091	.122	.110	9.9	3841.7	4339.5	-11.9	.432
44	4	416.0	.05059	.122	.110	9.7	3854.0	4340.2	-11.4	.432
45	4	426.0	.05062	.122	.110	10.0	3852.8	4355.3	-11.0	.434
46	4	436.0	.04944	.121	.109	9.7	3898.3	4382.1	-11.0	.436

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ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00272	.021	.022	-4.2	2452.3	2445.2	.3	.975
2	1	10.0	.03072	.089	.092	-3.7	714.5	710.3	.6	.954
3	1	20.0	.04840	.104	.108	-3.2	794.8	789.2	.7	.923
4	1	30.0	.06187	.113	.116	-3.0	879.6	873.2	.7	.907
5	1	40.0	.07142	.118	.121	-3.0	968.1	960.5	.8	.897
6	1	50.0	.07843	.121	.124	-3.1	1055.6	1047.0	.8	.890
7	1	60.0	.08329	.123	.127	-3.1	1142.9	1133.4	.8	.886
8	6	67.5	.06373	.076	.078	-1.4	1668.7	1648.4	1.2	.607
9	6	76.5	.20230	.110	.108	1.9	562.7	579.7	-3.0	.418
10	6	86.5	.09461	.086	.087	-.9	1349.2	1335.9	1.0	.542
11	6	95.0	.06474	.077	.078	-1.9	2075.6	2040.6	1.7	.602
12	6	104.5	.04606	.069	.071	-2.9	3046.4	2981.5	2.1	.656
13	6	113.5	.04823	.070	.072	-3.0	3010.7	2942.9	2.3	.647
14	6	122.5	.05036	.071	.073	-3.0	2977.3	2908.0	2.3	.640
15	5	131.5	.05985	.100	.101	-1.0	2517.9	2485.3	1.3	.504
16	5	140.5	.06258	.102	.103	-1.0	2472.6	2440.4	1.3	.495
17	4	149.5	.08465	.146	.140	4.2	1659.4	1806.4	-8.4	.310
18	4	159.0	.08843	.148	.142	4.3	1610.6	1763.1	-8.9	.303
19	4	169.0	.09257	.150	.144	4.6	1559.5	1723.6	-10.5	.296
20	4	179.0	.09738	.153	.145	5.3	1502.8	1696.2	-12.9	.291
21	4	189.0	.10213	.155	.146	5.9	1457.2	1668.5	-14.5	.287
22	5	199.0	.03916	.086	.088	-2.4	4516.2	4415.9	2.2	.585
23	5	209.0	.04125	.088	.090	-2.1	4435.3	4345.1	2.0	.576
24	5	219.0	.04312	.089	.091	-1.8	4365.9	4289.2	1.8	.568
25	5	229.0	.04445	.090	.092	-1.5	4318.9	4251.5	1.6	.563
26	5	239.5	.04537	.091	.093	-1.7	4287.1	4212.4	1.7	.558
27	5	250.5	.04603	.092	.093	-1.7	4264.6	4191.0	1.7	.555
28	5	261.0	.03165	.079	.082	-3.4	6226.7	6066.4	2.6	.625
29	5	271.0	.03141	.079	.082	-3.9	6240.2	6056.6	2.9	.624
30	5	281.0	.03110	.079	.082	-4.4	6255.0	6056.6	3.2	.624
31	5	291.0	.03065	.078	.082	-4.7	6276.6	6072.2	3.3	.626
32	5	301.0	.02994	.078	.082	-5.1	6311.1	6100.9	3.3	.629
33	5	310.5	.02916	.077	.081	-5.6	6350.5	6125.6	3.5	.631
34	5	319.5	.02843	.076	.081	-5.8	6387.9	6163.3	3.5	.635
35	4	328.5	.03998	.111	.113	-1.5	4307.2	4236.7	1.6	.422
36	4	337.5	.04056	.112	.112	.1	4279.5	4286.3	-.2	.427
37	4	346.5	.04263	.114	.112	1.5	4183.7	4253.6	-1.7	.424
38	4	356.0	.04577	.117	.115	2.0	4046.9	4143.5	-2.4	.413
39	4	366.0	.04847	.120	.117	2.2	3936.2	4047.0	-2.8	.403
40	4	376.0	.05148	.123	.120	2.7	3820.4	3956.7	-3.5	.394
41	4	386.0	.05340	.125	.121	2.9	3749.6	3900.9	-4.0	.388
42	4	396.0	.05456	.126	.122	3.0	3708.2	3863.4	-4.1	.385
43	4	406.0	.05540	.126	.122	3.1	3679.0	3841.7	-4.4	.383

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44	4	416.0	.05464	.126	.122	2.9	3705.4	3854.0	-4.0	.384
45	4	426.0	.05461	.126	.122	2.8	3706.6	3852.8	-3.9	.384
46	4	436.0	.05290	.124	.121	2.6	3767.7	3898.3	-3.5	.388

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ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00263	.021	.021	-1.3	2454.2	2452.3	.1	.978
2	1	10.0	.02843	.088	.089	-1.3	715.2	714.5	.1	.960
3	1	20.0	.04633	.103	.104	-1.5	797.4	794.9	.3	.930
4	1	30.0	.05928	.111	.113	-1.3	882.4	879.6	.3	.914
5	1	40.0	.06853	.116	.118	-1.2	971.1	968.1	.3	.904
6	1	50.0	.07500	.119	.121	-1.3	1059.1	1055.6	.3	.897
7	1	60.0	.07985	.121	.123	-1.2	1146.5	1142.9	.3	.893
8	6	67.5	.06086	.075	.076	-1.5	1690.0	1668.7	1.3	.615
9	6	76.5	.20156	.110	.110	-.1	563.6	562.7	.2	.400
10	6	86.5	.09094	.085	.086	-1.1	1365.8	1349.2	1.2	.547
11	6	95.0	.06166	.076	.077	-1.5	2103.8	2075.6	1.3	.612
12	6	104.5	.04379	.067	.069	-1.8	3085.6	3046.4	1.3	.670
13	6	113.5	.04573	.069	.070	-1.9	3051.9	3010.7	1.4	.662
14	6	122.5	.04780	.070	.071	-1.8	3017.7	2977.3	1.3	.655
15	5	131.5	.05736	.099	.100	-1.4	2561.1	2517.8	1.7	.511
16	5	140.5	.06001	.100	.102	-1.4	2515.1	2472.6	1.7	.502
17	4	149.5	.08955	.149	.146	1.7	1599.0	1659.4	-3.8	.285
18	4	159.0	.09409	.151	.148	1.9	1541.4	1610.6	-4.5	.277
19	4	169.0	.10166	.155	.150	2.8	1460.7	1559.5	-6.8	.268
20	4	179.0	.10892	.158	.153	3.1	1408.3	1502.8	-6.7	.259
21	4	189.0	.11593	.160	.155	3.3	1361.0	1457.2	-7.1	.250
22	5	199.0	.03793	.085	.086	-1.2	4566.0	4516.2	1.1	.598
23	5	209.0	.04005	.087	.088	-1.1	4481.1	4435.3	1.0	.588
24	5	219.0	.04197	.089	.089	-1.0	4408.6	4365.9	1.0	.578
25	5	229.0	.04329	.090	.090	-1.0	4360.2	4318.9	.9	.572
26	5	239.5	.04401	.090	.091	-1.1	4334.5	4287.1	1.1	.568
27	5	250.5	.04451	.090	.092	-1.2	4317.0	4264.6	1.2	.565
28	5	261.0	.03030	.078	.079	-1.9	6293.4	6226.7	1.1	.641
29	5	271.0	.02982	.078	.079	-2.1	6317.0	6240.2	1.2	.643
30	5	281.0	.02929	.077	.079	-2.4	6343.7	6255.0	1.4	.644
31	5	291.0	.02877	.077	.078	-2.5	6370.2	6276.6	1.5	.647
32	5	301.0	.02803	.076	.078	-2.5	6409.2	6311.1	1.5	.650
33	5	310.5	.02717	.075	.077	-2.7	6455.6	6350.5	1.6	.654
34	5	319.5	.02645	.074	.076	-2.8	6495.3	6387.9	1.7	.658
35	4	328.5	.03791	.109	.111	-2.3	4409.8	4307.2	2.3	.429
36	4	337.5	.03992	.111	.112	-.7	4310.1	4279.5	.7	.426
37	4	346.5	.04271	.114	.114	.1	4180.3	4183.7	-.1	.417
38	4	356.0	.04625	.118	.117	.4	4026.7	4046.8	-.5	.403
39	4	366.0	.04926	.121	.120	.6	3905.3	3936.2	-.6	.392
40	4	376.0	.05279	.124	.123	.9	3771.9	3820.4	-1.3	.380
41	4	386.0	.05506	.126	.125	1.1	3690.7	3749.6	-1.6	.373
42	4	396.0	.05642	.127	.126	1.2	3643.8	3708.2	-1.8	.369
43	4	406.0	.05740	.128	.126	1.3	3610.6	3679.0	-1.9	.366
44	4	416.0	.05649	.127	.126	1.2	3641.4	3705.4	-1.8	.369
45	4	426.0	.05633	.127	.126	1.1	3646.9	3706.6	-1.6	.369
46	4	436.0	.05444	.126	.124	1.1	3712.5	3767.7	-1.5	.375

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ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO TYPE DEPTH UNIFRM. <---- DAMPING ----> <---- SHEAR MODULUS -----> G/Go

		(ft)	STRAIN	NEW	USED	ERROR	NEW	USED	ERROR	RATIO
1	6	2.5	.00258	.021	.021	-.6	2455.1	2454.2	.0	.979
2	1	10.0	.02886	.087	.088	-.6	715.5	715.2	.0	.960
3	1	20.0	.04532	.102	.103	-.7	798.7	797.4	.2	.933
4	1	30.0	.05801	.110	.111	-.7	883.8	882.4	.2	.916
5	1	40.0	.06710	.115	.116	-.6	972.6	971.1	.2	.907
6	1	50.0	.07334	.119	.119	-.6	1060.9	1059.1	.2	.900
7	1	60.0	.07817	.121	.121	-.6	1148.4	1146.5	.2	.896
8	6	67.5	.05903	.075	.075	-1.0	1704.2	1690.0	.8	.623
9	6	76.5	.19771	.109	.110	-.6	568.7	563.6	.9	.407
10	6	86.5	.08846	.084	.085	-.5	1377.4	1365.6	.8	.554
11	6	95.0	.05993	.075	.076	-.9	2120.2	2102.8	.8	.620
12	6	104.5	.04264	.067	.067	-.9	3106.2	3085.6	.7	.679
13	6	113.5	.04454	.068	.068	-.9	3072.4	3051.9	.7	.671
14	6	122.5	.04656	.069	.070	-.9	3038.0	3017.7	.7	.664
15	5	131.5	.05569	.098	.098	-1.0	2591.1	2561.1	1.2	.520
16	5	140.5	.05830	.099	.100	-.9	2544.5	2515.1	1.2	.510
17	4	149.5	.09154	.150	.149	.6	1572.0	1599.0	-1.7	.275
18	4	159.0	.09802	.153	.151	1.1	1495.6	1541.4	-3.1	.265
19	4	169.0	.10835	.157	.155	1.7	1412.3	1460.7	-3.4	.251
20	4	179.0	.11601	.160	.158	1.7	1360.5	1408.3	-3.5	.242
21	4	189.0	.12386	.163	.160	1.7	1310.8	1361.0	-3.8	.234
22	5	199.0	.03744	.085	.085	-.5	4586.3	4566.0	.4	.605
23	5	209.0	.03959	.087	.087	-.4	4499.5	4481.1	.4	.594
24	5	219.0	.04148	.088	.089	-.4	4426.8	4408.6	.4	.584
25	5	229.0	.04277	.089	.090	-.4	4379.0	4360.2	.4	.578
26	5	239.5	.04338	.090	.090	-.5	4356.8	4334.5	.5	.574
27	5	250.5	.04376	.090	.090	-.6	4343.5	4317.0	.6	.572
28	5	261.0	.02980	.078	.078	-.7	6318.3	6293.4	.4	.648
29	5	271.0	.02924	.077	.078	-.7	6346.5	6317.0	.5	.651
30	5	281.0	.02858	.076	.077	-.9	6380.0	6343.7	.6	.654
31	5	291.0	.02802	.076	.077	-1.0	6409.5	6370.2	.6	.656
32	5	301.0	.02725	.075	.076	-1.1	6451.3	6409.2	.7	.660
33	5	310.5	.02635	.074	.075	-1.2	6500.9	6455.6	.7	.665
34	5	319.5	.02562	.073	.074	-1.3	6543.2	6495.3	.7	.669
35	4	328.5	.03856	.107	.108	-1.8	4478.8	4409.8	1.5	.436
36	4	337.5	.03525	.110	.111	-.7	4343.0	4310.1	.6	.429
37	4	346.5	.04242	.114	.114	-.1	4193.1	4180.3	.3	.416
38	4	356.0	.04620	.118	.118	.0	4029.0	4026.7	.1	.401
39	4	366.0	.04944	.121	.121	.1	3898.3	3905.3	-.2	.389
40	4	376.0	.05331	.125	.124	.4	3753.1	3771.9	-.5	.376
41	4	386.0	.05582	.127	.126	.5	3664.4	3690.7	-.7	.367
42	4	396.0	.05737	.128	.127	.6	3611.5	3643.8	-.9	.363
43	4	406.0	.05845	.129	.128	.7	3575.5	3610.6	-1.0	.356
44	4	416.0	.05752	.128	.127	.7	3606.5	3641.4	-1.0	.363
45	4	426.0	.05725	.128	.127	.6	3615.5	3646.9	-.9	.363
46	4	436.0	.05532	.126	.126	.6	3681.7	3712.5	-.8	.370

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ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	EPROF	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00256	.021	.021	-.3	2455.1	2455.1	.0	.979
2	1	10.0	.02856	.087	.087	-.3	715.6	715.5	.0	.961
3	1	20.0	.04480	.102	.102	-.4	799.3	798.7	.1	.935
4	1	30.0	.05734	.110	.110	-.4	884.6	883.8	.1	.918
5	1	40.0	.06633	.115	.115	-.3	973.4	972.6	.1	.908
6	1	50.0	.07246	.118	.119	-.4	1061.9	1060.9	.1	.902
7	1	60.0	.07725	.120	.121	-.3	1149.4	1148.4	.1	.898
8	6	67.5	.05796	.074	.075	-.6	1712.6	1704.2	.5	.628
9	6	76.5	.19410	.108	.109	-.5	573.5	564.7	.8	.410
10	6	86.5	.08697	.084	.084	-.5	1384.5	1377.4	.5	.559
11	6	95.0	.05902	.075	.075	-.5	2129.1	2124.2	.4	.625

12	6	104.5	.04207	.067	.067	-.5	3116.6	3106.2	.3	.683
13	6	113.5	.04397	.068	.068	-.5	3082.4	3072.4	.3	.676
14	6	122.5	.04597	.069	.069	-.4	3047.9	3038.0	.3	.668
15	5	131.5	.05476	.097	.098	-.6	2608.3	2591.1	.7	.526
16	5	140.5	.05732	.099	.099	-.6	2561.7	2544.5	.7	.516
17	4	149.5	.09255	.150	.150	.3	1559.7	1572.0	-.8	.270
18	4	159.0	.10090	.154	.153	.9	1466.4	1495.6	-2.0	.257
19	4	169.0	.11203	.159	.157	.9	1387.0	1412.3	-1.8	.243
20	4	179.0	.12011	.162	.160	.9	1334.1	1360.5	-2.0	.234
21	4	189.0	.12856	.165	.163	1.0	1282.5	1310.8	-2.2	.225
22	5	199.0	.03727	.085	.085	-.2	4593.3	4586.3	.2	.608
23	5	209.0	.03943	.087	.087	-.1	4505.6	4499.5	.1	.596
24	5	219.0	.04130	.088	.088	-.2	4433.4	4426.8	.1	.586
25	5	229.0	.04256	.089	.089	-.2	4386.5	4379.0	.2	.580
26	5	239.5	.04312	.089	.090	-.2	4366.2	4356.8	.2	.577
27	5	250.5	.04342	.090	.090	-.3	4355.6	4343.5	.3	.575
28	5	261.0	.02961	.077	.078	-.2	6327.6	6318.3	.1	.651
29	5	271.0	.02901	.077	.077	-.3	6358.0	6346.5	.2	.654
30	5	281.0	.02829	.076	.076	-.4	6395.3	6380.0	.2	.657
31	5	291.0	.02770	.075	.076	-.4	6426.6	6409.5	.3	.660
32	5	301.0	.02690	.075	.075	-.5	6470.0	6451.3	.3	.665
33	5	310.5	.02599	.074	.074	-.5	6521.2	6500.9	.3	.670
34	5	319.5	.02523	.073	.073	-.6	6565.5	6543.2	.3	.674
35	4	328.5	.03576	.106	.107	-1.0	4522.1	4478.8	1.0	.446
36	4	337.5	.03873	.110	.110	-.6	4360.4	4343.0	.6	.432
37	4	346.5	.04214	.114	.114	-.3	4206.1	4193.1	.3	.417
38	4	356.0	.04603	.118	.118	-.1	4035.7	4029.0	.2	.401
39	4	366.0	.04945	.121	.121	.0	3897.7	3898.3	.0	.388
40	4	376.0	.05353	.125	.125	.2	3745.0	3753.1	-.2	.374
41	4	386.0	.05620	.127	.127	.3	3651.3	3664.4	-.4	.365
42	4	396.0	.05792	.128	.128	.3	3593.2	3611.5	-.5	.360
43	4	406.0	.05907	.129	.129	.4	3555.2	3575.5	-.6	.356
44	4	416.0	.05816	.129	.128	.4	3585.1	3606.5	-.6	.359
45	4	426.0	.05782	.128	.128	.4	3596.4	3615.5	-.5	.360
46	4	436.0	.05589	.127	.126	.4	3661.9	3681.7	-.5	.367

E-25

ACCELEROGRAM - riodl-h:.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING NEW	USED	----> ERROR	<---- SHEAR MODULUS NEW	USED	----> ERROR	G/Go RATIO
1	6	2.5	.00254	.021	.021	-.2	2456.0	2455.7	.0	.980
2	1	10.0	.02840	.087	.087	-.2	715.7	715.6	.0	.961
3	1	20.0	.04451	.101	.102	-.2	799.7	799.3	.0	.935
4	1	30.0	.05697	.110	.110	-.2	885.0	884.6	.0	.919
5	1	40.0	.06590	.115	.115	-.2	973.9	973.4	.0	.909
6	1	50.0	.07198	.118	.118	-.2	1062.4	1061.9	.0	.903
7	1	60.0	.07673	.120	.120	-.2	1150.0	1149.4	.1	.898
8	6	67.5	.05734	.074	.074	-.3	1717.5	1712.6	.3	.631
9	6	76.5	.19142	.108	.108	-.4	577.1	573.5	.6	.414
10	6	86.5	.08611	.084	.084	-.3	1388.7	1384.5	.3	.562
11	6	95.0	.05853	.074	.075	-.3	2133.9	2129.1	.2	.628
12	6	104.5	.04177	.066	.067	-.2	3122.1	3116.6	.2	.685
13	6	113.5	.04368	.067	.068	-.2	3087.5	3082.4	.2	.678
14	6	122.5	.04567	.069	.069	-.2	3052.9	3047.9	.2	.670
15	5	131.5	.05425	.097	.097	-.3	2617.7	2608.3	.4	.529
16	5	140.5	.05679	.098	.099	-.3	2571.3	2561.7	.4	.520
17	4	149.5	.09301	.151	.150	.2	1554.2	1559.7	-.4	.268
18	4	159.0	.10288	.155	.154	.5	1451.6	1466.4	-1.0	.252
19	4	169.0	.11407	.160	.159	.5	1373.3	1387.0	-1.0	.238
20	4	179.0	.12252	.163	.162	.5	1319.1	1334.1	-1.1	.229
21	4	189.0	.13141	.165	.165	.6	1265.9	1282.5	-1.3	.220
22	5	199.0	.03722	.085	.085	.0	4595.2	4593.3	.0	.609
23	5	209.0	.03939	.087	.087	.0	4507.2	4505.6	.0	.597
24	5	219.0	.04125	.088	.088	.0	4435.4	4433.4	.0	.587

25	5	229.0	.04249	.089	.089	-.1	4389.1	4366.5	.1	.581
26	5	239.5	.04302	.089	.089	-.1	4369.9	4366.2	.1	.578
27	5	250.5	.04327	.090	.090	-.1	4360.9	4355.6	.1	.577
28	5	261.0	.02954	.077	.077	-.1	6331.3	6327.6	.1	.652
29	5	271.0	.02892	.077	.077	-.1	6362.8	6358.0	.1	.655
30	5	281.0	.02816	.076	.076	-.2	6402.4	6395.3	.1	.659
31	5	291.0	.02755	.075	.075	-.2	6434.6	6426.6	.1	.662
32	5	301.0	.02674	.074	.075	-.2	6479.0	6470.0	.1	.667
33	5	310.5	.02582	.073	.074	-.3	6531.1	6521.2	.2	.672
34	5	319.5	.02504	.073	.073	-.3	6576.6	6565.5	.2	.676
35	4	328.5	.03528	.105	.106	-.6	4548.3	4522.1	.6	.450
36	4	337.5	.03838	.109	.110	-.4	4386.0	4368.4	.4	.435
37	4	346.5	.04192	.113	.114	-.2	4216.0	4206.1	.2	.419
38	4	356.0	.04589	.118	.118	-.1	4041.9	4035.7	.2	.402
39	4	366.0	.04943	.121	.121	.0	3898.6	3897.7	.0	.388
40	4	376.0	.05363	.125	.125	.1	3741.3	3745.0	-.1	.373
41	4	386.0	.05641	.127	.127	.1	3644.1	3651.3	-.2	.364
42	4	396.0	.05825	.129	.128	.2	3582.2	3593.2	-.3	.358
43	4	406.0	.05946	.130	.129	.2	3542.7	3555.2	-.4	.354
44	4	416.0	.05858	.129	.129	.3	3571.3	3585.1	-.4	.357
45	4	426.0	.05819	.129	.128	.2	3584.1	3596.4	-.3	.358
46	4	436.0	.05628	.127	.127	.3	3648.6	3661.9	-.4	.365

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN (%)	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	5.0	2.5	.00385	94.59	.31529	6.02
2	1	10.0	10.0	.04303	307.95	.31764	6.02
3	1	10.0	20.0	.06744	539.10	.31162	6.02
4	1	10.0	30.0	.08632	763.56	.30198	6.02
5	1	10.0	40.0	.09985	972.02	.28959	6.02
6	1	10.0	50.0	.10907	1158.16	.27533	6.02
7	1	10.0	60.0	.11626	1336.30	.26349	6.00
8	6	5.0	67.5	.08689	1487.99	.25514	5.98
9	6	13.0	76.5	.29003	1663.21	.23886	5.98
10	6	7.0	86.5	.13047	1806.43	.22032	5.98
11	6	10.0	95.0	.06863	1887.97	.20428	5.98
12	6	9.0	104.5	.06328	1972.35	.18980	5.96
13	6	9.0	113.5	.06618	2040.02	.17769	5.96
14	6	9.0	122.5	.06920	2109.28	.16781	5.94
15	5	9.0	131.5	.08220	2144.04	.15703	5.96
16	5	9.0	140.5	.08604	2204.07	.14959	5.94
17	4	9.0	149.5	.14092	2197.83	.13898	5.96
18	4	10.0	159.0	.15588	2285.66	.13483	6.10
19	4	10.0	169.0	.17283	2397.13	.13204	6.08
20	4	10.0	179.0	.18563	2476.56	.12796	6.08
21	4	10.0	189.0	.19910	2553.50	.12423	6.06
22	5	10.0	199.0	.05640	2590.65	.11898	6.04
23	5	10.0	209.0	.05968	2689.05	.11684	6.02
24	5	10.0	219.0	.06250	2770.85	.11424	6.02
25	5	10.0	229.0	.06439	2824.30	.11078	6.02
26	5	11.0	239.5	.06518	2846.14	.10621	6.02
27	5	11.0	250.5	.06556	2855.58	.10141	6.00
28	5	10.0	261.0	.04475	2831.91	.09609	6.00
29	5	10.0	271.0	.04382	2785.78	.09065	6.00
30	5	10.0	281.0	.04266	2728.41	.08528	5.98
31	5	10.0	291.0	.04175	2682.83	.08068	5.98
32	5	10.0	301.0	.04052	2621.56	.07596	5.98
33	5	9.0	310.5	.03912	2551.21	.07144	5.98
34	5	9.0	319.5	.03794	2490.97	.06781	5.96
35	4	9.0	328.5	.05346	2417.38	.06336	5.38
36	4	9.0	337.5	.05815	2540.45	.06409	5.38
37	4	9.0	346.5	.06352	2671.70	.06497	5.36
38	4	10.0	356.0	.06953	2805.84	.06573	5.36
39	4	10.0	366.0	.07489	2919.13	.06594	5.34
40	4	10.0	376.0	.08126	3043.39	.06617	5.34
41	4	10.0	386.0	.08547	3120.72	.06551	5.34
42	4	10.0	396.0	.08826	3171.41	.06434	5.32
43	4	10.0	406.0	.09009	3202.82	.06287	5.32

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44	4	10.0	416.0	.08876	3182.21	.06051	5.30
45	4	10.0	426.0	.08817	3171.06	.05846	5.30
46	4	19.0	436.0	.08577	3122.47	.05587	5.28

PERIOD = 2.021 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 871.7 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 6.36
FOR FREQUENCY (f) = .57 c/sec
FOR PERIOD (1 / f) = 1.74 sec

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM = riodl-hz.sar
D E F O S I T = Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	.0	.21306	6.02	1.61	.000	0
WITHIN	5.0	.31231	6.02	1.60	.000	0
WITHIN	15.0	.25970	6.00	1.43	.000	0
WITHIN	25.0	.28172	6.00	1.26	.000	0
WITHIN	35.0	.26549	5.98	1.18	.000	0
WITHIN	45.0	.25540	5.96	1.21	.000	0
WITHIN	55.0	.23961	5.94	1.31	.000	0
WITHIN	65.0	.22081	5.94	1.42	.000	0
WITHIN	76.0	.21153	5.94	1.43	.000	0
WITHIN	83.0	.18905	5.98	1.56	.000	0
WITHIN	90.0	.18502	5.86	1.60	.000	0
WITHIN	100.0	.16187	5.88	1.58	.000	0
WITHIN	108.0	.15580	5.86	1.55	.000	0
WITHIN	118.0	.14692	5.84	1.51	.000	0
WITHIN	127.0	.13712	5.84	1.49	.000	0

****** OPTION 6 *** COMPUTE MOTION IN NEW SUBLAYERS

ACCELEROGRAM = riodl-hz.sar
D E F O S I T = Paducah U Landfill - free-field prof

LAYER	DEPTH (ft)	MAX. ACC. (g)	TIME (sec)	MN.SQ.FR. (c/sec)	ACC. RATIO QUIET ZONE	TH SAVED ACC.REC.
WITHIN	136.0	.12269	5.84	1.51	.000	0
WITHIN	441.0	.19012	5.50	3.97	.000	0
OUTCR.	441.0	.21280	5.50	4.00	.000	0

****** OPTION 7 *** COMPUTE STRESS/STRAIN HISTORY

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 8
SCALE FOR PLOTTING .0000
IDENTIFICATION = -- stress in layer 8

COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF LAYER 8
SCALE FOR PLOTTING .0000
IDENTIFICATION = -- strain in layer 8

```
*********************************************************
* SHAKE  --   A COMPUTER PROGRAM FOR EARTHQUAKE RESPONSE  *
*             ANALYSIS OF HORIZONTALLY LAYERED SITES      *
*             by: Per B. Schnabel & John Lysmer -- 1970   *
* ----------------------------------------------------- *
* Shake85   : IBM-PC version of SHAKE                     *
*             by: S.S. (Willie) Lai, January 1985         *
* ----------------------------------------------------- *
* Shake88   : New modulus reduction curves for clays      *
*             added using results from Sun et al. (1988)  *
*             by: J. I. Sun & Ramin Golesorkhi            *
*             February 26, 1988                           *
* ----------------------------------------------------- *
* Shake90/91: Adjust last iteration; Input now is either  *
*             Gmax or max Vs; up to 13 material types can *
*             be specified by user; up to 50 Layers can   *
*             be specified; object motion can be read in  *
*             from a separate file and can have user      *
*             specified format; Different periods for     *
*             response spectral calculations; options     *
*             are renumbered; and general cleanup         *
*             by: J. I. Sun, I. M. Idriss & P. Dirrim     *
*             June 1980 - February 1991                   *
* ----------------------------------------------------- *
* Shake91   : General cleanup and finalization of input / *
*             output format ... etc                       *
*             by: I. M. Idriss                            *
*             December 1991                               *
* ----------------------------------------------------- *
* Shake98   : Routine for direct calculation of average   *
*             acceleration is added to the program. Out-  *
*             put format is modified to enable the two -  *
*             - page landscape printing.  The following   *
*             modulus reduction and  damping curves are   *
*             added:  Matasovic & Kavazanjian (1998) for  *
*             municipal solid waste; Matasovic & Vucetic  *
*             (1993) for SMB sand; and Vucetic and Dobry  *
*             (1991) for clays of various plasticities.   *
*             by: Neven Matasovic                         *
*             August 1993 - May 1998                      *
*********************************************************

MAX. NUMBER OF TERMS IN FOURIER TRANSFORM  =      4096
NECESSARY LENGTH OF BLANK COMMON X         =     25619

******   OPTION  1  ***  READ RELATION BETWEEN SOIL PROPERTIES AND STRAIN

********************
 MATERIAL TYPE NO. 1
********************

CURVE NO.  1:      #1 Modulus for OII Waste (Matasovic & Kavazanjian, 1998
CURVE NO.  2:      #1 Damping for OII Waste (Matasovic & Kavazanjian, 1998
```

CURVE NO. 1		CURVE NO. 2	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	1.13
.0003	1.000	.0003	1.77
.0010	1.000	.0010	2.58
.0032	.994	.0032	4.03
.0100	.983	.0100	5.89
.0316	.959	.0316	8.97
.1000	.881	.1000	12.91
.3160	.655	.3160	17.63
1.0000	.316	1.0000	21.92
3.1600	.130	3.1600	25.17


```
********************
 MATERIAL TYPE NO. 4
********************

CURVE NO.  7:    #4 Modulus for Sand (PI=0) (Vucetic and Dobry, 1991)
CURVE NO.  8:    #4 Damping for Sand (PI=0) (Vucetic and Dobry, 1991)
```

CURVE NO. 7		CURVE NO. 8	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	1.04
.0010	.964	.0010	1.66
.0032	.870	.0032	3.00
.0100	.712	.0100	5.48
.0316	.474	.0316	10.01
.1000	.253	.1000	15.40
.3160	.103	.3160	20.23
1.0000	.028	1.0000	23.94
3.1600	.004	.0000	.00

```
********************
 MATERIAL TYPE NO. 5
********************

CURVE NO.  9:      #5 Modulus for CL (PI=15) (Vucetic and Dobry, 1991)
CURVE NO. 10:      #5 Damping for CL (PI=15) (Vucetic and Dobry, 1991)
```

CURVE NO. 9		CURVE NO.10	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	2.58
.0003	1.000	.0003	2.58
.0010	.995	.0010	2.58
.0030	.936	.0030	2.58
.0100	.828	.0100	4.64
.0320	.640	.0300	7.77
.1000	.405	.1000	11.67
.3160	.210	.3000	16.08
1.0000	.095	1.0000	20.12
3.1600	.034	.0000	.00

```
********************
 MATERIAL TYPE NO. 6
********************

CURVE NO. 11:      #6 Modulus for C  (PI=30) (Vucetic and Dobry, 1991)
CURVE NO. 12:      #6 Damping for C  (PI=30) (Vucetic and Dobry, 1991)
```

CURVE NO.11		CURVE NO.12	
STRAIN	G/Gmax	STRAIN	DAMPING
.0001	1.000	.0001	.85
.0003	1.000	.0003	.85
.0010	1.000	.0010	1.36
.0030	.976	.0030	2.18
.0100	.901	.0100	3.82
.0300	.743	.0320	6.00
.1000	.538	.1000	8.72
.3000	.332	.3160	12.41
1.0000	.158	1.0000	16.90
3.0000	.048	3.1600	21.26

```
******   OPTION  2  ***  READ SOIL / WASTE PROFILE
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SOIL PROFILE NO. 1 Paducah U Landfill - fee-field prof

NUMBER OF LAYERS 47
DEPTH TO BEDROCK 441.0

NO.	TYPE	THICKNESS (ft)	DEPTH (ft)	TOT. PRESS. (psf)	MODULUS (ksf)	DAMPING (%)	UNIT WT. (pcf)	SH. VEL. (fps)
1	6	5.00	2.50	300.00	2507.	5.00	120.00	820.2
2	1	10.00	10.00	969.50	745.	5.00	73.90	569.6
3	1	10.00	20.00	1730.00	855.	5.00	78.20	593.2
4	1	10.00	30.00	2528.50	963.	5.00	81.50	616.8
5	1	10.00	40.00	3356.50	1071.	5.00	84.10	640.4
6	1	10.00	50.00	4206.50	1176.	5.00	85.90	664.0
7	1	10.00	60.00	5071.50	1279.	5.00	87.10	687.7
8	6	5.00	67.50	5832.00	2715.	5.00	130.00	820.0
9	6	11.00	76.50	6963.00	1366.	5.00	124.00	600.0
10	6	7.00	86.50	8203.00	2465.	5.00	124.00	800.0
11	6	10.00	95.00	9242.00	3391.	5.00	121.00	950.0
12	6	9.00	104.50	10391.50	4547.	5.00	121.00	1100.0
13	6	9.00	113.50	11489.50	4547.	5.00	121.00	1100.0
14	6	9.00	122.50	12569.50	4547.	5.00	121.00	1100.0
15	5	9.00	131.50	13654.00	4929.	5.00	120.00	1150.0
16	5	9.00	140.50	14734.00	4929.	5.00	120.00	1150.0
17	4	9.00	149.50	15814.00	5823.	5.00	120.00	1250.0
18	4	10.00	159.00	16954.00	5823.	5.00	120.00	1250.0
19	4	10.00	169.00	18154.00	5823.	5.00	120.00	1250.0
20	4	10.00	179.00	19354.00	5823.	5.00	120.00	1250.0
21	4	10.00	189.00	20554.00	5823.	5.00	120.00	1250.0
22	5	10.00	199.00	21774.00	7548.	5.00	124.00	1400.0
23	5	10.00	209.00	23014.00	7548.	5.00	124.00	1400.0
24	5	10.00	219.00	24254.00	7548.	5.00	124.00	1400.0
25	5	10.00	229.00	25494.00	7548.	5.00	124.00	1400.0
26	5	11.00	239.50	26796.00	7548.	5.00	124.00	1400.0
27	5	11.00	250.50	28160.00	7548.	5.00	124.00	1400.0
28	5	10.00	261.00	29472.00	9707.	5.00	126.00	1575.0
29	5	10.00	271.00	30732.00	9707.	5.00	126.00	1575.0
30	5	10.00	281.00	31992.00	9707.	5.00	126.00	1575.0
31	5	10.00	291.00	33252.00	9707.	5.00	126.00	1575.0
32	5	10.00	301.00	34512.00	9707.	5.00	126.00	1575.0
33	5	9.00	310.50	35709.00	9707.	5.00	126.00	1575.0
34	5	9.00	319.50	36843.00	9707.	5.00	126.00	1575.0
35	4	9.00	328.50	38152.50	10043.	5.00	165.00	1400.0
36	4	9.00	337.50	39637.50	10043.	5.00	165.00	1400.0
37	4	9.00	346.50	41122.50	10043.	5.00	165.00	1400.0
38	4	10.00	356.00	42690.00	10043.	5.00	165.00	1400.0
39	4	10.00	366.00	44340.00	10043.	5.00	165.00	1400.0
40	4	10.00	376.00	45990.00	10043.	5.00	165.00	1400.0
41	4	10.00	386.00	47640.00	10043.	5.00	165.00	1400.0
42	4	10.00	396.00	49290.00	10043.	5.00	165.00	1400.0
43	4	10.00	406.00	50940.01	10043.	5.00	165.00	1400.0
44	4	10.00	416.00	52590.01	10043.	5.00	165.00	1400.0
45	4	10.00	426.00	54240.01	10043.	5.00	165.00	1400.0
46	4	10.00	436.00	55890.01	10043.	5.00	165.00	1400.0
47	BASE				415062.	5.00	165.00	9000.0

PERIOD = 1.446 sec FROM AVERAGE SHEAR WAVE VELOCITY OF 1220.3 ft/sec

FREQUENCY AMPLITUDE:
MAXIMUM AMPLIFICATION = 16.07
FOR FREQUENCY (f) = .87 c/sec
FOR PERIOD (1 / f) = 1.15 sec

****** OPTION 3 *** READ INPUT MOTION

FILE NAME FOR INPUT MOTION = tabas.sar
NO. OF INPUT ACCEL. POINTS = 2904
NO. OF POINTS USED IN FFT = 4096
NO. OF HEADING LINES = 5
NO. OF POINTS PER LINE = 8
TIME STEP FOR INPUT MOTION = .0100

FORMAT FOR OF TIME HISTORY = (8F9.6)

***** A C C E L E R O G R A M H E A D E R *****

Tabas Accelerogram; Tabas-e-Golshan, Iran Eq. Of 09-16-1978; Mw = 7.39
Epic. Dist. = 3 km; Thrust Fault
1-Story Building; Rock ; Predom. Period = 0.1540 sec; Ds = 16.3 s
Uncorr. Max. Acc. = 0.78516 g; Max. in file = 0.811560 g; To = 0.1540 s
363*8=2904 pts. @ 0.01 sec

** FIRST & LAST 5 LINES OF INPUT MOTION *****

1	-.005890	-.010260	-.010540	-.009570	-.007780	-.005880	-.004440	-.003040
2	-.002460	-.003650	-.006020	-.008090	-.009720	-.011810	-.014020	-.014980
3	-.014750	-.014370	-.013550	-.011130	-.007750	-.005320	-.004000	-.002460
4	-.000930	-.001030	-.002500	-.003290	-.003020	-.003440	-.005170	-.006860
5	-.007910	-.009080	-.010120	-.009670	-.007840	-.006180	-.004950	-.003170

..... INPUT MOTION READ NOT ECHOED.....

359	-.008320	-.000200	.010240	.016040	.015310	.012190	.010050	.006790
360	-.000560	-.010860	-.022440	-.036560	-.051930	-.060490	-.055670	-.042240
361	-.030870	-.024900	-.019760	-.013470	-.009080	-.006700	-.002250	.003530
362	.002460	-.010120	-.027280	-.037640	-.017170	-.030500	-.023900	-.020440
363	-.019670	-.018510	-.013770	-.011960	.000000	.000000	.000000	.000000

MAXIMUM ACCELERATION = .811560
AT TIME = 10.95 sec

THE VALUES WILL BE MULTIPLIED BY A FACTOR = .44359020
TO GIVE NEW MAXIMUM ACCELERATION = .36000000

MEAN SQUARE FREQUENCY = 3.94 c/sec
MAXIMUM ACCELERATION = .359997 FOR FREQUENCIES REMOVED ABOVE 25.00 c/sec

****** OPTION 4 *** READ WHERE OBJECT MOTION IS GIVEN

OBJECT MOTION IN LAYER NUMBER 39 OUTCROPPING

****** OPTION 5 *** OBTAIN STRAIN COMPATIBLE SOIL PROPERTIES

MAXIMUM NUMBER OF ITERATIONS = 7
FACTOR FOR UNIFORM STRAIN IN TIME DOMAIN = .66

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 1

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00462	.028	.050	-80.6	2379.3	2507.1	-5.4	1.000
2	1	10.0	.04953	.105	.050	52.4	681.4	744.6	-7.7	1.000
3	1	20.0	.07165	.118	.050	57.5	772.2	854.6	-10.7	1.000
4	1	30.0	.08305	.123	.050	59.3	860.4	962.9	-11.9	1.000
5	1	40.0	.08670	.124	.050	59.8	954.0	1071.1	-12.3	1.000
6	1	50.0	.08690	.124	.050	59.8	1047.4	1176.2	-12.3	1.000
7	1	60.0	.08480	.123	.050	59.5	1141.3	1279.3	-12.1	1.000
8	6	67.5	.04179	.066	.050	34.7	1863.8	2714.7	-45.7	1.000
9	6	76.5	.08651	.084	.050	40.3	780.1	1386.3	-77.7	1.000
10	6	86.5	.04960	.070	.050	29.1	1620.2	2464.2	-52.1	1.000
11	6	95.0	.03530	.062	.050	19.8	2425.8	3391.4	-38.9	1.000
12	6	104.5	.02802	.058	.050	13.1	3422.9	4546.9	-32.8	1.000
13	6	113.5	.02916	.058	.050	14.2	3397.0	4546.9	-33.9	1.000
14	6	122.5	.02993	.059	.050	14.9	3379.8	4546.9	-34.5	1.000
15	5	131.5	.02873	.076	.050	34.6	3235.6	4928.6	-52.3	1.000
16	5	140.5	.03067	.078	.050	36.2	3186.4	4928.6	-54.7	1.000
17	4	149.5	.02869	.096	.050	46.1	2876.3	5623.0	-102.4	1.000
18	4	159.0	.03135	.100	.050	49.9	2769.7	5623.0	-110.2	1.000

19	4	169.0	.03383	.103	.050	51.6	2684.0	5823.0	-117.0	1.000
20	4	179.0	.03600	.106	.050	52.9	2614.3	5823.0	-122.7	1.000
21	4	189.0	.03814	.109	.050	54.1	2550.0	5823.0	-128.4	1.000
22	5	199.0	.03113	.079	.050	36.6	4862.6	7547.8	-55.2	1.000
23	5	209.0	.03251	.081	.050	38.0	4786.8	7547.8	-57.7	1.000
24	5	219.0	.03468	.082	.050	39.3	4705.3	7547.8	-60.4	1.000
25	5	229.0	.03647	.084	.050	40.5	4627.2	7547.8	-63.1	1.000
26	5	239.5	.03830	.086	.050	41.6	4550.8	7547.8	-65.9	1.000
27	5	250.5	.04002	.087	.050	42.6	4482.6	7547.8	-68.4	1.000
28	5	261.0	.03229	.080	.050	37.6	6194.1	9706.8	-56.7	1.000
29	5	271.0	.03324	.081	.050	38.3	6136.4	9706.8	-58.2	1.000
30	5	281.0	.03395	.082	.050	38.8	6094.0	9706.8	-59.3	1.000
31	5	291.0	.03455	.082	.050	39.2	6058.8	9706.8	-60.2	1.000
32	5	301.0	.03495	.083	.050	39.5	6036.0	9706.8	-60.8	1.000
33	5	310.5	.03509	.083	.050	39.6	6028.0	9706.8	-61.0	1.000
34	5	319.5	.03502	.083	.050	39.6	6031.7	9706.8	-60.9	1.000
35	4	328.5	.03364	.103	.050	51.5	4639.9	10043.5	-116.5	1.000
36	4	337.5	.03325	.102	.050	51.2	4662.3	10043.5	-115.4	1.000
37	4	346.5	.03271	.102	.050	50.8	4694.3	10043.5	-113.9	1.000
38	4	356.0	.03266	.102	.050	50.8	4696.9	10043.5	-113.8	1.000
39	4	366.0	.03416	.104	.050	51.8	4610.6	10043.5	-117.8	1.000
40	4	376.0	.03547	.106	.050	52.6	4538.1	10043.5	-121.3	1.000
41	4	386.0	.03659	.107	.050	53.3	4478.2	10043.5	-124.3	1.000
42	4	396.0	.03755	.108	.050	53.8	4428.3	10043.5	-126.8	1.000
43	4	406.0	.03829	.109	.050	54.2	4390.7	10043.5	-128.7	1.000
44	4	416.0	.03911	.110	.050	54.6	4350.0	10043.5	-130.9	1.000
45	4	426.0	.03990	.111	.050	55.0	4311.1	10043.5	-133.0	1.000
46	4	436.0	.04052	.112	.050	55.2	4281.7	10043.5	-134.6	1.000

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 2

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00266	.021	.029	-32.4	2453.4	2379.3	3.0	.949
2	1	10.0	.02920	.088	.105	-20.0	715.3	691.4	3.3	.929
3	1	20.0	.04398	.101	.118	-16.5	800.4	772.2	3.5	.904
4	1	30.0	.05293	.107	.123	-14.4	889.8	860.4	3.3	.894
5	1	40.0	.05715	.110	.124	-13.0	984.2	954.0	3.1	.891
6	1	50.0	.05837	.111	.124	-12.3	1079.1	1047.4	2.9	.891
7	1	60.0	.05746	.110	.123	-12.1	1175.0	1141.3	2.9	.892
8	6	67.5	.03607	.063	.066	-5.6	1931.9	1863.8	3.5	.687
9	6	76.5	.08874	.084	.084	.7	774.0	780.1	-.8	.563
10	6	86.5	.04620	.069	.070	-2.5	1650.0	1620.2	1.8	.657
11	6	95.0	.03276	.061	.063	-3.0	2469.0	2425.8	1.8	.715
12	6	104.5	.02688	.057	.058	-1.4	3450.2	3422.9	.8	.753
13	6	113.5	.03066	.059	.058	1.6	3361.6	3397.0	-1.1	.747
14	6	122.5	.03432	.062	.059	4.7	3274.2	3379.8	-3.2	.743
15	5	131.5	.03936	.086	.076	11.6	2943.8	3235.6	-9.9	.657
16	5	140.5	.04310	.089	.078	12.3	2851.7	3186.4	-11.7	.647
17	4	149.5	.05089	.122	.096	21.3	2227.7	2876.3	-29.1	.494
18	4	159.0	.05576	.127	.100	21.2	2125.7	2769.7	-30.3	.476
19	4	169.0	.06025	.130	.103	20.7	2039.3	2684.0	-31.6	.461
20	4	179.0	.06420	.133	.106	20.3	1968.3	2614.3	-32.8	.449
21	4	189.0	.06776	.136	.109	19.8	1906.1	2550.0	-33.6	.438
22	5	199.0	.03656	.084	.079	6.2	4623.1	4862.6	-5.2	.644
23	5	209.0	.03795	.085	.081	5.4	4565.2	4786.8	-4.9	.634
24	5	219.0	.03929	.086	.082	4.7	4511.3	4705.3	-4.3	.623
25	5	229.0	.04031	.087	.084	3.7	4471.2	4627.2	-3.5	.613
26	5	239.5	.04167	.088	.086	3.1	4419.5	4550.8	-3.0	.603
27	5	250.5	.04400	.090	.087	2.4	4334.8	4482.6	-3.4	.594
28	5	261.0	.03271	.081	.080	.5	6168.2	6194.1	-.4	.638
29	5	271.0	.03395	.082	.081	.8	6093.7	6136.4	-.7	.632
30	5	281.0	.03509	.083	.082	1.3	6027.9	6094.0	-1.1	.628
31	5	291.0	.03613	.084	.082	1.7	5969.3	6058.8	-1.5	.624

32	5	301.0	.03710	.085	.083	2.3	5916.4	6036.0	-2.0	.622
33	5	310.5	.03785	.085	.083	2.9	5876.1	6028.0	-2.6	.621
34	5	319.5	.03848	.086	.083	3.6	5843.0	6031.7	-3.2	.621
35	4	328.5	.05132	.123	.103	16.1	3826.2	4639.9	-21.3	.462
36	4	337.5	.05174	.123	.102	16.8	3810.5	4662.3	-22.4	.464
37	4	346.5	.05177	.123	.102	17.4	3809.5	4694.3	-23.2	.467
38	4	356.0	.05176	.123	.102	17.5	3809.7	4696.9	-23.3	.468
39	4	366.0	.05237	.124	.104	16.2	3787.4	4610.6	-21.7	.459
40	4	376.0	.05261	.124	.106	14.9	3778.5	4538.1	-20.1	.452
41	4	386.0	.05256	.124	.107	13.7	3780.1	4478.2	-18.5	.446
42	4	396.0	.05242	.124	.108	12.6	3785.3	4428.3	-17.0	.441
43	4	406.0	.05223	.124	.109	11.8	3792.4	4390.7	-15.8	.437
44	4	416.0	.05226	.124	.110	11.0	3791.4	4350.0	-14.7	.433
45	4	426.0	.05258	.124	.111	10.4	3779.5	4311.1	-14.1	.429
46	4	436.0	.05398	.125	.112	10.7	3729.1	4281.7	-14.8	.426

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 3

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00324	.020	.021	-6.6	2462.9	2453.4	.4	.979
2	1	10.0	.02442	.083	.088	-5.8	718.1	715.3	.4	.961
3	1	20.0	.03692	.095	.101	-6.2	810.5	800.4	1.1	.937
4	1	30.0	.04468	.102	.107	-5.7	900.9	889.8	1.2	.924
5	1	40.0	.04852	.104	.110	-5.4	996.1	984.2	1.2	.919
6	1	50.0	.04978	.105	.111	-5.2	1091.8	1079.1	1.2	.917
7	1	60.0	.04923	.105	.110	-5.0	1188.4	1175.0	1.1	.919
8	6	67.5	.03080	.059	.063	-6.0	2004.8	1931.9	3.6	.712
9	6	76.5	.07926	.082	.084	-3.3	800.7	774.0	3.3	.558
10	6	86.5	.04009	.065	.069	-5.2	1709.5	1650.0	3.5	.669
11	6	95.0	.02962	.059	.061	-3.4	2526.0	2469.0	2.3	.728
12	6	104.5	.02452	.055	.057	-3.1	3510.1	3450.2	1.7	.759
13	6	113.5	.02856	.058	.059	-2.3	3410.6	3361.6	1.4	.739
14	6	122.5	.03268	.060	.062	-1.9	3312.2	3274.2	1.1	.720
15	5	131.5	.03998	.087	.086	.6	2928.1	2943.8	-.5	.597
16	5	140.5	.04451	.090	.089	1.2	2818.8	2851.7	-1.2	.579
17	4	149.5	.06055	.131	.122	6.2	2033.7	2227.7	-9.5	.383
18	4	159.0	.06665	.135	.127	6.2	1926.4	2125.7	-10.3	.365
19	4	169.0	.07223	.139	.130	6.1	1836.6	2039.3	-11.0	.350
20	4	179.0	.07701	.142	.133	6.0	1765.1	1968.3	-11.5	.338
21	4	189.0	.08093	.144	.136	5.8	1709.5	1906.1	-11.4	.326
22	5	199.0	.03446	.082	.084	-2.3	4715.3	4623.1	2.0	.613
23	5	209.0	.03539	.083	.085	-2.7	4673.6	4565.2	2.3	.605
24	5	219.0	.03667	.084	.086	-2.7	4618.6	4511.3	2.3	.598
25	5	229.0	.03865	.086	.087	-1.6	4536.8	4471.2	1.4	.592
26	5	239.5	.04061	.088	.088	-1.0	4459.6	4419.5	.9	.586
27	5	250.5	.04282	.089	.090	-1.0	4377.3	4334.8	1.0	.574
28	5	261.0	.03071	.078	.081	-2.6	6273.3	6168.2	1.7	.635
29	5	271.0	.03179	.080	.082	-2.7	6222.3	6093.7	2.1	.628
30	5	281.0	.03275	.081	.083	-2.8	6166.0	6027.9	2.2	.621
31	5	291.0	.03365	.081	.084	-2.8	6111.7	5969.3	2.3	.615
32	5	301.0	.03451	.082	.085	-2.9	6061.4	5916.4	2.4	.610
33	5	310.5	.03522	.083	.085	-2.8	6020.2	5876.1	2.4	.605
34	5	319.5	.03589	.084	.086	-2.7	5982.8	5843.0	2.3	.602
35	4	328.5	.05628	.127	.123	3.4	3648.7	3826.2	-4.6	.381
36	4	337.5	.05695	.128	.123	3.5	3625.8	3810.5	-5.1	.379
37	4	346.5	.05694	.128	.123	3.5	3626.2	3809.5	-5.1	.379
38	4	356.0	.05660	.127	.123	3.3	3637.8	3809.7	-4.7	.379
39	4	366.0	.05618	.127	.124	2.6	3652.1	3787.4	-3.7	.377
40	4	376.0	.05548	.126	.124	2.0	3676.2	3778.5	-2.8	.376
41	4	386.0	.05495	.126	.124	1.6	3694.7	3780.1	-2.2	.376
42	4	396.0	.05462	.126	.124	1.5	3706.1	3785.3	-2.1	.377
43	4	406.0	.05443	.126	.124	1.5	3713.0	3792.4	-2.1	.378
44	4	416.0	.05476	.126	.124	1.7	3701.4	3791.4	-2.4	.377

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Solid Waste Branch

45	4	426.0	.05593	.127	.124	2.3	3660.4	3779.5	-3.3	.376
46	4	436.0	.05770	.128	.125	2.4	3600.4	3729.1	-3.6	.371

ACCELEROGRAM - tabas.sar
P R O F I L E - Paducah U Landfill - fee-field prof

ITERATION NUMBER 4

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00215	.019	.020	-1.5	2465.1	2462.9	.1	.982
2	1	10.0	.02349	.082	.083	-1.3	718.7	718.1	.1	.964
3	1	20.0	.03518	.093	.095	-1.8	813.3	810.5	.3	.948
4	1	30.0	.04258	.100	.102	-1.6	904.0	900.9	.3	.936
5	1	40.0	.04626	.103	.104	-1.6	999.6	996.1	.3	.930
6	1	50.0	.04761	.104	.105	-1.5	1095.3	1091.8	.3	.928
7	1	60.0	.04706	.103	.105	-1.5	1192.3	1189.4	.3	.929
8	6	67.5	.02871	.058	.059	-2.3	2034.1	2004.8	1.4	.739
9	6	76.5	.07428	.080	.082	-1.9	816.0	800.7	1.9	.576
10	6	86.5	.03769	.064	.065	-2.3	1735.5	1709.5	1.5	.684
11	6	95.0	.02824	.058	.059	-1.6	2549.3	2526.0	.9	.745
12	6	104.5	.02344	.054	.055	-1.6	3539.8	3510.1	.8	.772
13	6	113.5	.02739	.057	.058	-1.4	3437.9	3410.6	.8	.750
14	6	122.5	.03151	.060	.060	-1.3	3340.4	3312.2	.8	.728
15	5	131.5	.03924	.086	.087	-.7	2947.0	2928.1	.6	.594
16	5	140.5	.04405	.090	.090	-.4	2829.5	2818.8	.4	.572
17	4	149.5	.06488	.134	.131	2.4	1956.4	2032.7	-3.9	.349
18	4	159.0	.07185	.139	.135	2.5	1842.5	1926.4	-4.6	.331
19	4	169.0	.07824	.143	.139	2.6	1747.4	1836.6	-5.1	.315
20	4	179.0	.08356	.146	.142	2.6	1673.9	1765.1	-5.4	.303
21	4	189.0	.08764	.148	.144	2.5	1620.5	1709.5	-5.5	.294
22	5	199.0	.03287	.081	.082	-1.9	4788.9	4715.3	1.5	.625
23	5	209.0	.03359	.081	.083	-2.1	4754.9	4673.6	1.7	.619
24	5	219.0	.03541	.083	.084	-1.4	4672.9	4618.6	1.2	.612
25	5	229.0	.03762	.085	.086	-1.0	4578.6	4536.8	.9	.601
26	5	239.5	.03971	.087	.088	-.8	4494.6	4459.6	.8	.591
27	5	250.5	.04177	.088	.089	-.9	4415.8	4377.3	.9	.580
28	5	261.0	.02969	.077	.078	-1.4	6323.5	6273.3	.8	.646
29	5	271.0	.03056	.078	.080	-1.6	6280.6	6222.3	.9	.641
30	5	281.0	.03136	.079	.081	-1.8	6242.5	6166.0	1.2	.635
31	5	291.0	.03213	.080	.081	-1.9	6204.4	6111.7	1.5	.630
32	5	301.0	.03285	.081	.082	-2.0	6160.1	6061.4	1.6	.624
33	5	310.5	.03349	.081	.083	-2.0	6121.0	6020.2	1.6	.620
34	5	319.5	.03413	.082	.084	-2.0	6083.3	5982.8	1.7	.616
35	4	328.5	.05760	.128	.127	.9	3603.7	3648.7	-1.2	.363
36	4	337.5	.05839	.129	.128	.9	3577.5	3625.9	-1.4	.361
37	4	346.5	.05841	.129	.128	.9	3577.1	3626.2	-1.4	.361
38	4	356.0	.05786	.128	.127	.8	3595.3	3637.8	-1.2	.362
39	4	366.0	.05685	.128	.127	.4	3629.1	3652.1	-.6	.364
40	4	376.0	.05567	.127	.126	.1	3669.6	3676.2	-.2	.366
41	4	386.0	.05504	.126	.126	.1	3691.4	3694.7	-.1	.368
42	4	396.0	.05475	.126	.126	.1	3701.6	3706.1	-.1	.369
43	4	406.0	.05467	.126	.126	.2	3704.4	3713.0	-.2	.370
44	4	416.0	.05542	.126	.126	.4	3678.1	3701.4	-.6	.369
45	4	426.0	.05700	.128	.127	.7	3623.9	3680.4	-1.0	.364
46	4	436.0	.05903	.129	.128	.8	3556.5	3600.4	-1.2	.358

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ITERATION NUMBER 5

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO

1	6	2.5	.00212	.019	.019	-.0	2465.9	2465.1	.0	.983
2	1	10.0	.02313	.081	.082	-.5	718.9	718.7	.0	.965
3	1	20.0	.03454	.093	.092	-.7	814.4	813.3	.1	.952
4	1	30.0	.04179	.099	.100	-.6	905.2	904.0	.1	.939
5	1	40.0	.04541	.102	.103	-.6	1000.9	999.6	.1	.933
6	1	50.0	.04678	.103	.104	-.6	1096.7	1095.3	.1	.931
7	1	60.0	.04625	.103	.103	-.6	1193.8	1192.3	.1	.932
8	6	67.5	.02789	.057	.058	-1.0	2045.5	2034.1	.6	.749
9	6	76.5	.07185	.079	.080	-1.0	823.9	816.0	1.0	.589
10	6	86.5	.03675	.063	.064	-.9	1746.0	1735.5	.6	.704
11	6	95.0	.02773	.057	.056	-.6	2558.2	2549.3	.3	.752
12	6	104.5	.02299	.054	.054	-.7	3552.2	3539.8	.4	.779
13	6	113.5	.02689	.057	.057	-.6	3450.0	3437.9	.4	.756
14	6	122.5	.03095	.059	.060	-.6	3354.1	3340.4	.4	.735
15	5	131.5	.02866	.086	.086	-.6	2962.1	2947.0	.5	.598
16	5	140.5	.04351	.090	.090	-.4	2842.0	2829.5	.4	.574
17	4	149.5	.06686	.135	.134	1.0	1922.9	1956.4	-1.7	.336
18	4	159.0	.07453	.140	.139	1.2	1801.6	1842.5	-2.3	.316
19	4	169.0	.08148	.144	.143	1.3	1702.1	1747.4	-2.7	.300
20	4	179.0	.08717	.146	.146	1.3	1626.6	1673.9	-2.9	.287
21	4	189.0	.09133	.150	.148	1.3	1574.5	1620.5	-2.8	.278
22	5	199.0	.03201	.080	.081	-1.1	4830.0	4788.9	.9	.634
23	5	209.0	.03265	.080	.081	-1.2	4799.5	4754.9	.9	.630
24	5	219.0	.03491	.083	.083	-.6	4695.2	4672.9	.5	.619
25	5	229.0	.03716	.085	.085	-.5	4597.8	4578.6	.4	.607
26	5	239.5	.03926	.086	.087	-.4	4512.6	4494.6	.4	.595
27	5	250.5	.04124	.088	.088	-.5	4435.7	4415.8	.4	.585
28	5	261.0	.02931	.077	.077	-.5	6342.7	6323.5	.3	.651
29	5	271.0	.03010	.078	.078	-.6	6303.0	6280.6	.4	.647
30	5	281.0	.03077	.079	.078	-.8	6270.6	6242.5	.4	.643
31	5	291.0	.03140	.079	.080	-.9	6240.6	6204.4	.6	.639
32	5	301.0	.03203	.080	.081	-1.0	6210.7	6160.1	.8	.635
33	5	310.5	.03263	.080	.081	-1.0	6173.1	6121.0	.8	.631
34	5	319.5	.03324	.081	.082	-1.1	6136.5	6083.3	.9	.627
35	4	328.5	.05781	.128	.128	.1	3596.7	3603.7	-.2	.359
36	4	337.5	.05868	.129	.129	.2	3568.0	3577.5	-.3	.356
37	4	346.5	.05874	.129	.129	.2	3566.1	3577.1	-.3	.356
38	4	356.0	.05810	.129	.128	.2	3587.2	3595.3	-.2	.358
39	4	366.0	.05679	.128	.128	.0	3631.0	3629.1	.1	.361
40	4	376.0	.05541	.126	.127	-.2	3676.4	3669.6	.2	.365
41	4	386.0	.05479	.126	.126	-.2	3700.2	3691.4	.2	.368
42	4	396.0	.05458	.126	.126	-.1	3707.8	3701.6	.2	.369
43	4	406.0	.05461	.126	.126	.0	3706.7	3704.4	.1	.369
44	4	416.0	.05571	.127	.126	.2	3668.1	3678.1	-.3	.366
45	4	426.0	.05750	.128	.128	.3	3607.3	3623.9	-.5	.361
46	4	436.0	.05945	.130	.129	.3	3543.1	3556.5	-.4	.354

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ITERATION NUMBER 6

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS ----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00210	.019	.019	-.2	2466.4	2465.9	.0	.984
2	1	10.0	.02296	.081	.081	-.2	719.0	718.9	.0	.966
3	1	20.0	.03424	.092	.093	-.3	814.9	814.4	.1	.953
4	1	30.0	.04143	.099	.099	-.3	905.8	905.2	.1	.940
5	1	40.0	.04502	.102	.102	-.3	1001.6	1000.9	.1	.934
6	1	50.0	.04640	.103	.103	-.3	1097.4	1096.7	.1	.932
7	1	60.0	.04587	.102	.103	-.3	1194.5	1193.6	.1	.933
8	6	67.5	.02753	.057	.057	-.4	2050.5	2045.5	.2	.754
9	6	76.5	.07065	.079	.079	-.5	827.5	823.9	.5	.597
10	6	86.5	.03637	.063	.063	-.4	1750.4	1746.0	.2	.708
11	6	95.0	.02755	.057	.057	-.2	2561.4	2558.2	.1	.754
12	6	104.5	.02282	.054	.054	-.3	3557.2	3552.2	.1	.781

13	6	113.5	.02667	.057	.057	-.3	3455.3	3450.0	.2	.759
14	6	122.5	.03070	.059	.059	-.3	3360.4	3354.1	.2	.738
15	5	131.5	.03832	.086	.086	-.3	2971.2	2962.1	.2	.601
16	5	140.5	.04315	.089	.090	-.3	2850.4	2842.0	.3	.577
17	4	149.5	.06776	.136	.135	.5	1908.0	1922.9	-.8	.330
18	4	159.0	.07595	.141	.140	.6	1780.5	1801.6	-1.2	.309
19	4	169.0	.08328	.145	.144	.7	1677.5	1702.1	-1.5	.292
20	4	179.0	.08925	.149	.148	.7	1600.2	1626.6	-1.6	.279
21	4	189.0	.09344	.151	.150	.7	1549.0	1574.5	-1.6	.270
22	5	199.0	.03158	.079	.080	-.6	4846.0	4830.0	.3	.640
23	5	209.0	.03231	.080	.080	-.4	4815.5	4799.5	.3	.636
24	5	219.0	.03473	.082	.083	-.2	4703.1	4695.2	.2	.622
25	5	229.0	.03699	.084	.085	-.2	4605.2	4597.8	.2	.609
26	5	239.5	.03907	.086	.086	-.2	4520.0	4512.5	.2	.598
27	5	250.5	.04102	.088	.088	-.2	4444.1	4435.7	.2	.588
28	5	261.0	.02918	.077	.077	-.2	6349.3	6342.7	.1	.653
29	5	271.0	.02994	.078	.078	-.2	6311.1	6303.0	.1	.649
30	5	281.0	.03056	.078	.079	-.3	6280.6	6270.6	.2	.646
31	5	291.0	.03112	.079	.079	-.4	6253.9	6240.6	.2	.643
32	5	301.0	.03165	.079	.080	-.5	6228.9	6210.7	.3	.640
33	5	310.5	.03223	.080	.080	-.5	6198.2	6173.1	.4	.636
34	5	319.5	.03281	.081	.081	-.5	6162.5	6136.5	.4	.632
35	4	328.5	.05771	.128	.128	-.1	3600.3	3596.7	.1	.358
36	4	337.5	.05863	.129	.129	.0	3569.8	3569.0	.0	.355
37	4	346.5	.05873	.129	.129	.0	3566.6	3566.1	.0	.355
38	4	356.0	.05806	.129	.129	.0	3588.5	3587.2	.0	.357
39	4	366.0	.05661	.127	.128	-.1	3637.3	3631.0	.2	.362
40	4	376.0	.05516	.126	.126	-.2	3687.4	3678.4	.2	.366
41	4	386.0	.05457	.126	.126	-.2	3708.1	3700.2	.2	.368
42	4	396.0	.05442	.126	.126	-.1	3713.3	3707.8	.1	.369
43	4	406.0	.05454	.126	.126	.0	3708.1	3706.7	.1	.369
44	4	416.0	.05592	.127	.127	.1	3660.8	3668.1	-.2	.365
45	4	426.0	.05782	.128	.128	.2	3596.6	3607.3	-.3	.359
46	4	436.0	.05955	.130	.130	.1	3539.8	3543.1	-.1	.353

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ITERATION NUMBER 7

VALUES IN TIME DOMAIN

NO	TYPE	DEPTH (ft)	UNIFRM. STRAIN	<---- DAMPING ----> NEW	USED	ERROR	<---- SHEAR MODULUS -----> NEW	USED	ERROR	G/Go RATIO
1	6	2.5	.00209	.019	.019	-.2	2466.6	2466.4	.0	.984
2	1	10.0	.02287	.081	.081	-.1	719.1	719.0	.0	.966
3	1	20.0	.03409	.092	.092	-.2	815.2	814.9	.0	.954
4	1	30.0	.04124	.099	.099	-.2	906.1	905.8	.0	.941
5	1	40.0	.04482	.102	.102	-.1	1001.9	1001.6	.0	.935
6	1	50.0	.04619	.103	.103	-.1	1097.7	1097.4	.0	.933
7	1	60.0	.04567	.102	.102	-.1	1194.8	1194.5	.0	.934
8	6	67.5	.02736	.057	.057	-.2	2052.9	2050.5	.1	.755
9	6	76.5	.07002	.079	.079	-.3	830.0	827.9	.3	.597
10	6	86.5	.03621	.063	.063	-.2	1752.2	1750.4	.1	.710
11	6	95.0	.02748	.057	.057	-.1	2562.7	2561.4	.0	.755
12	6	104.5	.02275	.054	.054	-.1	3559.3	3557.2	.1	.782
13	6	113.5	.02657	.057	.057	-.1	3457.6	3455.3	.1	.760
14	6	122.5	.03058	.059	.059	-.1	3363.4	3360.4	.1	.739
15	5	131.5	.03813	.085	.086	-.2	2976.1	2971.2	.2	.603
16	5	140.5	.04294	.089	.089	-.2	2855.3	2850.4	.2	.578
17	4	149.5	.06819	.136	.136	.2	1900.9	1908.0	-.4	.328
18	4	159.0	.07671	.142	.141	.3	1769.4	1780.5	-.6	.306
19	4	169.0	.08432	.146	.145	.4	1663.8	1677.5	-.8	.288
20	4	179.0	.09048	.149	.149	.4	1585.0	1600.2	-1.0	.275
21	4	189.0	.09469	.151	.151	.4	1534.2	1549.0	-1.0	.266
22	5	199.0	.03139	.079	.079	-.2	4852.9	4846.0	.1	.642
23	5	209.0	.03222	.080	.080	-.1	4820.1	4815.5	.1	.638
24	5	219.0	.03468	.082	.082	-.1	4705.3	4703.1	.0	.623
25	5	229.0	.03693	.084	.084	-.1	4607.6	4605.2	.1	.610

26	5	239.5	.03900	.086	.086	-.1	4522.7	4520.0	.1	.599
27	5	250.5	.04094	.088	.088	-.1	4447.1	4444.1	.1	.589
28	5	261.0	.02914	.077	.077	-.1	6351.4	6349.3	.0	.654
29	5	271.0	.02989	.078	.078	-.1	6313.8	6311.1	.0	.650
30	5	281.0	.03049	.078	.078	-.1	6284.2	6280.6	.1	.647
31	5	291.0	.03101	.079	.079	-.1	6258.9	6253.9	.1	.644
32	5	301.0	.03150	.079	.079	-.2	6235.7	6228.9	.1	.642
33	5	310.5	.03204	.080	.080	-.2	6209.5	6198.2	.2	.639
34	5	319.5	.03260	.080	.081	-.3	6174.5	6162.5	.2	.635
35	4	328.5	.05754	.128	.128	-.1	3605.9	3600.3	.2	.358
36	4	337.5	.05850	.129	.129	-.1	3574.1	3569.8	.1	.355
37	4	346.5	.05862	.129	.129	-.1	3570.0	3566.6	.1	.355
38	4	356.0	.05796	.128	.129	-.1	3592.0	3588.5	.1	.357
39	4	366.0	.05644	.127	.127	-.1	3642.9	3637.3	.2	.362
40	4	376.0	.05497	.126	.126	-.1	3693.8	3687.4	.2	.367
41	4	386.0	.05441	.126	.126	-.1	3713.5	3708.1	.1	.369
42	4	396.0	.05432	.125	.126	-.1	3716.8	3713.3	.1	.370
43	4	406.0	.05450	.126	.126	.0	3710.4	3709.1	.0	.369
44	4	416.0	.05610	.127	.127	.1	3654.7	3660.8	-.2	.364
45	4	426.0	.05806	.129	.128	.1	3588.7	3596.6	-.2	.358
46	4	436.0	.05967	.130	.130	.1	3535.9	3539.8	-.1	.352

VALUES IN TIME DOMAIN

LAYER	MAT. TYPE	THICKNESS (ft)	DEPTH (ft)	MAX. STRAIN ( )	MAX. STRESS (psf)	AVG. ACC. (g)	TIME (sec)
1	6	5.0	2.5	.00317	78.26	.26087	11.40
2	1	10.0	10.0	.03466	249.20	.25704	11.41
3	1	10.0	20.0	.05165	420.93	.24331	11.41
4	1	10.0	30.0	.06249	565.99	.22385	11.41
5	1	10.0	40.0	.06791	680.27	.20264	11.42
6	1	10.0	50.0	.06999	768.04	.18258	11.42
7	1	10.0	60.0	.06920	826.64	.16300	11.42
8	6	5.0	67.5	.04146	850.06	.14576	11.41
9	6	13.0	76.5	.10810	878.33	.12614	11.40
10	6	7.0	86.5	.05486	960.31	.11707	5.70
11	6	10.0	95.0	.04163	1066.33	.11536	11.52
12	6	9.0	104.5	.03446	1225.94	.11798	11.80
13	6	9.0	113.5	.04026	1391.26	.12118	11.85
14	6	9.0	122.5	.04634	1557.15	.12366	11.88
15	5	9.0	131.5	.05777	1716.48	.12571	11.88
16	5	9.0	140.5	.06507	1854.62	.12587	11.87
17	4	9.0	149.5	.10331	1971.22	.12465	11.86
18	4	10.0	159.0	.11623	2069.46	.12206	11.87
19	4	10.0	169.0	.12775	2143.06	.11805	11.86
20	4	10.0	179.0	.13709	2193.78	.11235	11.85
21	4	10.0	189.0	.14346	2222.23	.10812	11.84
22	5	10.0	199.0	.04756	2304.65	.10584	11.82
23	5	10.0	209.0	.04861	2350.60	.10214	11.94
24	5	10.0	219.0	.05255	2471.40	.10190	11.94
25	5	10.0	229.0	.05595	2576.79	.10107	11.93
26	5	11.0	239.5	.05909	2670.82	.09987	11.94
27	5	11.0	250.5	.06203	2756.64	.09789	11.85
28	5	10.0	261.0	.04415	2803.41	.09512	11.94
29	5	10.0	271.0	.04528	2857.95	.09300	11.94
30	5	10.0	281.0	.04619	2901.33	.09069	11.94
31	5	10.0	291.0	.04699	2938.60	.08837	11.93
32	5	10.0	301.0	.04773	2972.93	.08614	11.92
33	5	9.0	310.5	.04854	3008.81	.08426	11.92
34	5	9.0	319.5	.04940	3044.23	.08263	11.91
35	4	9.0	328.5	.08718	3138.89	.08227	11.91
36	4	9.0	337.5	.08863	3163.96	.07982	11.90
37	4	9.0	346.5	.08882	3167.90	.07704	11.90
38	4	10.0	356.0	.08781	3151.19	.07382	11.88
39	4	10.0	366.0	.08552	3110.62	.07015	11.86
40	4	10.0	376.0	.08329	3071.28	.06678	11.86
41	4	10.0	386.0	.08245	3057.20	.06417	11.85
42	4	10.0	396.0	.08231	3056.24	.06201	11.84
43	4	10.0	406.0	.08258	3062.90	.06013	11.83
44	4	10.0	416.0	.08500	3111.71	.05917	12.78

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  45    4     10.0     426.0        .08790    3163.68       .05833    12.78
  46    4     10.0     434.0        .09041    3298.15       .05726    12.77

 PERIOD = 1.991 sec  FROM AVERAGE SHEAR WAVE VELOCITY OF  886.0 ft/sec


 FREQUENCY  AMPLITUDE:
 MAXIMUM AMPLIFICATION =   6.31
 FOR FREQUENCY  (f)    =    .50 c/sec
 FOR PERIOD (1 / f)    =   1.99 sec

 ******   OPTION  6  ***  COMPUTE MOTION IN NEW SUBLAYERS

 ACCELEROGRAM  =                        tubas.sar
 D E P O S I T -  Paducah U Landfill - free-field prof

 LAYER        DEPTH    MAX. ACC.      TIME    MN.SQ.FR.   ACC. RATIO  TH SAVED
              (ft)       (g)         (sec)     (c/sec)    QUIET ZONE  ACC.REC.
 WITHIN         .0      .24084       11.40       1.80        .000         0
 WITHIN        5.0      .25923       11.40       1.79        .000         0
 WITHIN       15.0      .22426       11.40       1.53        .000         0
 WITHIN       25.0      .17918       11.41       1.35        .000         0
 WITHIN       35.0      .13875       11.64       1.35        .000         0
 WITHIN       45.0      .12869       11.63       1.47        .000         0
 WITHIN       55.0      .13398       11.11       1.59        .000         0
 WITHIN       65.0      .13250       11.34       1.64        .000         0
 WITHIN       70.0      .13713       11.94       1.63        .000         0
 WITHIN       83.0      .14985       11.85       1.67        .000         0
 WITHIN       96.0      .15340       11.57       1.73        .000         0
 WITHIN      100.0      .15776       11.67       1.73        .000         0
 WITHIN      109.0      .15752       11.67       1.69        .000         0
 WITHIN      118.0      .15242       11.87       1.63        .000         0
 WITHIN      127.0      .14836       11.86       1.61        .000         0

 ******   OPTION  6  ***  COMPUTE MOTION IN NEW SUBLAYERS

 ACCELEROGRAM  =                        tubas.sar
 D E P O S I T -  Paducah U Landfill - free-field prof

 LAYER        DEPTH    MAX. ACC.      TIME    MN.SQ.FR.   ACC. RATIO  TH SAVED
              (ft)       (g)         (sec)     (c/sec)    QUIET ZONE  ACC.REC.
 WITHIN       136.0      .13752       11.85       1.67        .000         0
 WITHIN       441.0      .23535       11.01       6.02        .000         0
 OUTCR.       441.0      .25890       11.31       6.07        .000         0

 ******   OPTION  7  ***  COMPUTE STRESS/STRAIN HISTORY

 COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    3
 SCALE FOR PLOTTING       .0000
 IDENTIFICATION -  -- stress in layer  3

 COMPUTE STRESS OR STRAIN HISTORY AT THE TOP OF  LAYER    3
 SCALE FOR PLOTTING       .0000
 IDENTIFICATION -  -- strain in layer  6
```

APPENDIX F

EVALUATION OF SCENARIO S4E—GEOSYNTEC CONSULTANTS

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APPENDIX F

Scenario S4E: Evaluation of PGA for M_w 5.5 @ 2.5 km

This appendix has been prepared by Geosyntec Consultants (Geosyntec) on behalf of LATA Environmental Services of Kentucky, LLC (LATA Kentucky) to address a particular comments from Kentucky Division of Waste Management (KDWM) on the report entitled, "Evaluation of Seismic Design Adequacy for C-746-U Landfill at the Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky," (subject report) that was prepared by Geosyntec.

Comment

Attachment 2: The S1E and S2E scenario earthquakes are acceptable both in location and magnitude as reasonable, geologically defensible, scenario earthquakes for the site.

However, the local earthquake, S3E, lacks sufficient geological justification. The local scenario earthquake should not be chosen on the presumed frequency of the event as Section 3.2 of the Beavers Report suggests. Rather, it should be chosen as the local earthquake that is reasonably likely to cause the greatest expected earthquake ground motions at the site based upon the weight of the geological evidence, including local seismicity.

In general, KDWM agrees that an Mw 5.5 local earthquake is a geologically defensible local MCE for PGDP. However, KDWM feels that the distance to the S3E earthquake is excessive because of recent seismicity in the immediate PGDP area. (The USGS earthquake database lists numerous recent local earthquakes as close as approximately 2.6 kilometers from the center of the C-746-U Landfill. When the uncertainty of calculating earthquake locations is considered, the C-746-U Landfill is potentially within the epicentral area.)

Response

In response to the comment, we repeated our calculations by calculating the peak ground acceleration (PGA) for a M_w 5.5 event at a distance of 2.5 km. The calculations are attached in a spreadsheet form [mean value; bedrock; median value of calculations using 5 NGA attenuation relationships (Abrahamson et al. 2008)]. The calculated PGA value of 0.22 g is significantly lower that the controlling S1E (M_w 7.6 New Madrid Seismic Zone event) PGA value of 0.36 g and hence is dismissed from further considerations.

REFERENCES

Abrahamson, N., G. Atkinson, D. Boore, Y. Bozorgnia, C. Campbell, B. Chiou, I.M. Idriss, W. Silva, and R. Youngs, [2008], "Comparisons of the NGA Ground-Motion Relations," *Earthquake Spectra*, Vol. 24, No. 1, pp. 45-66.

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Geosyntec consultants

Acceleration Response Spectra, PHGA & PGV

Model: Suite of NGA Models (Abrahamson et al., 2008)

Site: Paducah Gaseous Diffusion Plant - C746-U Landfill

Fault: Postulated Local Fault (M_w 5.5)

Model Parameter	Value
Source Parameters	**PHGA -->**
Moment Magnitude	**5.5**
Top of Rupture (km)	**0**
Ftype	**-1**
Dip (degrees)	**0**
Rup Width (km) (matters only fo	13
Location (distance) Parameters	
Rrup (km)	**2.5**
Rjb(km)	**2.5**
Rx (km) (used only for HW site:	**2.5**
HW Flag (0 or 1)	**1**
Site Response Parameters	
VS30 (m/s)	**2750**
Z1.0 (km)	**0**
Z2.5 (km)	2.974
Vs30 est class (A&S; impacts onl	**1**
Soil Depth Model (A&S)	**0**
Number of Standard Deviations	
epsilon (0 = mean; 1 = 84%; 2	**0**

Results of Spreadsheet Calculation

Period (sec)	Sa (g) A & S	Sa (g) B & A	Sa (g) C & B	Sa (g) C & Y	Sa (g) Idriss	Sa (g) Median
0.001	0.24332	0.1321	0.2421	0.2181	0.2819	**0.2235**
0.01	0.24479	0.1333	0.2421	0.2181	0.2819	**0.2240**
0.02	0.25563	0.1396	0.2491	0.2245	0.2819	**0.2301**
0.03	0.28488	0.1570	0.2777	0.2458	0.2963	**0.2523**
0.04	0.32599			0.2737	0.3115	
0.05	0.37934	0.2070	0.3645	0.3099	0.3413	**0.3204**
0.075	0.52200	0.2842	0.4359	0.4032	0.4079	**0.4106**
0.1	0.63139	0.3422	0.4829	0.4698	0.4677	**0.4788**
0.15	0.66258	0.3751	0.5175	0.5156	0.5366	**0.5215**
0.2	0.54403	0.2888	0.5016	0.4766	0.5140	**0.4650**
0.25	0.43950	0.2289	0.4132	0.4085	0.4702	**0.3921**
0.3	0.35936	0.1915	0.3401	0.3568	0.4155	**0.3327**
0.4	0.25396	0.1555	0.2685	0.2693	0.3218	**0.2538**
0.5	0.19162	0.1161	0.2154	0.2111	0.2511	**0.1971**
0.75	0.12936	0.0601	0.1277	0.1308	0.1445	**0.1185**
1	0.08969	0.0426	0.0861	0.0927	0.0938	**0.0810**
1.5	0.04810	0.0228	0.0458	0.0532	0.0440	**0.0428**
2	0.02905	0.0134	0.0267	0.0334	0.0235	**0.0252**
3	0.01372	0.0055	0.0112	0.0169	0.0099	**0.0115**
4	0.00772	0.0027	0.0058	0.0102	0.0049	**0.0063**
5	0.00494	0.0015	0.0036	0.0067	0.0027	**0.0039**
7.5	0.00220	0.0005	0.0016	0.0027	0.0010	**0.0016**
10	0.00123	0.0020	0.0009	0.0013	0.0005	**0.0012**
PGV	**12.47847**	**4.9483**	**9.9252**			

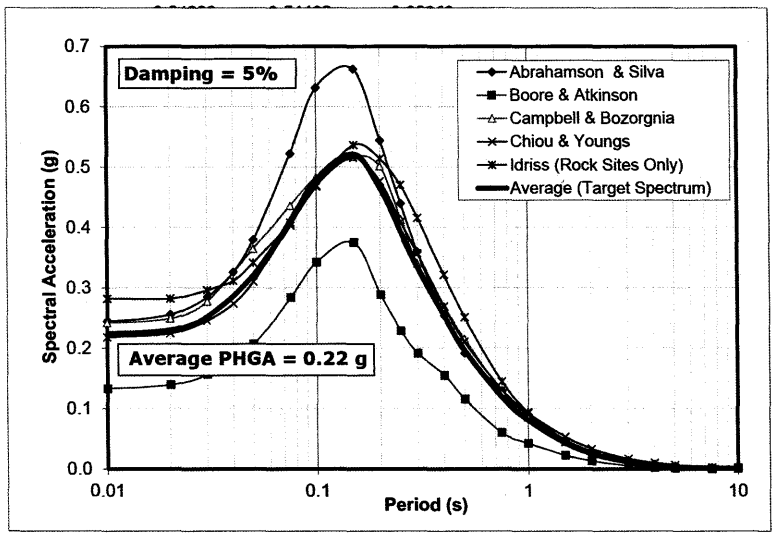
Fault Type Variables:	Ftype
REV	1
REV/OBL	0.5
SS	0
NML/OBL	-0.5
NML	-1
Site Class	Vs30 class
measured	1
estimated (as per data set)	0

Rx is only used for HW sites
It can be skipped for non HW

med Z1.0 (km) from A&S	0.000
med Z1.0 (km) from C&Y	0.000
Abrahamson & Silva	A & S
Boore & Atkinson	B & A
Campbell & Bozorgnia	C & B
Chiou & Youngs	C & Y
Idriss (Rock Sites Only)	Idriss

Sa = Spectral Acceleration
PHGA = Peak Horizontal Ground Acceleration
PGV = Peak Ground Vellocity

Acceleration Response Spectra



ATTACHMENT 2

PART 2

INVESTIGATION OF HOLOCENE FAULTING PROPOSED C-746-U LANDFILL EXPANSION, PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

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INVESTIGATION OF HOLOCENE FAULTING

PROPOSED C-746-U LANDFILL EXPANSION

Paducah Gaseous Diffusion Plant

Paducah, Kentucky

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EXECUTIVE SUMMARY

This report presents the findings of a fault hazard investigation for the C-746-U landfill's proposed expansion located at the Department of Energy's (DOE) Paducah Gaseous Diffusion Plant (PGDP), in Paducah, Kentucky. The planned expansion is located directly north of the present-day C-746-U landfill. Previous geophysical studies within the PGDP site vicinity interpret possible northeast-striking faults beneath the proposed landfill expansion, although prior to this investigation the existence, locations, and ages of these inferred faults have not been confirmed through independent subsurface exploration. The Code of Federal Regulations (CFR), Subtitle D, Title 40, Part 258, subpart B (258.13) requires that disposal facilities (such as the C-746-U landfill and possible expansions) be located more than 200 feet from a fault that has had surface displacement within Holocene time (i.e., approximately the past 11,000 years). The purpose of this investigation is to assess whether or not Holocene-active fault displacement is present beneath the footprint of the proposed landfill expansion. This information can be used to address compliance of the proposed expansion with CFR, Subtitle D, Title 40, Part 258, subpart B (258.13). The investigation was completed as a collaborative effort involving William Lettis & Associates, Inc., the Geology Department of the University of Kentucky, the University of Kentucky-Kentucky Research Consortium Energy and Environment (KRCEE), and the University of Chicago. Technical peer review of the approach, methods, results and conclusions of this study have been provided by scientists and technical experts with the Kentucky Geological Survey, the Illinois Geological Survey, the University of Memphis, the University of Illinois – Champaign, Science Applications International Corporation (SAIC), and M. Tuttle & Associates.

The geologic assessment included (a) review of relevant geologic and geotechnical data from the site vicinity, (b) analysis of detailed aerial photography, (c) field reconnaissance of the site vicinity and other important sites of previous investigations, (d) collection and stratigraphic analysis of 86 subsurface sediment cores, (e) laboratory chronological (age-dating) analyses, and (f) preparation of this report. All of these activities were completed at or above the accepted standard-of-practice for geologic investigations in the mid-continent region; overall this investigation represents an effort that exceeds previous levels of investigation for site-specific fault-rupture assessments in the mid-continent. Detailed subsurface geologic information was collected along several transects at the proposed landfill site to define buried strata and assess the possibility of fault-related differences in elevation of the strata. Stratigraphic data were collected from 86, 30-ft-long continuous soil cores (a total of 2,580 feet) using direct push technology (DPT). The DPT coring method involves pushing a hollow, 1-11/16 inch

diameter, cylindrical coring tube into subsurface material and extracting the core sample for laboratory analysis. Immediately upon extraction at the proposed landfill site, the cores were sealed and transported to the Kentucky Geological Survey Core Laboratory (in Lexington), where they were unsealed and analyzed for lithologic and pedogenic (soil) characteristics. The analytical process included simultaneous exposure of multiple cores, arranged within the laboratory facility according to depth and position along a given transect, and detailed logging of each core in its entirety. This arrangement facilitated core logging and enabled definitive correlation of stratigraphy among several cores. Strata exposed by the cores are identified and differentiated based on lithologic characteristics, such as grain size (texture), sorting, color, contact irregularities, soil (pedogenic) structure, pedogenic clay or iron-oxide accumulation, and other characteristics. A total of 12 samples of wind-blown loess deposits were sent to the University of Chicago for age-dating via the optically stimulated luminescence (OSL) dating method.

Geologic cross-sections prepared from the DPT data identified laterally continuous horizontal strata for assessing the possibility of fault displacement, and for evaluating the timing of such displacements. Seven primary geologic units are present beneath the site at depths of less than 30 ft, as generalized in the table below. Based on the OSL age-dating analyses, the deposits encountered in the cores range in age from about 16 ka to greater than 125 ka (see table below), which is in good agreement with ages determined for similar loess and fluvial packages elsewhere in the central United States.

Unit Name	Unit Number	Depth Below Ground Surface (Feet)	Unit Age (1000 x years)	Potential Fault- or Fold-related Deformation?	Number of Potential Fault-related or Fold-related Features
Upper Peoria	Unit 1	0– 6	15.4 – 25.2	No	0
Lower Peoria	Unit 2	7 – 9	21.8 – 30.9	Possibly	1
Roxana Silt	Unit 3	9 – 11	32.1 – 50.7	Possibly	3
Unnamed Intermediate Silt	Unit 4	12 –13	53.6 – 75.5	Possibly	14
Metropolis Formation	Units 5.1, 5.2, and 5.3	≥15	≥125 – 180	Possibly	25

Geologic cross-sections developed from the DPT data show that the upper three units (i.e. the Upper Peoria Loess, Lower Peoria Loess, and Roxana Silt) generally are flat-lying and mantle pre-existing topography. In contrast, the lower, older units (Unnamed Intermediate Loess and the Metropolis

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Formation) exhibit occasional subtle to abrupt undulations of basal contacts, which may reflect fluvial processes and/or tectonic-related deformation. The geologic cross sections allow for as many as four folds and 21 features with noticeable elevation changes along stratigraphic and/or pedologic boundaries, as summarized in the table above. These possible elevation changes represent differences in the elevation of a given stratigraphic boundary that exceed the uncertainty in the boundary depths based on laboratory measurements, and thus probably are related to natural (tectonic or non-tectonic) processes.

Of the 25 features interpreted to represent elevation changes of stratigraphic boundaries within the Metropolis Formation (units 5.1 to 5.3), 14 may extend upward into the Unnamed Intermediate Silt (unit 4). Similarly, only three of these 14 features possibly extend upward into the Roxana Silt (unit 3) and only one may extend into the Lower Peoria Loess (unit 2). None of the features extends into the Upper Peoria Loess. Any of these 25 features may have formed as a result of non-tectonic processes, such as local fluvial or wind erosion. In particular, the three elevation changes in the base of the Roxana Silt are unlikely to be related to fault displacement, because the sense of vertical separation differs among the various boundaries. Also, if any of these features were to be interpreted as a fault, it would have an anomalously shallow dip, and thus the differences in sense of displacement upsection would imply both normal and reverse faulting, depending on the stratigraphic level. The absence of similar elevation differences elsewhere in the sections lends support to the interpretation of a non-tectonic origin for these three features.

Therefore, if late Quaternary displacement has occurred beneath the site, the most-recent displacement occurred following deposition of the Unnamed Intermediate Silt between approximately 53,600 and 75,500 years ago. Although unlikely, the data do not preclude the possibility of displacement of the Roxana Silt beneath the site, which is approximately 34,600 to 47,200 years old. There is no perceptible displacement of the base of the Upper Peoria Loess, which is approximately 16,600 to 23,500 years old. If late Pleistocene faulting occurred at the site, the age of such deformation would be similar to the youngest age of faulting previously interpreted along northeast-striking faults in southern Illinois.

Thus, the detailed coring data collected during this investigation show no evidence for Holocene (<11,000 years) displacement along previously interpreted faults underlying the site. The data and interpretations do not preclude the possibility of late Pleistocene displacements at a few localities beneath the site, although the stratigraphic elevation changes may also be interpreted as stratigraphic variability related to erosional or depositional processes. Based on these data, we conclude that the latest Pleistocene strata

have not been displaced, and that faults beneath the site, if they exist, have been inactive during the Holocene. On the basis of the findings of this study, and in compliance with Code of Federal Regulations (CFR), Subtitle D, Title 40, Part 258, subpart B (258.13), a setback of 200 feet from the previously interpreted faults is not warranted.

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1.0 INTRODUCTION

This report presents the results of a fault rupture hazard investigation for Holocene faulting across a proposed expansion at the C-746-U landfill, in Paducah, McCracken County, Kentucky. The existing C-746-U landfill is a Class II solid waste facility that is operated by the Paducah Gaseous Diffusion Plant (PGDP), and owned by the U.S. Department of Energy (DOE). The site is located approximately 4 miles south of the Ohio River and approximately 10 miles west of Paducah in western Kentucky (Figure 1). The DOE-owned property encompasses 3,600 acres of which 750 acres are occupied by an uranium enrichment facility (PGDP) that lies within a restricted area (Figure 2). The proposed landfill expansion lies outside of this restricted PGDP area and is directly adjacent to a wildlife management area managed by the Commonwealth of Kentucky. The proposed landfill expansion area of interest for this fault study lies directly outside of the operating C-746-U landfill along its western and northern perimeters, and north of two inactive PGDP landfills (Figure 2).

1.1 Purpose

The purpose of this investigation is to assess the presence or absence of Holocene active faulting across the footprint of the proposed C-746-U landfill expansion. Seismic reflection profiles previously acquired and interpreted by Blackhawk Geosciences (2003) suggest two faults (Fault 1 and Fault 2) offsetting Quaternary to Tertiary (Mounds Gravel) deposits beneath the project area (defined as the west-central part of the C-746-U landfill) (Figure 2). However, the existence, locations and ages of these inferred faults have not been confirmed through independent subsurface exploration; thus, the intent of this latest fault hazard investigation is to comply with Code of Federal Regulations (CFR), Subtitle D, Title 40, Part 258, subpart B (258.13) which states:

New MSWLF (Municipal Solid Waste Landfill Facility) units and lateral expansions shall not be located within 200 feet (60 meters) of a fault that has had displacement in Holocene time unless the owner or operator demonstrates to the Director of an approved State that an alternative setback distance of less than 200 feet (60 meters) will prevent damage to the structural integrity of the MSWLF unit and will be protective of human health and the environment. (Note that Holocene time means the most recent epoch of the Quaternary period, extending from the end of the Pleistocene Epoch to the present. This generally refers to the last 11,000 years.)

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1.2 Scope of Work

The primary purpose of this investigation is to evaluate the absence or presence of Holocene faulting at the site of the proposed C-746-U landfill expansion. The suitability of the C-746-U landfill with respect to fault location and age was evaluated following regulatory criteria provided in the 2005 Code of Federal Regulations, Subtitle D, Title 40, Part 258, subpart B (258.13). These regulations emphasize the importance of identifying any Holocene active fault that could produce primary surface fault rupture within 200 feet (61 m) of the proposed landfill footprint. If large displacements were to occur beneath the site, such ruptures presumably would damage the integrity of the liner as well as monitoring and waste collection systems, possibly leading to groundwater movement between the landfill and surrounding geologic strata. The purpose of the fault investigation is to assess the location and Holocene activity of previously interpreted Faults 1 and 2 at the site, and provide recommendations, if necessary, for setback conditions in compliance with CFR, Subtitle D, Title 40 for surface-fault rupture hazard (e.g., ground rupture along a surface fault trace).

Our scope of work was designed to focus on previously interpreted near-surface faults intersecting the proposed landfill expansion and was outlined in our proposal dated September 30, 2004 to the Geology Department of the University of Kentucky, and University of Kentucky-Kentucky Research Consortium Energy and Environment (KRCEE). The scope of work for the project consisted of the following:

- Compile and review existing subsurface data obtained from previous geologic and geotechnical investigations of the site and surrounding vicinity. Analysis of readily available aerial photography (November 2001 vintage) provided by KRCEE to evaluate the Quaternary geology and geomorphology in the direct vicinity of the PGDP site and to provide guidance on the appropriate investigation plan.

- Conduct field reconnaissance of the site area to provide relevant information on the type, location, and bedding of existing bedrock and surficial deposits in the direct vicinity of the site, and to assess possible logistical constraints imposed on the project.

- Conduct field reconnaissance of the Barnes Creek fault zone on April 20, 2005 in Massac County, southern Illinois with Mr. John Nelson of the Illinois Geological Survey to obtain a general understanding of the findings of several recent geologic studies performed along this fault zone.

- Augment available subsurface site data by collecting and logging 86 closely spaced direct push technology (DPT) cores along the northern and western perimeters of the existing C-746-U landfill, in September and October 2005. In lieu of permitting the excavation and documentation of an exploratory trench at a DOE facility, the drilling program was designed to evaluate the presence or absence of vertical separation across the previously inferred faults. Four of the 86 cores were drilled for the purpose of collecting sediment (loess deposits) for dating by the optically stimulated luminescence (OSL) technique.

- Prepare this report summarizing the results of the fault-rupture hazard study.

1.2.1 Geologic References Reviewed

We reviewed published maps and literature pertaining to geologic and seismic conditions in the project area. As part of our study, we reviewed the following:

- "Seismotectonic Investigation Report for Siting of a Potential On-site CERCLA Waste Disposal Facility at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky", prepared by SAIC, dated March 2004.

- "Technical Memorandum for the C-746-U Landfill Fault Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky", prepared by Bechtel Jacobs Company, LLC, October 2003.

- "Final Shear Wave Seismic Survey Report C-746-U Landfill Seismic Assessment, Paducah Gaseous Diffusion Plant, Paducah, Kentucky", prepared by Blackhawk Geoservices, dated October 2003.

- "Archival Photo Analysis Paducah Gaseous Diffusion Plan", prepared by U.S. Army Corps of Engineers, September, 2000.

- "Acquisition of SH-wave Seismic Reflection and Refraction Data in the Area of the Northeastward Trending Contaminant Plume at the PGDP", prepared by Langston and Street, dated July 31, 1998.

- "Geologic Features Relevant to Ground-water Flow in the Vicinity of the Paducah Gaseous Diffusion Plant", prepared by Drahovzal and Hendricks, 1996.

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- "Paducah Gaseous Diffusion Plant, Notice of Intent Application, 1995, Solid Waste Landfill"

- "Application for a Solid Waste Landfill, Notice of Intent to Apply (application form dated 1992): Hazardous Solid Waste Landfill Subsurface Investigation Report", prepared by SAIC, February 1994

We also consulted a variety of other unpublished reports and references pertaining to the geology and hydrogeology of the vicinity of the PGDP site. A list of selected references is presented in "Section 9, References." Some of the data contained in the referenced reports were used and relied upon during our geologic evaluation of conditions affecting the proposed landfill expansion. The locations of nearby geotechnical borings and monitoring wells are shown on Plate 1.

1.3 Acknowledgments

This fault hazard investigation, performed by WLA, was managed by Dr. Ed Woolery of the University of Kentucky, Department of Geological Sciences, and Mr. Steve Hampson of the University of Kentucky-Kentucky Research Consortium for Energy and Environment. John Baldwin, Keith Kelson, Robert Givler, and Sean Sundermann of WLA performed the data collection, analysis and reporting for the fault hazard study. The execution of the field work was accomplished by KRCEE's other subcontractors which included: Science Application International Corporation, Inc. (SAIC) oversaw the Field Operations Management; Miller Drilling Company drilled the DPT cores; and Tricord, Inc. oversaw Health and Safety. Data collection and interpretation of the cores by WLA also included a technical peer review by a three-person internal review panel consisting of Mr. John Nelson of the Illinois State Geological Survey (ISGS), Dr. Roy Van Arsdale of the University of Memphis, and Dr. Martitia Tuttle of M. Tuttle & Associates. This included a review of logged cores at the Kentucky Geological Survey core library and this report. Additional peer review services were provided by Dr. Leon Follmer of the ISGS, Dr. Steve Forman of the University of Illinois, at Chicago, Dr. David Amick of SAIC, and Mr. Marshall Davenport of Jacobs Engineering.

2.0 REGIONAL SETTING

2.1 Regional Seismotectonic Setting

An understanding of the regional seismotectonic setting is essential for evaluating the style, pattern and timing of deformation that previously has been interpreted (i.e., Faults 1 and 2) in the vicinity of the proposed landfill expansion. Faults 1 and 2 lie at the northern margin of the Mississippi embayment, near the transition zone between two late Precambrian-early Paleozoic rifts (i.e., the Reelfoot rift and Rough Creek graben) and the southernmost part of the Illinois Basin (Stearns, 1957; Stearns and Marcher, 1962; Braile et al., 1982; Kolata and Nelson, 1991; Potter et al., 1997; Kolata and Hildenbrand, 1997) (Figure 3). The northeast-trending Reelfoot rift includes the active New Madrid seismic zone (NMSZ) located about 100 km southwest of Paducah (Ervin and McGinnis, 1975; Kane et al., 1981; Hildenbrand et al., 1982); however, bands of contemporary microseismicity associated with the NMSZ project northeast toward Paducah (Wheeler, 1997) (Figure 3). The Illinois Basin includes the Wabash Valley fault zone (McBride et al., 1997). Faults within the Wabash Valley fault zone have been shown to terminate at the intersection of the northern margin of the Rough Creek graben, 60 km north of the PGDP, and thus are not considered a surface-fault rupture hazard at the C-746-U landfill (Hildenbrand and Ravat, 1997). The Rough Creek graben lies directly northeast of Paducah and is relatively aseismic (Wheeler, 1997) (Figure 3).

Within the intersection between the Reelfoot rift and Rough Creek graben, and directly to the north-northwest of Paducah in southern Illinois, is an approximately 40-km-wide zone of steeply dipping, northeast-striking bedrock faults that comprise the Fluorspar Area fault complex (FAFC) (Kolata and Nelson, 1991) (Figure 3). The FAFC was active during the latest Proterozoic to early Cambrian (several hundred million years ago), coincident with the formation of the northeast-striking faults associated with the Reelfoot rift. These faults were reactivated during late Pennsylvanian (290 to 300 million years ago) and Permian (250 to 290 million years ago) time in response to the Alleghenian orogeny. This episode of deformation produced displacements of Paleozoic bedrock in excess of 800 meters, through a combination of normal, reverse and strike-slip faulting, and also included ultramafic igneous activity. In Cretaceous time (65 to 135 million years ago), the Reelfoot rift was reactivated and underwent subsidence, forming the Mississippi embayment. More recently, some faults within the Reelfoot rift (i.e., the NMSZ) have been reactivated in the Quaternary and, consequently, northeast-trending faults, including some within the FAFC exhibit evidence of Quaternary displacement (Nelson et al., 1999). A

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key question and the focus of this study is to determine if the faults identified below the landfill offset Holocene stratigraphy.

Several faults within the FAFC, such as the Lusk Creek, Raum, Hobbs Creek and Barnes Creek fault zones are postulated to extend southwest across the Ohio River into western Kentucky close to the PGDP facility (Nelson et al., 1999; McBride et al., 2002) (Figure 4). These fault zones consist primarily of high-angle, northeast-striking normal faults that bound northeast-striking horsts and grabens, with a fewer number of reverse and strike-slip faults (Nelson, 1991; Potter et al., 1997; Nelson et al., 1997 and 1999; McBride et al., 2002). Nelson et al. (1999) interpret the graben as pull-apart structures produced by strike-slip faulting, however no master fault is proposed or has been identified to date (Potter et al., 1997; McBride et al., 2002). Thus, during the interpretation of DPT core data collected during this study, both oblique dextral strike-slip and dip-slip displacements accompanied by warping and folding were considered. Models that include pure dextral strike-slip faulting, however, were not considered as a possible mode of deformation because of the preponderance of regional and local seismic reflection data that strongly suggests oblique-slip displacement as the primary style of deformation.

Recent seismic reflection studies in the PGDP site vicinity and south of the Ohio River by Langston and Street (1998) and Woolery and Street (2002) provide evidence for the southwest projection of FAFC structures into western Kentucky (Figures 2 and 4). On the seismic reflection profiles, near-vertical, northeast-striking faults are interpreted to displace Quaternary reflectors, extending within approximately 25 feet (7.6 m) of the ground surface (Woolery and Street, 2002). These northeast-trending faults and structures exhibit a similar structural style to faults identified in the FAFC of southern Illinois. Drahovzal and Hendricks (1996) further suggest that some of these northeast-trending structures in western Kentucky displace Tertiary alluvium and may act as migratory pathways for contaminant plumes at the PGDP facility.

On the basis of similar fault orientations and tectonic origin with the failed Reelfoot rift, some workers have postulated that faults within the FAFC may connect with active northeast striking faults that presently accommodate strain within the NMSZ (Potter et al., 1995; Wheeler, 1997). If true, faults associated with the FAFC may be Holocene active, and preferentially oriented for accommodating dextral strain within the central United States. For instance, Wheeler (1997) interprets faults within the FAFC align with the projection of a northeast-trending band of microseismicity that extends from the NMSZ in southeastern Missouri into western Kentucky (Figure 3). The possible association of northeast-trending

NMSZ contemporary microseismicity aligned with northeast-striking faults in western Kentucky,. suggests that some of the FAFC faults may accommodate Holocene deformation (Wheeler, 1997); however, recent studies by Nelson et al. (1999) and McBride et al. (2002) do not support this interpretation and find no evidence of faulting along several FAFC structures within the past 55,000 to 128,000 years. In river valleys east of Paducah, sand dikes exist that cut sediment mapped as Pleistocene and recent fluvial and lacustsrine depostis (Amos and Wolfe, 1966; Amos and Finch, 1968; Olive, 1966). The sand dikes are somewhat weathered and do not appear to be historical in age. Radiocarbon dating of the sediment adjacent to dike terminations indicated that most, if not all, of the liquefaction features formed within the past approximately 4,850 years (M. Tuttle, written communication, 2006). The timing, source, and magnitude of the late Holocene earthquake that induced this liquefaction east of Paducah have not yet been determined M. Tuttle, written communication, 2006). To summarize, regional and local geologic and geophysical studies support a seismotectonic model in which northeast-striking faults of the FAFC, which were active during the Quaternary, extend southwest into western Kentucky close to the C-746-U landfill (Figure 4).

2.2 Fluorspar Area Fault Complex

Several fault evaluation studies performed in the FAFC provide valuable information on the style, geometry and timing of faulting that is directly applicable to assessing the faults interpreted to underlie the C-746-U landfill. For instance, recently identified faults in western Kentucky are interpreted to have orientations and patterns of deformation similar to the northeast-striking fault zones identified in southern Illinois. At least four fault zones (e.g., Barnes Creek, Hobbs Creek, Raum and Lusk Creek fault zones) of the FAFC have been extensively studied by the Illinois Geological Survey, the United States Geological Survey and SAIC (2004) (Figure 4). Nelson et al. (1999) defines the FAFC as consisting of relatively long, narrow grabens bounded by both normal and reverse faults that formed as "pull-apart" structures in response to poorly understood oblique strike-slip faulting. To date, no master strike-slip fault, or direct evidence of strike-slip faulting has been documented to validate this interpretation. It is based primarily on circumstantial evidence that includes an assumed regional stress orientation that would be similar to present-day orientation, and a structural pattern of deformation best explained by transtension deformation (i.e., pull-apart basins along step-overs). Brief descriptions of the four primary fault zones of the FAFC are provided below, including the Barnes and Hobbs Creek fault zones, which project southwest near or through the proposed landfill expansion (Figure 4).

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2.2.1 Barnes Creek Fault Zone

The 25-mile-long (40 km), northeast-trending Barnes Creek fault zone is located about 6 miles (10 km) northeast of the proposed landfill expansion (Figure 4). The fault zone is defined as a complex system of grabens and horsts that merges to the southwest with the Hobbs Creek fault zone north of Metropolis, Illinois. The Barnes Creek fault zone is characterized as a zone of narrow (100-to 200-ft-wide) to relatively broad (650-to 980-ft-wide) N20E°- to N40°E-trending grabens bound by high-angle normal and reverse faults (Sexton et al., 1996; Nelson et al., 1999; McBride et al., 2002). Based on borehole data, vertical separation is inferred to be as much as 95 feet (29 meters) for the Metropolis Formation and less than 5 feet (1.5 meters) for the Sangamon Geosol (Nelson et al., 2002). The Barnes Creek fault zone has been the focus of numerous detailed geologic and paleoseismic investigations to assess activity (Nelson et al., 1997 and 1999; SAIC, 2004). Based on creek bank exposures, geophysical profiles and geologic cross-sections supplemented with geotechnical borehole information, McBride et al. (2002) interpret the fault zone as displacing Cretaceous through lower Pleistocene stratigraphy.

As part of a study for a proposed PGDP Site 3A landfill, SAIC (2004) performed a subsequent study of the Barnes Creek fault zone that included additional acquisition of geophysical, ground penetrating radar and borehole data, as well as interpretation of the same creek bank exposures of Nelson et al. (1997 and 1999). The Barnes Creek study by SAIC (2004) concludes that some faults offset Holocene-age deposits. Our reconnaissance-level review of the same exposures with J. Nelson in March 2005 suggests that while relatively young geologic deformation is present, SAIC's (2004) interpretation of Holocene faulting is equivocal. We base this interpretation on: (1) an apparent absence of faulting observed in the upper younger deposits (i.e. presence of only a fracture); (2) uncertain origin of observed fractures (e.g., possibly related to roots); and (3) absence of distinct stratigraphic offset of Holocene deposits.

2.2.2 Hobbs Creek Fault Zone

The southern portion of the 43-mile-long (70 km) Hobbs Creek fault zone is defined by the Massac Creek graben (Nelson et al., 2002) (Figure 4). The Massac Creek graben consists of an approximately N30°E-trending, 2,300 ft-wide (700 m) graben occupied by a complex zone of high-angle normal and some reverse faults that displace Mississippian limestone, Cretaceous McNairy Formation and Pleistocene Metropolis Formation. Based on borehole and geophysical data, the Metropolis Formation is interpreted to be vertically displaced as much as 100 feet (30 m) (Nelson et al., 2002). A review of the geologic map of Nelson et al. (2002) shows that the Tertiary-Quaternary Mounds Gravel exhibits an apparent right-

lateral deflection of up to 0.62 mi (1 km) across the Massac Creek fault zone. The Massac Creek graben is mapped as far southwest as the city of Metropolis based on the interpretation of city water wells, alignment of the valley walls of Massac Creek, and local exposures showing offset Metropolis Formation (McBride et al., 2002). The trend of the Massac Creek graben projects about 1.6 mi (2.5 km) east of the proposed C-746-U landfill (Nelson et al., 2002) and may correlate with a similar-sized graben imaged by Langston and Street (1998) (Figure 4). Geologic cross-sections developed from geotechnical borings aligned across the Massac Creek graben show no elevation changes in the overlying Wisconsin loess or Holocene alluvium. Therefore, McBride et al. (2002) and Nelson et al. (2002) interpret this structure to be inactive during the Holocene. The Massac Creek graben appears to have been inactive for at least 75,000 years (Nelson et al., 2002).

2.2.3 Raum Fault Zone

The 50-km-long Raum fault zone is about 4.3 mi (7 km) west of the Hobbs Creek fault zone in southern Illinois (McBride et al., 2002) (Figure 4). On the basis of seismic reflection and borehole profiles, the fault zone is characterized as a 1.0 mi-wide (1.6 km) zone of north- to northeast-trending, steeply dipping faults bounding horst and graben structures. Faults displace Paleozoic bedrock and apparently continue upsection into the overlying Quaternary Metropolis Formation (McBride et al., 2002). Stratigraphic contacts associated with late Pleistocene loess and late Pleistocene to Holocene alluvium show no evidence of displacement across the Raum fault, indicating this fault zone is not active during the Holocene.

2.2.4 Lusk Creek Fault Zone

The northwestern boundary of the FAFC is bound by the Lusk Creek fault zone (Figure 4). Geophysical profiles and boreholes show the fault zone is characterized by subparallel high-angle normal and reverse faults with vertical displacements of up to 230 ft (70 m) in the Cretaceous McNairy Formation, and possibly up to about 16 ft (5 m) of the Pleistocene Metropolis Formation (McBride et al., 2002). The fault zone is composed of numerous, 330 to 980 ft-wide (100-to 300-m) grabens that displace the middle Pleistocene Metropolis Formation, but do not appear to offset overlying late Pleistocene loess deposits.

2.3 Fault Studies at the PGDP in Western Kentucky

Several local and site-specific fault studies have been performed in the vicinity of the PGDP facility (Figure 2). These investigations consisted mostly of geophysical surveys to identify subsurface structures

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aligned with faults mapped or imaged in southern Illinois. In addition, a site-specific fault hazard study was performed by SAIC (2004) at the existing PGDP facility located south of the proposed C-746-U landfill. In general, these studies suggest possible evidence for a southwest continuation of the FAFC into western Kentucky. For instance, Langston and Street (1998) and Woolery and Street (2002) image numerous northeast-striking, steeply dipping faults bounding horst and graben structures at and near the PGDP facility (Figure 2). Faulting near the PGDP facility typically is interpreted as extensional, with a smaller number of contractional structures. Many of the normal faults can be traced upsection into the Quaternary Metropolis Formation and possibly into overlying Pleistocene loess deposits (Woolery and Street, 2002). Langston and Street (1998) postulate that some of the fault zones act as preferential pathways for contaminants in the Mounds Gravel and Metropolis Formation, providing further evidence that the faults may displace Neogene fluvial deposits.

Site-specific fault studies at the PGDP facility using geophysical data and cross-sections prepared from DPT cores (SAIC, 2004) for the proposed Site 3A landfill in the southern part of the facility interpret as many as 6 to 11 potential north to northeast-striking faults (Figure 2). SAIC (2004) interpret narrow structures bounded primarily by normal faults exhibiting down to the east vertical displacement. Several of the faults are interpreted as extending upsection into the Metropolis Formation, and based on S-wave profiles interpreted by SAIC (2004). On the basis of limited DPT core data, SAIC (2004) concludes that the "study did not find Holocene-age displacement of faults at Site 3A" and that faulting is interpreted to extend within 20 feet (6.1 m) of the ground surface. However, SAIC (2004) also interpret possible post-Metropolis faulting exposed in stream cuts bordering Barnes Creek, approximately 10 km northeast of the PGDP (Figures 1 and 4). Collectively, these previous studies suggest the presence of northeast-striking normal and reverse faults of Quaternary age near the C-746-U landfill that may be laterally continuous with the FAFC in southern Illinois (Figure 4).

2.4 Geomorphology of the FAFC

The regional landforms of this part of the central United States are dominated by numerous large fluvial systems (Ohio, Cache, Obion and Tennessee Rivers) that have coursed toward the Mississippi embayment throughout much of the late Pleistocene (Saucier, 1996; Frye et al., 1962; Fisk, 1944; Esling et al., 1989; Autin et al., 1991; Blum et al., 2000). The ancestral course of the Ohio River represents a prominent physiographic feature that trends oblique across the FAFC in southern Illinois. The ancestral Ohio River once flowed westward through the Cache Valley northwest of its present-day location, and transported outwash deposits from Wisconsin glaciers located to the north-northeast up to about 25,000 years ago

(Fisk, 1944; Esling et al., 1989) (Figure 1). The ancestral Ohio River is interpreted to have abandoned this northern course and migrated to its present-day location about 14,000 years ago, at or near the time of the Maumee Flood on the Tennessee River (Wayne and Zumberge, 1965; Olive, 1980).

Some faults comprising the FAFC are recognizable in DEM images as 6- to 12-mi-long (10- to 20-km) northeast-trending lineaments that coincide with linear valleys, bluffs and drainages (Figure 1). Nelson et al. (2002) suggest that numerous creeks, as well as the ancient path of the Ohio River in southern Illinois, appear deflected across faults within the FAFC. For instance, the ancestral Ohio River valley exhibits about 6 to 9 miles (10 to 15 km) of possible left-lateral deflection across the Lusk Creek fault zone of the FAFC, whereas smaller creeks such as Barnes and Massac Creek follow the northeast-southwest structural grain of the FAFC (Figure 1). Faults associated with the FAFC, however, do not appear to deflect the present-day courses of the Ohio River and Mayfield Creek (Figure 1). Alternatively, the apparent deflection of the Ohio River may be in response to the juxtaposition of different rock types at the fault and differences in resistance to erosion. In this case, the apparent deflection is bedrock-controlled and represents a fault-line escarpment along the Lusk Creek fault zone, and thus the deflection may not be related to recent tectonic activity (J. Nelson, personal communication, 2006).

South of the Ohio River in the elevated terrain of the PGDP, there is little geomorphic expression of prominent northeast-trending lineaments (e.g., linear valleys, drainages and bluffs) similar to those readily observed in southern Illinois (Figure 1). For instance, a digital elevation map (Figure 1) exhibits few northeast-trending lineaments or linear drainage patterns suggestive of structural control. Furthermore, the modern day Ohio River and Mayfield Creek also show no distinct deflection across the southern projection of the FAFC that might be construed as tectonic-related deformation. Drahovzal and Hendricks (1996) performed a comprehensive geomorphic analysis of the region and identified numerous northeast-trending lineaments in the vicinity of the PGDP that are similar in style and orientation, and project toward the FAFC (see their Plate 2). Based on 1:250,000-scale SLAR (synthetic-aperture radar data) imagery, Drahovzal and Hendricks (1996) interpret two lineaments about 800 feet (244 m) northwest and southeast of the margins of the proposed C-746-U landfill (Figure 2). The northwest-bounding SLAR-lineament appears to coincide with a northeast-striking fault previously imaged in geophysical profiles of Woolery and Street (2002), as well as a groundwater contaminant plume within the Tertiary-Quaternary Mounds Gravel. The study by Drahovzal and Hendricks (1996) suggests that some of the SLAR-lineaments coinciding with faults may be of structural origin.

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3.0 REGIONAL STRATIGRAPHY

The regional stratigraphy is based on the geologic mapping of the area by Finch, 1967; Olive, 1980 and Nelson et al., 2002 and site specific subsurface studies performed by SAIC (1994 and 2004).

3.1 Pre- Late Quaternary Stratigraphy

The stratigraphic history of the site region is greatly influenced by its position at the northern margin of the Mississippi embayment and the structural control imparted by the Illinois basin, Rough Creek graben, and Reelfoot rift. The regional stratigraphy consists of south-dipping Cretaceous through Tertiary clastic sediments thinning over northwest-dipping Paleozoic bedrock at the northern end of the Mississippi embayment (Nelson et al., 1999). Post-Paleozoic regional stratigraphy includes northwest-dipping Mississippian limestone unconformably overlain by about 300 to 330 feet (92 to 101 m) of south- to southwest-dipping Upper Cretaceous and Tertiary deposits, which in turn are overlain by Quaternary material (Finch, 1967; Olive, 1980) (Figure 5). A generalized stratigraphic column for the region is shown in Figure 6. The Upper Cretaceous deposits are about 200 feet (61 m) thick, and include non-lithified, interbedded fine-grained sand and clay of the McNairy Formation present at about 70 to 80 feet (21 to 24 m) below the ground surface (Woolery and Street, 2002; SAIC, 1994). Stratigraphically above the McNairy Formation is the Porters Creek clay, which is dark gray, slightly to very micaceous clay of Paleocene age. Unconformably overlying the Cretaceous and Paleocene deposits is about 100 feet (30 m) of Plio-Pleistocene sand and gravel that locally are referred to as the Upper and Lower Continental Deposits, The Lower Continental Deposits regionally correlate with the Mounds Gravel and the Upper Continental Deposits largely correlate with the Metropolis Formation in southern Illinois and western Kentucky (Nelson, personal communication, 2005). Based on borehole data south of the proposed landfill, Mounds Gravel unconfomably overlies the McNairy Formation and Porters Creek Clay (SAIC, 2004). At the PGDP facility, Mounds Gravel is defined as a buried paleo-terrace riser trending roughly west to northwest across the southern part of the facility (Phillips, 1992) (Figure 2). Grading into the Mounds Gravel is an approximately 30-foot-thick (9 m) "silt and sand" terrace deposit previously mapped by Finch (1967) and Pryor and Ross (1962), which largely correlates with the Metropolis Formation of southern Illinois (Nelson et al., 1999; John Nelson, personal communication, 2005). The Metropolis Formation is overlain by several packages of late Pleistocene loess deposits as described below.

3.2 Late Quaternary Stratigraphy

The Plio-Pleistocene Metropolis Formation, Pleistocene loess packages, and associated paleosols developed in the loess are less than a few million years old, and thus form the fundamental stratigraphic sequence and marker units of the Holocene faulting investigation. Nelson et al. (2002) describe the Metropolis Formation as a fluvial deposit consisting principally of silt and sand with lesser amounts of clay and chert gravel. The Tennessee, Ohio, Mississippi and Cumberland Rivers are sources of the sediment for the Metropolis Formation (Olive, 1980; Nelson et al., 1999). Nelson et al. (1999) interpret fluvial units in the Metropolis Formation to be aggradation phases of a glacial-interglacial cycle, and buried soils developed within these deposits to represent interglacial phases during the late Pleistocene.

In this part of the central United States, at least three late Pleistocene loess deposits formed as a result of the extensive glaciation and de-glaciation during the late Quaternary overlie the Metropolis Formation. Each loess deposit has a subsequent soil (i.e., "paleosol", or buried soil) developed near the top of the deposit denoting an interglacial period of relative landscape stability (Follmer, 1996; Grimley et al., 2003). The three late Pleistocene loess deposits that have been recognized on a regional scale are thought to have been deposited between approximately 200,000 and 10,000 years ago (200 to 10 ka). Regional models interpret the loess deposits as follows: Loveland Silt (180 to >125 ka), Roxana Silt (55 to 28 ka), and Peoria Loess (25 to 10 ka) (Curry and Follmer, 1992; Leigh, 1994; Follmer, 1996; Grimley et al., 2003; Forman and Pierson,, 2002; Bettis III, et al., 2003). Locally near the PGDP facility, these deposits are as much as 20 feet (6.1 m) thick. If faulting has occurred within the time frame of loess deposition (200 to 10 ka), one or more of the loess units should exhibit deformation.

The Loveland Silt is found stratigraphically below the Roxana Silt and Peoria Loess, along the major rivers of the Midwest (Follmer, 1996; Grimley et al., 2003). It generally is defined as silt, that is strongly mottled in yellow, orange, and gray. It is massive to blocky and commonly sandy, especially near its base, and has the same overall silty texture as the Peoria Loess (Nelson et al., 2002). The Loveland Silt is primarily aeolian in origin and was deposited during the late Illinoian glaciation (marine isotope stage 6), and has an age of about 125 to 180 ka.

The Roxana Silt is regionally defined as a pinkish brown to tan loess and colluvial silt that was deposited throughout much of the central United States during the middle Wisconsin (Follmer, 1996). The lower portion of the Roxana Silt has been interpreted as colluvial in origin, whereas the main body of Roxana

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Silt is believed to be loess that originated through deflation of valley-train deposits of the ancient Mississippi River between 55 and 28 ka (Curry and Follmer, 1992; Leigh and Knox, 1993).

The Peoria Loess is yellowish brown to grayish brown and is common throughout the central United States as the youngest surface-mantling loess unit. This unit was derived largely from valley-train deposits between about 25 and 10 ka along the Illinois and Mississippi valleys (Follmer, 1996; Hansel and Johnson, 1996). The Peoria Loess mantles the bluffs and ridges south of the Ohio River and at the proposed C-746-U landfill.

3.3 Regional Paleosols

Paleosols of regional extent developed during the interglacial periods, and in between the three late Pleistocene loess packages. These paleosols provide stratigraphic markers for assessing Holocene faulting at the proposed landfill expansion. The presence of buried paleosols, as well as the soil horizons near the ground surface ("relict soil"), indicates intermittent periods of relative landscape stability during which original deposits are altered by pedogenesis (soil formation; Birkeland, 1986). Development of the soil horizons is a function of five primarily factors: climate, biological activity, relief (topography), parent material and time (Jenny, 1941). Because of these factors, soil-forming (pedogenic) processes acting through geologic time produce soil stratigraphic characteristics that can be used to correlate deposits that have undergone similar depositional and post-depositional histories. Thus, buried paleosols can be correlated over fairly large distances if the soil-formation factors are taken into account, and can be used as local or regional stratigraphic markers to assess the presence or absence of deformation. For this study, paleosols provide the means to estimate deposit age through regional correlation with dated paleosols, and to evaluate fault displacements through correlations of soil horizons across fault zones.

Geologic and pedologic studies in the Midwestern United States have identified several prominent paleosols developed in Quaternary deposits. From oldest to youngest, the paleosols include the: (1) Yarmouth Geosol, which developed in the lower part of the Metropolis Formation and upper part of Mounds Gravel (Esling et al., 1989; Grimley et al., 2003); (2) Sangamon Geosol, which developed into the upper part of the Metropolis Formation and the Loveland Silt; (3) Farmdale Geosol, which formed in the Roxana Silt, and the (4) modern-day soil profile developed in the Peoria Loess. The Yarmouth Geosol formed over an extensive period of time and is broadly correlated with Marine Isotope Stages (MIS) 7 to 11, the Crowley's Ridge silt (Grimley et al., 2003), and parts of the Metropolis Formation. In most places, the Loveland Silt is modified by formation of the Sangamon Geosol that developed during

the Sangamon-time interval from about 65 to 125 ka (Grimley et al., 2003; Forman and Pierson, 2002). The Sangamon Geosol is characterized by a thick solum, an increase in illuviated clay with depth that is derived from the loess parent material, clay films, red hue (7.5YR or 5YR hues), prominent clay seams along prismatic and angular blocky peds, and well-developed zones of manganese oxide development. Development of the Sangamon Geosol ended during the deposition of the Roxana Silt upon which the Farmdale Geosol is developed. The Farmdale Geosol is considered to have formed in a cool climate over a period of about 3,000 to 5,000 years between 30 and 25 ka before the last glaciation (Follmer, 1983; Forman and Pierson, 2002).

The Peoria Loess overlies the Roxana Silt and is estimated to be between 25 and 10 ka in age (Forman and Pierson, 2002). Soils developed in the Peoria Loess and mapped previously at the C-746-U landfill are predominantly silt loams with moderately developed B-horizons that began developing about 12,000 years ago. The major soil series developed in the Peoria Loess at the site include the Calloway, Henry and Grenada silt loams (U.S. Department of Agriculture, 1976) that typically form on level to gently sloping hillsides. The surface soils consist of a moderately developed fragipan, and a relatively compact, unaltered silty clay loam that ranges from 66 cm (below the ground surface) to 125 cm in depth.

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4.0 PREVIOUS SITE-SPECIFIC C-746-U LANDFILL GEOLOGIC STUDIES

An initial geologic and geotechnical study for the C-746-U landfill and subsequent seismic reflection survey provide valuable information on site stratigraphy and inferred faults lying beneath the site. The following section provides a summary of the findings of the previous investigations performed at the landfill, and Woolery's (personal communication, 2005) re-interpretation of seismic felecion data previously acquired at the site.

4.1 SAIC (1994)

A geotechnical and geologic investigation performed by SAIC (1994) prior to construction of the existing C-746-U landfill included completion of 27 shallow (12 to 32 ft; 3 to 9.8 m) and 5 deep (85 to 90 ft; 26 to 27 m) exploratory borings across a former low ridge (Plate 1). Pre-development maps show the former site topography consisted of a relatively narrow northeast-trending ridge bounded by northeast trending creeks (e.g., Little Bayou Creek) and dissected by east and west-trending swales (SAIC, 1994) (Plate 1). The swales drain toward Bayou and Little Bayou Creeks located to the west and east of the site, respectively (Figure 5). The Bayou and Little Bayou Creeks drain to the Ohio River located north of the site.

Geotechnical borehole information indicate that the upper 30 feet (9 m) of stratigraphy at the site coarsens with depth, and includes a shallow (approx. upper 15 feet [4.6 m]) surficial package of loess directly overlying massive silt and clay (approx. 15 to 30 feet [4.6 to 9 m]) with occasional interbeds of silty sand to clayey sand (inferred as Metropolis Formation) (Figure 7). Particle-size data from the loess and upper part of the Metropolis Formation, within 5 to 15 feet (1.5 to 4.6 m) of the ground surface, indicate the clay fraction increases with depth (see Tables E5 and E6 of SAIC, 1994). This increase in clay likely represents, in part, the presence of the Sangamon Geosol that overprints much of the upper part of the Metropolis Formation. In addition, grain size analyses (see Figure 9 of SAIC, 1994) indicate the presence of two relatively continuous sandy units between 15 and 18 feet (4.6 and 5.5 m) below the ground surface (bgs) (i.e., contains as much as 20-25% sand) and 22 and 25 feet (6.7 and 7.6 m) bgs (i.e., contains as much as 60% sand) that are part of the Metropolis Formation (Figure 7). These paleosols and sandy units, in part, are marker horizons by which to assess tectonic-related deformation for the fault hazard investigation (this study).

4.2 Blackhawk Seismic Reflection Survey (2003)

Because of the recent studies that identified faulting at and near the vicinity of the PGDP (SAIC, 2004; Woolery and Street, 2002), the Commonwealth of Kentucky requested that a fault investigation be conducted at the proposed C-746-U landfill expansion. Consequently, a high-resolution horizontal shear wave (S-wave) seismic reflection survey was acquired at the C-746-U landfill by Blackhawk GeoSciences (Blackhawk, 2003). The purpose of the study was to identify potential subsurface anomalies suggestive of young and near-surface faulting, and to intersect faults striking predominantly northeast through the existing and proposed C-746-U landfill site. The survey consisted of two S-wave lines (SL-1 and SL-2) oriented parallel to the present-day northern and eastern boundaries of the landfill (Plate 1). Seismic line SL-1 is oriented north-south and is about 1,800 feet (550 m) long. Seismic line S-2, oriented east-west, is about 1,400 feet (427 m) long.

Blackhawk's (2003) interpretation of the seismic data includes identification of two clearly discernable buried reflectors correlating with the top of the local hydrologic unit known as the Regional Groundwater Aquifer (RGA; this unit is regionally correlated with the Mounds Gravel) at about 70 to 40 feet (21 to 12 m) bgs and the top of the McNairy Formation at about 60 to 80 feet (18 to 24 m) bgs (Figures 8 and 9). The reflector between 30 and 40 feet (9 and 12 m) bgs is interpreted as the top of a coarse-grained unit that presumably lies within the upper part of the Mounds Gravel or lower part of the Metropolis Formation. Based on discontinuities of these reflectors and incoherence patterns in the seismic data, Blackhawk (2003) interpreted two near-vertical faults, designated Fault 1 and Fault 2 (Figures 8 and 9). These faults are inferred to have northeasterly strikes with down-to-the-northwest vertical separation across the northern and central part of the C-746-U landfill footprint (Plate 1). Blackhawk (2003) shows displacements of the McNairy Formation by as much as 30 feet (9 m) and of a distinct overlying reflector within the Metropolis Formation or Mounds Gravel by as much as 20 feet (6.1 m). Blackhawk (2003) also interprets faulting within the older units (Metropolis Formation and Mounds Gravel), and suggests that faulting may extend within 15 to 20 feet (4.6 to 6.1 m) of the ground surface; however, the age of the shallowest units where deformation is interpreted could not be determined given the resolution of the data.

4.3 Alternative Interpretation of Seismic Lines SL-1 and SL-2

Prior to this study, SAIC (1994) borehole data and Blackhawk (2003) seismic lines provided the best subsurface information for delineating the locations and styles of possible deformation in the

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investigation area. These data are used in defining the target areas for detailed borehole arrays described in section 5.0 below. As part of this fault hazard investigation, Dr. Ed Woolery of the University of Kentucky provided an independent review of Blackhawk (2003) seismic lines SL-1 and SL-2 (Woolery, personal communication, 2005). Based on offset reflectors, abrupt terminations of strong reflection signals, residual diffraction patterns, abrupt changes in reflection dips, and associated folds the re-analysis suggests a more complex fault zone than previously interpreted by Blackhawk (2003). Woolery finds numerous normal and reverse faults, as well as warped and folded stratigraphy that collectively suggest a transpressional style of deformation (Figures 8 and 9). In general, the seismic lines exhibit episodic tectonic-related deformation that extends above the Paleozoic bedrock into overlying unconsolidated Quaternary deposits and close to the base of the inferred loess deposits. Deformation zones identified from the interpretation of the seismic lines are discussed below.

4.3.1 Alternative Interpretations of Seismic Line SL-1

In line SL-1, three primary zones of deformation (DZ1-1 to DZ1-3) are interpreted. The deformation zones of Woolery (personal communication, 2005) are shown in Figures 8 and 9.

4.3.1.1 Deformation Zone DZ1-1

Deformation zone DZ1-1 is about 260 feet (79 m) wide and lies along the southern part of line SL-1 between shot points UKK-1-100 to-235 (Figure 8). Blackhawk (2003) did not interpret faulting in this area. The zone of deformation is characterized by a series of steep, north- and south-dipping faults that exhibit both normal and reverse displacement. The northern margin of the deformation zone is bordered by a prominent zone of incoherent reflectors truncated near shot point UKK-1-235. Faults within deformation zone DZ1-1 have inferred displacements of as much as 25 feet (7.6 m) within the Mounds Gravel, whereas vertical displacements are less than about 3 feet (0.9 m) across disrupted reflectors representing strata likely within the Metropolis Formation.

4.3.1.2 Deformation Zone DZ1-2

Deformation zone DZ1-2 is relatively narrow (160-ft-wide;49-m-wide) and is between shot points UKK-1-350 to-430 (Figure 8). This zone is roughly coincident with Fault 2 of Blackhawk (2003), and is defined by a steep, north-dipping fault that extends upsection into the Metropolis Formation. Directly south of the fault is a region of incoherent reflectors that does not permit the interpretation of a readily identifiable or laterally continuous reflectors for assessing fault location.

4.3.1.3 Deformation Zone DZ1-3

Deformation zone DZ1-3 is about 120 feet (36.6 m) wide and is located at the northern end of line SL-1 (Figure 8). This portion of the seismic line is characterized by a loss of coherency between shot points UKK-1-785 to-905 (Figure 8). Although Blackhawk (2003) did not interpret faulting along this zone, Woolery (personal communication, 2005) identified two boundary faults that exhibit an apparent southside-down vertical separation. The northernmost boundary fault is interpreted to extend into the Metropolis Formation with a total vertical separation of about 2 feet (0.61 m). The overall structural style of deformation interpreted across deformation zone DZ1-3 is extensional. Because this area of the proposed landfill expansion lies within a forested region it was not investigated as part of the surface-fault rupture investigation.

4.3.2 Alternative Interpretations of Seismic Line SL-2

Re-interpretation of seismic line SL-2 suggests the presence of two primary deformation zones (DZ2-1 and DZ2-2) which respectively coincide with Faults 1 and 2 of Blackhawk (2003) (Figure 9).

4.3.2.1 Deformation Zone DZ2-1

Deformation zone DZ2-1 lies along the central part of seismic line SL-2 and is about 90 feet (27 m) wide and is located between shot points UKK-2-315 to-360 (Figure 9). Three relatively high-angle fault strands are interpreted as offsetting shallow reflectors within the Mounds Gravel and Metropolis Formation. The primary fault, which is located near shot point UKK-2-360, dips southerly and branches upsection into a half-flower structure accompanied by two north-dipping faults that offset the Metropolis Formation. Deformation zone DZ2-1 corresponds with Fault 1 of Blackhawk (2003)

4.3.2.2 Deformation Zone DZ2-2

Deformation zone DZ2-2 lies along the eastern part of seismic line SL-2 and is about 420 feet (128 m) wide and is located between shot points UKK-2-509 to 719 (Figure 9). This deformation zone represents the most prominent anomaly of the seismic reflection survey. Four possible high-angle north and south-dipping fault strands exhibiting both normal and reverse displacement are interpreted across deformation zone DZ2-2. The Mounds Gravel is interpreted as being displaced as much as 10 feet (3.0 m), whereas seismic reflections believed to be in the Metropolis Formation exhibit vertical displacements up to 2 feet 0.61 m). The pattern and style of deformation interpreted along this section of line SL-2 is suggestive of

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a "positive" flower structure, and thus may represent transpressional deformation. Deformation zone DZ2-2 coincides with Fault 2 of Blackhawk (2003).

5.0 ANALYTICAL APPROACH AND METHODS

The primary objective of this fault hazard evaluation of the proposed the C-746-U landfill expansion is to intersect shallow deposits and soil horizons, to assess their age and lateral continuity, and to identify the absence or presence of fault-related vertical displacements. A total of 86 DPT cores were collected at variable spacings along parts of seismic lines SL-1 and SL-2 to specifically target possible deformation zones identified by Blackhawk (2003), and Woolery (personal communication, 2005) (Plate 1). In addition, a total of 12 optically stimulated luminescence samples were collected from the cores to provide age estimates of the shallow loess deposits by which to assess active faulting (i.e., within the last 11,000 years; Holocene Epoch; see section 5. 3). Our approach was to span these zones with initial borehole spacings of 40 feet (12.2 m), followed by smaller intervals of 20 and 10 feet (6.1 and 3.0 m) in areas containing possible fault-related features interpreted from seismic data, or inferred from preliminary cross-sections developed from initial boreholes. The DPT core locations are indexed to the shotpoint numbers along seismic lines SL-1 and SL-2, and are designated according to the previous shotpoint designations.

The elevations along the two transects range from approximately 367 feet (112 m) above mean sea level (msl) at the eastern end of seismic line SL-1, to 372 feet (113 m) above msl at the southern end of seismic line SL-2 (Plate 1). The borehole transects traverse an area that is readily accessible, and currently is vegetated with grasses or covered with gravel. Both transects are outside of the C-746-U landfill security fence. The locations of the direct push cores and geophysical profiles are provided in Plate 1. The areas of detailed subsurface studies do not span the entire region of interpreted faulting by Woolery (personal communication, 2005), although the investigation intersects zones of deformation considered to be the most prominent and distinct on the interpreted seismic reflection profiles.

Miller Drilling Company collected 86 direct push technology (DPT) Geoprobe cores along the two transects to explore subsurface conditions at the site. The cores were collected as continuous cores. Four of the 86 DPT cores were collected in light-sensitive sample liners, placed within a PVC pipe and specially handled for optical stimulated luminescence (OSL) analysis. A Geoprobe, a hydraulically-powered, soil probing machine that utilizes static force and percussion to advance small-diameter soil sampling tubes collected the cores. All the DPT cores extended to a depth of 30 feet (9 m) and consist of approximately 1 and 11/16-inch-diameter samples within six (6), 5-foot-long (1.5 m) sections at each borehole location. The core samplers extended into undisturbed stratigraphy below the base of the

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sampler by static force from the Geoprobe machine. Clear, thin-walled plastic liners within the Geoprobe sampler tubes preserved the sediment cores. The sampler tubes were labeled, sealed and placed in wooden core boxes for shipment to the Kentucky Geological Survey (KGS) core facility in Lexington. Following the collection and labeling of each DPT core, the entire depth of each borehole was sealed with a bentonite/Portland cement grout mix. Following temporary storage of the cores on site, the WLA staff geologist and SAIC field operations manager containerized and padded the cores to maintain their integrity for shipment to the KGS core facility. The field staff followed standard chain-of-custody (COC) procedures throughout the sampling and transportation process of the cores. KGS project personnel at the KGS core library checked the cores and COC documents prior to accepting the cores. There were no inconsistencies encountered during transportation of the cores and chain-of-custody procedures.

Project geologists, scraped clean, and described the 30-ft-long (9 m) continuous cores in detail to identify stratigraphic marker horizons, buried soils and any concealed evidence of faulting. The project geologists placed sets of five to six DPT cores side-by-side and in sequential order for detailed characterization and direct correlation of soil and deposit stratigraphy between cores. Using the Unified Soil Classification System and standard geologic and pedologic observations (see site work plan dated June 21, 2005) geologists logged the cores. This logging procedure produced preliminary geologic cross-sections based on the DPT data and allowed confirmation of laterally continuous horizontal strata among adjacent borings.

5.1 Uncertainty Estimation

Geologic cross sections developed from the DPT data incorporate the uncertainty in the location of stratigraphic boundaries between the primary geologic units at the site. In estimating the elevations of the basal contacts of the stratigraphic horizons, six sources of uncertainty are considered: (1) actual stratigraphic variability; (2) mechanical error in measurement (assumed to be zero); (3) elevation error in survey of monuments; (4) core compression and/or recovery; (5) contact correlation and interpretation; and (6) presence of inclined basal contacts. The natural stratigraphic variability (#1) of each basal contact is assumed to be adequately represented in the 86 borehole samples. Mechanical uncertainty (#2) is considered minimal, if present at all, because the depth of each contact was measured numerous times and/or reviewed by several geologists during our internal review process. Uncertainty in elevation (#3) from the licensed survey is considered to be within the nearest 0.1 foot (0.03 m) horizontally and 0.01 foot (0.003 m) vertically, and thus is considered negligible in this analysis. Of these potential contributors to

the uncertainty in the basal contact elevation error, three types of uncertainty (#4 to #6) need to be critically evaluated.

Thus, the sources of basal contact elevation error that need to be addressed include: (#4) core compression and/or recovery, (#5) contact correlation and interpretation (i.e., distinct vs. gradational), and (#6) the presence of inclined basal contacts. The methods for determining these sources of uncertainty are described below. Core compression and recovery (#4) was documented for every core in this study during core collection and core analysis phases. Core compression often accounts for most, if not all, of the "missing" core where recovery was less than 100% for each 5-foot (1.5 m) core sample. Since the DPT method obtains cores by pushing the sampling tube into the ground, it is not uncommon for some of the soils to compress as they enter the sample tube. For example, during a 5-ft (1.5 m) sample run, only 4-ft (1.2 m) of core may be recovered from the sample tube with the 1-ft (0.3 m) of "missing core" representing a 20% compression of the 5-ft (1.5 m) soil due to sampling method. For each basal contact, we recorded the amount of compression (depth measured vs. amount of core recovered) and used this value as the range of uncertainty for any basal contact encountered within that 5-foot (1.5 m) sample interval. Compression and recovery uncertainty values ranged from 0.1 feet (0.03 m) to as much as 1.6 feet (0.5 m). The uncertainty contact correlation and evaluation (#5) was determined to estimate the geologist's confidence in choosing each basal contact. Essentially this value is a measure of how difficult it was to identify each contact. This uncertainty (#5) was evaluated by taking an estimate independently from each geologist that logged the core, and taking the average uncertainty value for each basal contact. The average uncertainty values of the basal contact are listed in Table 1. Significantly non-horizontal or inclined basal contacts (#6) were evaluated for selected basal contacts only. Based on core logging, the basal contact of unit 5.2 is erosional, and the only significantly non-horizontal (i.e., steeply inclined) contact. There were 5 significantly non-horizontal basal contacts with uncertainties ranging between 0.4 and 0.5 feet (0.12 and 0.15 m).

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Table 1. Average Uncertainty in Contact Correlation by Stratigraphic Unit

Basal Contact	Uncertainty (feet)
Base of Upper Peoria, unit 1	0.6
Base of Lower Peoria, unit 2	0.4
Base of Roxana Silt, unit 3	0.4
Base of Unnamed Intermediate Loess, unit 4	0.3
Base of Metropolis, unit 5.1	0.5
Base of Metropolis, unit 5.2	0.4

Overall, the greatest source of uncertainty in estimating the basal contact elevation is from (#4) core compression, and (#5) a lack of a distinct basal contact. For developing the geologic cross sections, the largest uncertainty of those described above (#4, #5, & #6) was selected as the range in possible uncertainty. For example, if 1 foot (0.3 m) of core compression (#4) represented the largest error for a basal contact, then an error of 0.5 feet (0.15 m) was placed on either side of the noted basal contact elevation. This is represented by an error bar at each basal contact for each DPT core on the geologic cross-sections discussed in Section 6.0.

5.2 Estimated Ages of Deposits

The assessment of fault activity requires an understanding of the Quaternary and depositional history of the site area, and a means to estimate the age of stratigraphic deposits or bedrock units. In assessing the age of surficial deposits at the C-746-U landfill, we use: (1) stratigraphic position and cross-cutting stratigraphic relations; (2) radiocarbon analyses of eight charcoal-like fragments collected from near-surface deposits encountered in the DPT cores; and (3) optical stimulated luminescence (OSL) analyses of 12 sediment samples collected from DPT cores. Pedogenic development also provided a means to assess relative ages of deposits among the core samples, and to obtain correlative ages by comparison with well-dated soil chronosequences in the region (i.e., Farmdale vs. Sangamon Geosols).

During the logging procedure, material resembling charcoal was noted on log forms and subsequently collected for radiocarbon analysis. The radiocarbon method is applicable primarily in dating organic material formed from photosynthetically fixed carbon within the last 50,000 to 60,000 years (Trumbore,

1998). The dimensions and angularity of each charcoal sample, as well as interpretation of the type of carbon extracted (e.g., detrital charcoal, wood, stick, seed, root, etc.) were noted on a sample log form. Individual carbon samples were wrapped securely in aluminum foil, which was labeled with a sample designation, collection date, project description, and placed in a sealed plastic bag. Individual charcoal samples were further screened for likelihood of containing carbon by analyzing the samples under a microscope. Out of a total of 46 samples, eight (8) possible charcoal samples were selected and submitted to Beta Analytic, Inc. (Miami, Florida) for radiocarbon analysis using the accelerator mass spectrometry (AMS) technique. The very small radiocarbon samples (between 1.3 and 189 milligrams) were treated with acid and base washes, followed by combustion prior to analysis. Following the combustion phase, Beta Analytic noted that there was not enough carbon available for the AMS technique, or the resultant material presumed to be charcoal was primarily iron or magnesium oxides comprised of fine-grained silt and clay particles. As a result, none of the eight (8) samples was adequate for radiometric analyses. The age estimates of the deposits encountered at the site are based on optically stimulated luminescence (OSL) samples derived from loess units, as well as correlative age estimates based on relative soil development.

Twelve (12) OSL samples were collected from the DPT cores and submitted to the University of Illinois, Chicago (UIC) for analyses by Dr. Steve Forman, director of the UIC OSL laboratory. The application of the OSL method closely parallels the application of carbon-14 dating and provides a complimentary dating range spanning a few centuries to limits in the range of 2 to 10 percent. Cores collected in light-sensitive sleeves were transported to UIC, where WLA opened and logged the core in the UIC OSL laboratory. Each core submitted for analysis was collected adjacent to a "pair" core that was logged in detail at the KGS library. Both cores for each OSL analysis were shipped from KGS and re-opened at UIC, and used as a guide for evaluating stratigraphic and pedologic boundaries during the OSL analysis. Samples identified for OSL analysis in both the light-sensitive and regular cores were selected based on proximity to stratigraphic and pedogenic boundaries, and the preferred absence of features related to bioturbation and other pedogenic processes. The results of the OSL analyses are presented in Table 2, and a description of the OSL analytical methods can be found in Forman and Pierson (2002).

5.3 Survey of Geoprobe Locations

Prior to drilling, Dummer Surveyors surveyed and marked the core locations with labeled wooden stakes. The proposed DPT core locations coincided with shot point designations from the Blackhawk (2003) seismic lines SL-1 and SL-2. Dummer Surveyors also preformed a civil survey of the final borehole

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locations and elevations following the drilling program to provide the location and elevation of the DPT boreholes. The elevations of each borehole are used for stratigraphic correlation among boreholes along the two transects. Elevation measurements are within the nearest 0.1 foot (0.03 m) horizontally and 0.01 foot (0.003 m) vertically, and are tied to the PGDP coordinate system and U.S. Coast and Geodetic Survey monuments.

6.0 EVALUATION OF LATE PLEISTOCENE STRATIGRAPHY

The DPT cores collected for this surface fault rupture investigation exhibit seven primary stratigraphic and pedologic late Pleistocene horizons. The late Pleistocene stratigraphic deposits consist of laterally continuous fining upward fluvial packages overlain by loess. The age of the surficial deposits encountered in the DPT cores are as much as 75.5 ka. Geologic cross-sections depicting subsurface conditions underlying the western and northern margins of the landfill provide the basis for assessing the absence or presence of Holocene (within the last 11,000 years) faulting at the site. From the cross-sections, as many as four (4) folds or warps, and 21 features with representative elevation changes across stratigraphic and/or pedologic boundaries are inferred from the Geoprobe data. However, no actual fault surfaces, slickensides, or fault gouge was observed in any of the cores; interpretations of possible fault displacements are based primarily on elevation changes among the various DPT core locations. These elevation changes can also be explained by original topographic variability and/or erosional contacts between strata. The estimated amount and style of vertical separation of the features are summarized in Tables 3 and 4 and discussed in Section 6.2. Most of the anomalous features are limited to horizons within the Metropolis Formation and unnamed intermediate loess, however it is possible that several of the fault-like features extend upward close to the base of the Peoria Loess. The near-surface stratigraphy encountered in the DPT cores, and possible near-surface structural features interpreted from the geologic cross section, are discussed in the following sections.

6.1 Near-Surface Stratigraphy at the C-746-U Landfill

Near-surface stratigraphy at the site is based on a review of previously drilled geotechnical boreholes and seismic reflection profiles, coupled with detailed descriptions of 86 DPT cores collected as part of this fault hazard study. At least seven distinct stratigraphic horizons (units 1 to 4 and units 5.1 to 5.3) are recognized in the upper 30 feet (9.1 m) of material at the C-746-U landfill. The upper three horizons are generally nearly flat-lying and mantle pre-existing topography. The lower horizons occasionally have subtle to abrupt undulations of stratigraphic contacts that reflect fluvial depositional processes. Between depths of about 19 and 30 feet (5.8 and 9.1 m) bgs, three stratigraphic horizons (units 5.1 to 5.3) are present within the Metropolis Formation. This part of the Metropolis Formation (approximately 25 to 30 feet [17.6 to 9.1 m] bgs) is composed primarily of interbeds of coarse-grained sand and gravel with channel-like morphology and cut and fill structures. These deposits were also interpreted at a similar depth in the geotechnical boreholes for the design of the landfill (SAIC, 1994) (Figure 7). The Metropolis

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Formation fines upsection, between about 25 and 19 feet (7.6 and 5.8 m), and consists of strongly mottled clay, silt and fine-grained sand with discontinuous interbeds of sand and sandy gravel and likely mixes, in part, with the Loveland Silt. The Sangamon Geosol overprints the upper section of the Metropolis Formation as prominent subvertical clay seams and orange and red mottles. Directly overlying the Metropolis Formation is a 15-to 19-ft-thick (4.6-to 5.8-m-thick) loess package that includes an unnamed loess, the Roxana Silt and the Peoria loess. As noted below, the Peoria Loess is herein subdivided informally into lower and upper parts.

6.1.1 Upper Peoria Loess (unit 1)

The uppermost surficial deposit in the study area is the Peoria Loess. At the site, Peoria Loess is subdivided into two units (units 1 and 2) based on the presence of a weak paleosol in the middle of the loess package. The Upper Peoria Loess (unit 1) is about 6 feet (1.8 m) thick and is characterized as a brown (10YR5/3) to yellowish brown (10YR5/8) clayey silt (up to 15% clay) to clean silt with minor traces of clay. In general, unit 1 is massive and speckled (3-5%) with small (<3mm) angular to sub-rounded blackish nodules of iron-manganese oxyhydroxides. Some cores have poorly developed brown-orange iron-oxide zones defined as mottles and fine nodules. The lower boundary of unit 1 is distinct when well expressed, but is often diffuse to gradual, because of bioturbation, compression from DPT sampling, or the poor expression of an underlying paleosol developed in the Lower Peoria Loess (unit 2). OSL dating of unit 1 yields a range in age between 25.2 and 15.4 ka, consistent with a Peoria Loess age (Table 2). As noted in Section 3.0, the Peoria Loess is approximately 12 to 25 ka (Forman and Pierson, 2002, Grimley et al., 2003).

The Upper Peoria Loess is overprinted by "modern" soil that began developing about 12 ka after the cessation of loess deposition (Forman and Pierson, 2002; Grimley et al., 2003). The soil consists of a thin A-horizon with minor organic accumulation, and a distinct whitish silt-rich E-horizon present at about 1 to 2 feet (0.3 to 0.6 m) bgs. Clay content increases below the E-horizon to as much as 15% where the loess becomes mottled at about 2 to 4 feet (0.6 to 1.2 m) bgs. The C-soil horizon is noted by the decrease in clay content, relatively clean, massive silt with little to no mottling.

6.1.2 Lower Peoria Loess (unit 2)

The Lower Peoria Loess, unit 2, is generally about 3 feet (0.9 m) thick, and the top of the unit is between 5.0 to 9.0 feet (1.5 to 2.7 m) below the ground surface. The Lower Peoria Loess is a brownish yellow

(10YR6/6) to yellowish brown (10YR 5/4-5/8) silt to clayey silt. The upper portion of the loess is weakly to moderately clay-rich and is interpreted to represent a slight illuvial clay accumulation. The upper portion of unit 2 has a similar texture and color to the Upper Peoria Loess (unit 1), but is clearly distinct from unit 1 due to the presence of discontinuous and subhorizontal whitish to light yellow silt laminae. A review of literature regarding the base of the Peoria Loess indicates that these discontinuous laminae are interpreted as mixing or welding from bioturbation and colluvial processes with the underlying Roxana Silt (L. Follmer, personal communication, 2005). With the exception of these laminae, unit 2 generally is massive, moist and soft and compresses readily with the DPT sampling technique. Unit 2 mimics present-day topography similar to unit 1 and generally is horizontal across much of the site explored. The basal contact of unit 2 is generally defined by a relatively distinct clean silt with laminae overlying a more clay-rich silt with abundant relict root casts and mottling. On the basis of OSL dating, the age of unit 2 ranges between approximately 30.9 to 21.8 ka (Table 2), consistent with the basal age of Peoria Loess and welding with Roxana Silt (unit 3).

A weakly developed soil horizon defines the top of unit 2. The soil horizon is identified in the cores based on the presence of subtle to moderate iron-manganese oxyhydroxides developed within the upper 0.5 feet (0.15 m) of the unit. As the oxyhydroxides decrease down section to less than 5% nodules, there is a corresponding subtle increase in clay content. This paleosol contains few randomly distributed pedogenic interfaces (e.g. fractures) lined with whitish silt.

6.1.3 Roxana Silt (unit 3)

In the study area, the Roxana Silt, unit 3, conformably overlies unit 4 (unnamed intermediate loess) and ranges from about 1 to 2.5 feet (0.3 to 0.76 m) in thickness. The Roxana Silt of the study area lacks the more distinct pinkish hue often reported elsewhere in the central United States (Grimley et al., 2003). Unit 3 consists of a yellowish brown (10YR5/4) to pale brown (10YR6/3) silt with clay and silty clay and contains distinct, discontinuous, yellowish-white thin laminations. Unit 3 also contains prominent clay films along well-developed pedogenic interfaces, a significant clay content compared to overlying loess packages, extensive mottling and well-developed, clay-filled root casts. The basal contact of unit 3 is about 10 to 11.5 feet (3.0 to 3.5 m) below the ground surface. The basal contact generally is defined as distinct and is marked by a thinly laminated yellowish-brown silt with little to no manganese-oxides. It overlies a darker brown to grayish-brown silty clay (interpreted as a buried paleosol) that denotes the top of unit 4 (unnamed intermediate loess). Based on the OSL analyses, the age of unit 3 ranges from 32.1 to

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50.7 ka (Table 2). This age range is consistent with reported ages for the Roxana Silt in the central United States (Grimley et al., 2003).

The Farmdale Geosol and associated mottling and clay development overprints and obscures much of the massive nature of unit 3. The upper part of the Farmdale Geosol is marked by the concentration of fine- to medium-sized iron and manganese oxyhydroxide (5-10%) nodules near the upper contact of unit 3. Down section the soil profile contains prominent dark gray subvertical clay seams filling pedogenic interfaces (clay films) and root casts with zones of prominent oxidation along the seams. The Farmdale Geosol exhibits extensive mottling and moderate clay film development in these DPT cores.

6.1.4 Unnamed Intermediate Loess (unit 4)

Within the study area, unit 4 ranges in thickness from 5.0 to 7.0 feet (1.5 to 2.1 m), and is defined as a yellowish brown (10YR5/6) or light brownish yellow (10YR6/4) to brown (10YR5/3) silty clay with thinly laminated silt interbeds. Although relict bedding is partly preserved in the unit, much of it is destroyed by soil forming processes responsible for the well-developed unnamed paleosols present throughout unit 4. The upper part of the unit is marked by a high clay content and manganese oxide staining and nodule development associated with the paleosol. Subvertical grayish clay-rich seams are pervasive throughout the unit and cross-cutting softer yellowish-brown silty clay to clayey silt. In some cores, a second zone of manganese staining and nodules occur about a foot (0.3 m) below the upper contact with unit 3, and are randomly distributed throughout the unit as fine roundish nodules or grains. Unit 4 is strongly mottled, generally moist and soft (silt) to stiff (clay). The basal contact, between 15 to 19 feet (4.6 to 5.8 m) bgs, is generally distinct and characterized by a distinct, massive silty to silty sand horizon with laminations and/or zones of mixing that directly overlie a darker gray clay-rich unit (interpreted as a buried paleosol possibly related to the Sangamon Geosol). Based on two OSL dates yielded from sediment samples collected at 12.1 to 12.3 feet (3.7 to 3.8 m) and 13.1 to 13.4 feet (4.0 to 4.1 m) in DPT UKK-2-544, the age of the central part of this unit ranges between 53.6 and 75.5 ka (Table 2) suggesting an intermediate loess unit exists directly below Roxana Silt and presumably above the Loveland Silt. The Loveland Silt is reported to be older than 120,000 years (Grimley et al., 2003). The basal age of unit 4 is unknown, and therefore may be more representative of Loveland Silt.

6.1.5 Metropolis Formation (units 5.1 to 5.3)

The Metropolis Formation, considered to be Pleistocene in age, consists of a complex fluvial sequence of clay, silt and sand with some gravel that occurs at about 15 to 19 feet (4.6 to 5.8 m) bgs and extends as deep as 30 feet (9.1 m) bgs (maximum depth explored). Based on the DPT cores, the Metropolis Formation is subdivided into three fluvial subunits (units 5.1 to 5.3) based on textural variations and a general fining-upward sequence observed within each unit. The Metropolis Formation encountered in the cores generally represents an upward-fining fluvial sequence that has been overprinted by multiple paleosols. The upper part is silty and has properties similar to the Loveland Silt (>120,000 years), thus the exact boundary between these stratigraphic boundaries is unclear and may lie within unit 5.1.

6.1.5.1 Metropolis Formation-unit 5.1

Unit 5.1 of the Metropolis Formation is generally about 5 feet (1.5 m) thick. The unit is defined as a light brownish gray (10YR6/2) to grayish brown (10YR5/2) clay to silty clay, which grades down section to a gray (10YR5/1) to light grayish brown (10YR6/2), or grayish brown (10YR5/2) clay with silty to sandy interbeds. The upper part of unit 5.1 is generally massive with occasional faint laminations of silt, which may be representative of the Loveland Silt. Vertical dark blue grey clay seams are extensive within the upper 2 feet (0.61 m) of the deposit and interpreted to be filled root casts within the Sangamon Geosol. The lower part of the unit generally contains thin interbeds of sandy silt, silty sand, silt and clay. Iron-manganese oxyhydroxide staining in unit 5.1 is minor and consists of mottling in the upper part of the unit. The basal contact is distinct and varies between 23 and 30 feet (7.0 and 9.1 m) deep. Based on the age of the overlying loess deposits, the estimated age of the upper part of this unit is believed to be close to the age of the Loveland Silt (i.e., 120 to 180 ka).

6.1.5.2 Metropolis Formation-unit 5.2

Within the study area, unit 5.2 of the Metropolis Formation consists of a reddish yellow (7.5YR6/8 to 6/6) to a strong brown (7.5YR5/8) sandy clay or clayey sand (60 to 70% sand) with clay interbeds. Compared to the overlying clay-rich unit 5.1, this unit is composed of a greater percentage of silt, sand and gravel, and characterized by more pronounced iron oxide staining. The upper part of unit 5.2 often contains thin clay interbeds about a foot (0.3 m) below its upper contact, suggesting the presence of a separate fining-upward sequence. Unit 5.2 often occurs below a depth of 26 to 29 feet (7.9 to 8.8 m), and occasionally extends below the depth of exploration. Unit 5.2 is moist to very moist, soft, stiff to hard, with little or no

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iron-manganese oxyhydroxide staining. The lower portion of the unit is up to 2 feet (0.61 m) thick and often fines upward into a silt or clay.

6.1.5.3 Metropolis Formation-unit 5.3

Unit 5.3 is a bedded, brown (7.5YR5/4) to strong brown (7.5YR5/8), fine- to medium-grained sand and gravel with silt and some reddish yellow (7.5YR6/8) clay laminations. This unit is moist and dense with a distinct orange sand and clay-rich laminae, and often is stained orange-brown. Minor, blue-grey clay subvertical seams that delineate ancient rootcasts or pedogenic clay seams are present throughout the unit. Iron and manganese oxyhydroxide staining is absent or weakly expressed. The base of this unit extends below the depth of subsurface exploration.

6.2 Possible Zones of Near-Surface Deformation

The geologic cross sections prepared from the DPT cores illustrate the lateral continuity of several distinct lithologic loess strata and soil horizons, as well as older fluvial strata, that lie beneath the C-746-U landfill (Plates 2 and 3). These strata and paleosols can be used as strain gauges for assessing: (1) Faults 1 and 2 of Blackhawk (2003), and (2) zones of deformation (e.g., warping, folding and faulting) interpreted from the re-evaluation of Blackhawk (2003) seismic reflection lines SL-1 and SL-2 (Woolery, personal communication, 2005). During the interpretation of the cross sections, anomalous features possibly related to faulting or folding were evaluated with respect to regional seismotectonic models that hypothesize Quaternary faulting along northeast-trending structures (see Section 2.2) (Wheeler, 1997; Nelson et al., 1999; McBride et al., 2002). The long-term deformation pattern of strata beneath the C-746-U landfill is constrained by stratigraphic continuity of the loess and fluvial deposits, and the soils developed in these deposits. The OSL data and regional stratigraphic correlations show that the material encountered is late to middle Pleistocene in age. Because no Holocene deposits are present at the site, any feature interpreted as displacing the Peoria Loess (units 1 and 2 dated between 15.4 and 30.9 ka) is considered conservatively to represent Holocene activity.

Along the western boundary of the landfill, three geologic cross-sections have been constructed to document the subsurface stratigraphy and possible fault-related structure beneath the site. These three sections are designated from south to north as cross-sections UKK-1-1A-1A', 1B-1B' and 1C-1C' and overlap, in part, with seismic line SL-1. Similarly, two cross-sections intersect much of the northern perimeter of the landfill and are designated from west to east as cross-sections UKK-2-2A-2A', 2B-2B',

which partly overlap with seismic line SL-2 (Plate 3). The locations of the cross-sections are shown on Plate 1, whereas Plates 2 and 3 show the geologic cross-sections UKK-1 and UKK-2, respectively. The geologic cross-sections display as many as seven primary stratigraphic horizons in the upper 30 feet (9.1 m) of material underlying the site, and coincide with the unit designations previously described in the above section. The cross-sections have a four times (4x) vertical exaggeration for the purpose of displaying thin stratigraphic and pedogenic horizons, and identifying subtle changes in stratigraphy across the site that might be representative of faulting or folding, or alternatively to original perturbations in the paleo-topography. Accompanying each exaggerated cross-section is an identical section without vertical exaggeration to better illustrate actual field conditions (shown on Plates 2 and 3). The cross-sections allow possible interpretation of as many as four (4) relatively large folds or warps, and 21 features with representative elevation changes across stratigraphic and/or pedologic boundaries. These features (labeled AA to DD; and A to U) are shown graphically in index figures 10a and 10b. The estimated amount and style of vertical separation of the features are summarized in Tables 3 and 4 and discussed below.

6.2.1 Geologic Sections Along Seismic Line SL-1

Cross-sections 1A-1A', 1B-1B' and 1C-1C' correspond with portions of seismic line SL-1. Geologic cross section 1A-1A' is oriented along the southern end of seismic reflection line SL-1 and intersects a narrow zone of previously interpreted steeply dipping faults having a normal sense of motion and coinciding with deformation zone DZ1-1 (Woolery, personal communication, 2005, see Figure 8). One broad warp (feature AA) and five possible distinct changes in the elevations of some stratigraphic contacts (features A to E) are inferred in cross section UKK-1A-1A'. Geologic cross section UKK-1B-1B' lies along the central part of seismic reflection line SL-1 and crosses a broad zone of moderately disturbed reflectors within the Metropolis Formation that are interpreted as being truncated across a near-vertical, north-dipping fault near shot point UKK-1-415 (Figure 8; Fault 2 of Blackhawk, 2003). In section UKK-1B-1B', two subtle warps (features BB and CC) and two features (features F and G) associated with possible vertical elevation changes across stratigraphic boundaries are interpreted (Tables 3 and 4). Geologic cross section UKK-1C -1C' lies along the north-central part of seismic reflection line SL-1 and intersects a steep, north-dipping fault interpreted as Fault 1 by Blackhawk (2003), and a steep, south-dipping fault interpreted by Woolery (personal communication, 2005) (Figure 8). In section UKK-1C-1C to 1C' no broad large possible structures are interpreted, however, five possible discrete features (H to J) associated with elevation changes across stratigraphic boundaries are interpreted.

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6.2.1.1 Zones of Possible Broad Tilting and Warping Along Seismic Line SL-1

As shown on Plate 2, the fluvial stratigraphy within the Metropolis Formation (units 5.1 to 5.3) dips very gently southward in section UKK-1A-1A' and is somewhat suggestive of a weakly expressed monoclinal feature (Feature AA; Figure 10a and Table 3). For example, the base of unit 5.1 decreases in elevation about 5 feet (1.5 m) across the section, indicating an apparent southerly dip of about 2°. However, this prominent dip is not present in higher stratigraphic boundaries coinciding with unit 4 and the younger loess packages, suggesting that the feature, if present, formed prior to deposition of units 1 to 3. The approximate location, sense and amount of tilt of the Metropolis Formation (units 5.3 to 5.1) is consistent with deformation interpreted in line SL-1 between shot points 180 and 215 (Woolery, personal communication, 2005).

Based on north-dipping basal contacts of 5.2 and 5.1 in cross-section UKK-1B-1B' it is possible to interpret two relatively broad north-facing warps exhibiting northside-down separation. The two warps (features BB and CC) are interpreted at the southern and northern ends of the geologic profile (Figure 10a). A possible north-facing warp, feature BB, interpreted along the southern part of the section lies between DPT cores UKK-1-350 and 380 (Figure 10a). Feature BB is defined by gentle (3°), north dipping stratigraphy associated with units 5.2 and 5.1. The amount of vertical elevation change associated with the tilting is as much as about 3 feet (0.9 m) across the unit 5.2 basal contact. Unit 4 and the overlying late Pleistocene loess (units 1 to 3) packages exhibit an overall gentle north-dip to flat-lying character that is consistent with overlying topography. Feature CC is defined by a gently north dipping panel of Metropolis Formation stratigraphy (units 5.2, 5.1 and 4) located between DPT cores UKK-1-405 and 430 (Figure 10a). These units dip up to about 3° to the south and account for a decrease in elevation of about 2.25 feet (0.69 m). The overlying strata comprising the late Pleistocene loess material generally dip gently north or are nearly flat-lying.

6.2.1.2 Distinct Elevation Changes in Stratigraphy Along Seismic Line SL-1

Based on the geologic cross-sections constructed from DPT data it is permissible to interpret as many as 10 features (features A through J) aligned with moderate to abrupt vertical changes in elevations across stratigraphic boundaries (Figure 10a). Of the ten (10) possible features, seven (7) are constrained to stratigraphic horizons equal to or older than unit 4 (53.6 to 75.5 ka). It is possible to interpret as many as three features (features G, I and J) projecting into the Roxana Silt (unit 3) and Peoria Loess (units 1 and 2). Each of the ten (10) features possibly associated with fault-related deformation are discussed below.

Feature A is a low-angle, south-dipping feature that can be inferred to intersect DPT cores UKK-1-200 to 220 and exhibits a southside-down, normal sense of vertical separation. Given the range in uncertainty of the basal contact of unit 5.1, there is a relatively abrupt difference in this contact's elevation between DPT boreholes 205 and 210 (Figure 10a). Similarly, the base of unit 4 shows a trough between DPT cores 210 and 220 and a south-facing slope between DPT 215A and 220. Changes in elevation are as much as 2 feet (0.61 m) across the unit 5.1 basal contact and decrease upsection to about 1.75 feet (0.53 m) across the base of unit 4. If these features are related to fault deformation, the fault would dip gently (20° to 30°) to the south. However, an absence of a similar south-facing dip panel across the basal contact of unit 3 (within a resolution of ~0.4 feet [~0.12 m]) indicates an absence of deformation of the Roxana Silt (Figure 10a and Plate 2).

Distinct vertical changes in elevation across stratigraphic boundaries associated with basal units 5.2 and 5.1 contacts between DPT cores UKK-1-205 and 215A defines the location of feature B (Figure 10a). Feature B dips north about 40° and exhibits as much as about 2 feet (0.61 m) of northside-up vertical separation across the base of unit 5.1, consistent with a reverse sense of separation. This feature does not extend upsection into the overlying nearly flat-lying stratigraphy of unit 4 (unnamed intermediate loess) within a limit of resolution of ~0.3 feet (0.09 m).

Feature C coincides with an abrupt northerly dip of the stratigraphic basal horizon of unit 5.2 that lies between DPT cores UKK-1-215A and 220 (Figure 10a). This feature is relatively steep (80° to 90°) and exhibits a north-side down vertical separation of as much as ~1.75 feet (0.53 m) across the base of unit 5.2, consistent with a normal sense of separation. Feature C does not project upsection across the overlying stratigraphic boundary of unit 5.1 within a resolution of ~0.5 feet (0.15 m).

Feature D is interpreted as a near-vertical (80° to 90°) feature that separates the south-dipping (~3°) stratigraphic basal contacts of units 5.2 and 5.1 between DPT cores UKK-1-220 and 225 (Figure 10a). The southside-down vertical separation is subtle and can be interpreted to be as much as ~1.25 feet (0.38 m). This feature does not extend upward into unit 4 which dips north, or the overlying, relatively flat-lying loess deposits (units 1 to 3) within a resolution of about 0.3 feet (0.09 m).

Feature E is a near-vertical feature that is defined by a relatively abrupt change in elevation of the south-dipping (~6°) basal contact of unit 5.2 between DPT cores UKK-1-230 and 235 (Figure 10a). The sense of separation is as much as ~1.75 feet (0.53 m) with a southside-down sense of separation. Feature E

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cannot be projected upsection through the relatively flat-lying stratigraphic boundaries of the upper Metropolis Formation (unit 5.1) and loess deposits (units 1 to 4) within a resolution ~0.3 feet (0.09 m).

Feature F is interpreted as dipping south about 35° and coincides with the broad north-directed tilting (~5°) associated with feature BB near DPT cores UKK-1-350 to 380 (Figure 10a). Feature F vertically separates the basal contacts associated with units 5.2, 5.1, and 4.0 with the apparent separation being reverse and progressively decreasing upsection. The apparent vertical separation is as much as about 3 feet (0.91 m) across the base of unit 5.2 and decreases upsection to about 1 foot (0.30 m) across the basal contact of unit 4. Within a resolution of about 0.4 feet (0.12 m), the overlying loess packages are generally flat-lying to gently north-dipping above this zone and show no evidence of vertical separation. Feature F closely aligns with Blackhawk (2003) Fault 2, but exhibits a reverse sense of separation in contrast to the normal separation interpreted across Fault 2.

Feature G coincides with abrupt north-dipping (~10°) fluvial stratigraphy of the Metropolis Formation and units 5.2 and 5.1 between DPT cores UKK-1-405 to 415 (Figure 10a). The feature aligns with the broad north-facing warp of feature CC, as well as a near-vertical fault interpreted in line SL-1 (deformation zone DZ1-2 of Woolery; Figure 8). Feature G dips approximately 45° to the south, and exhibits a northside-down elevation change that is consistent with reverse separation. Across the basal contact of unit 5.2 there is as much as about 1.75 feet (0.53 m) of vertical separation. The overlying Peoria Loess (units 1 and 2) does not appear vertically offset within a limit of resolution of about 0.4 feet (0.12 m).

Feature H coincides with the interpretation of a shallow (20°) south-dipping feature that coincides with an abrupt inflection (~7°) of the lowermost units (basal contact of unit 5.2) of the Metropolis Formation, and can be projected upsection across the basal contacts associated with units 5.1 and 4.0 between DPT cores UKK-1-530 and 555 (Figure 10a). The feature exhibits a southside-up vertical separation ranging from about 2 feet (0.61 m) across the unit 5.2 contact and decreasing upsection to about 1.25 feet (0.38 m) across the basal contact of unit 4. The sense of separation is consistent with reverse motion along feature H. The overlying loess packages of units 1 to 3 generally are flat-lying within a limit of resolution of ~0.4 feet (0.12 m). Lastly, feature H closely aligns with Blackhawk (2003) Fault 1, however it displays an opposite sense of vertical separation to that of Fault 1.

Feature I lies between DPT cores UKK-1-565 and 575 and coincides with the alignment of a discrete change in elevation across the south-dipping (~12°) basal boundaries of units 5.2 and 5.1 (Figure 10a). The feature dips south approximately 70°, and exhibits a sense of separation that is consistent with a southside-down, normal separation. The estimated change in elevation across feature I is about 3.25 feet (1.0 m) at the basal contact of unit 5.2, and decreases upsection to about 1.25 feet (0.4 m) across the base of unit 5.1. It is possible to interpret as much as 2 feet (0.61 m) of vertical separation within the overlying loess units, however, because several of the inferred separations are based on anomalous contacts in DPT core UKK-1-575, these displacements are considered suspect. Furthermore, the upward projection of feature I from the Metropolis Formation into the overlying loess boundaries is highly questionable, because these cores experienced adverse drilling and sampling conditions imparted by moderately thick artificial fill that may have influenced the location of the stratigraphic boundaries. Lastly, the overall sense of separation is consistent with Woolery's (personal communication, 2005) re-interpretation of seismic line SL-1, however, the apparent vertical separations that are possible across the loess boundaries are considered unlikely.

Feature J is interpreted as a near-vertical alignment of elevation changes across the north-dipping (~6°) base of units 5.2 and 5.1 horizons between DPT cores UKK-1-585 and 590 along the northern end of section UKK-1-C-C' (Figure 10a). The feature is defined primarily by abrupt north-dipping stratigraphic panels of the Metropolis Formation that exhibit a northside-down sense of vertical separation. It is permissible to project feature J upsection into the two lowermost loess packages (units 3 and 2); however, the amount of vertical separation in the overlying loess unit is inconsistent stratigraphically, and suggests that the presence of artificial fill influences the elevation at which the stratigraphic contacts are encountered. Feature J does not align with any previously interpreted faults of seismic line SL-1.

6.2.2 Geologic Cross Sections Along Seismic Line SL-2

Geologic cross-sections UKK-2A-2A' and 2B-2B' coincide with seismic line SL-2, and lie along the northern perimeter of the present-day landfill (Plates 1 and 3). Geologic section UKK-2A-2A' overlaps with a narrow zone of previously interpreted steeply dipping reverse faults, including Fault 1 of Blackhawk (2003), and numerous discontinuities of Woolery (zone DZ2-1; personal communication, 2005) (Figure 9). In section UKK-2A-2A' it is possible to interpret an antiform (feature DD) and numerous distinct elevation changes (features K to P) across stratigraphic boundaries in the Metropolis Formation. Geologic cross-section UKK-2B-2B' lies along the eastern end of seismic reflection line SL-2 and spans a zone of east- and west-dipping faults interpreted by Woolery (zone DZ2-2; personal

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communication, 2005), as well as Fault 2 of Blackhawk (2003) (Figure 9). Overall, cross-section UKK-2B-2B' depicts: (1) relatively flat-lying stratigraphy with no prominent large structural-like features, and (2) five distinct elevation changes (features Q to U) that are limited primarily to unit 4 and older units, except for feature U that extends into Roxana Silt.

6.2.2.1 Zones of Possible Broad Tilting and Warping Along Seismic Line SL-2

It is permissible to interpret an antiform (feature DD) based on east and west tilted fluvial stratigraphy of the Metropolis Formation that span DPT cores UKK-2-319 and UKK-2-379 (Figure 10b). For example, the base of unit 5.2 dips about 6° to the east and west, and changes about 5 feet (1.5 m) in elevation across the antiform. The apparent tilting decreases upsection and is constrained primarily within units comprising the Metropolis Formation and possibly unit 4.0 (unnamed intermediate loess). Feature DD does not propagate into the overlying, gently west-dipping to nearly flat-lying loess packages of units 1 to 3 (Roxana Silt and Peoria Loess). The approximate location and sense of vertical separation, and pattern of tilted stratigraphy is consistent with deformation interpreted in line SL-2 between shot points UKK-2-310 and 360 (Figures 9 and 10b).

6.2.2.2 Distinct Elevation Changes in Stratigraphy Along Seismic Line SL-2

Based on the geologic cross-sections constructed from DPT data, it is permissible to interpret as many as 11 features (features K through U) aligned with moderate to abrupt vertical changes in elevation across stratigraphic boundaries (Figure 10b). Of the eleven (11) possible features nine (9) are constrained to stratigraphic horizons of unit 4 (53.6 to 75.5 ka unnamed intermediate loess) and older deposits. Two features (L and U) may intersect the basal boundaries of the Roxana Silt and Peoria Loess. Each of the eleven (11) features possibly associated with fault-related deformation are discussed below.

Feature K is a steeply dipping feature that coincides with a subtle westward-directed tilt (~9°) of the base of unit 5.1 (Figure 10b). It is unclear if it vertically separates the base of unit 5.2, because where the feature would project down-section and intersect unit 5.2, the basal contact lies beneath the depth of exploration. This feature exhibits a westside-down, normal component of vertical separation that accounts for 1.0 to 1.5 feet (0.3 to 0.46 m) of elevation change across the base of unit 5.1. Feature K does not extend across the base of unit 3.0 within a resolution of about 0.4 feet (0.12 m). Feature K also closely coincides with an east-dipping fault displaying normal displacement of Woolery (personal communication, 2005) but does not overlap with any faults interpreted by Blackhawk (2003).

Feature L coincides with a moderately expressed inflection of units 5.2 to 4.0 that comprise the western limb of a possible antiform (Feature DD) (Feature 10b). Feature L accounts for vertical changes in contact elevations between DPT cores UKK-2-329 to 349. The feature dips about 40° east, and vertically separates west-dipping (~10°) stratigraphy associated with basal contacts of units 5.2 and 4.0 as much as 2.0 and ~1.75 feet (0.61 and 0.53 m), respectively. It is permissible to interpret feature L as intersecting the base of unit 2.0 (Lower Peoria Loess) possibly as much as 1.0 feet, (0.3 m), however unit 1.0 (Upper Peoria Loess) is flat-lying within a resolution of about 0.6 feet (0.18 m). The character of the feature changes upsection near the base of unit 4, where it coincides with an anomalous trough rather than a continuous panel of west dipping stratigraphy. This suggests that it is unlikely feature L projects upward into the overlying Roxana Silt and Peoria Loess.

Feature M coincides with an abrupt west-tilted (10°) basal horizon of unit 5.2 within the Metropolis Formation that projects upsection across the base of a slightly less tilted (<5°) unit 5.1 (Figure 10b). These west-tilted fluvial strata define a near vertical feature consistent with a normal component of separation. Changes in elevation are up to about 2.0 and 1.5 feet (0.61 and 0.46 m) for the base of unit 5.2 and 5.1, respectively. Feature M does not offset the base of unit 4.0, or the upper loess packages, within a resolution of about 0.3 feet (0.09 m). Feature M is closely aligned with a steep west-dipping normal fault interpreted as the main fault in DZ2-1 (E. Woolery, personal communication, 2005) and as Fault 1 (Blackhawk, 2003) (Figure 9).

Feature N dips about 85° east, and coincides with east-dipping (~5°) basal contacts of units 5.2 and 5.1 (Figure 10b). The unit boundaries exhibit as much as ~1.5 feet (0.46 m) of elevation change across the feature, consistent with a down-to-the-east, normal sense of vertical separation. Feature N does not offset the base of unit 4.0, nor the overlying loess packages within a resolution of ~0.3 feet (0.09 m). This possible fault-related feature lies within the fault zone of Fault 1 (Blackhawk, 2003) and DZ2-1 (E. Woolery, personal communication, 2005) but exhibits an opposite sense of vertical separation (Figure 9).

Feature O dips east about 40° and coincides with the west-tilted (~10°) basal boundary of units 5.2, 5.1, and 4.0 (Figure 10b). The basal unit horizons of the Metropolis Formation exhibit down-to-the-west vertical separation that is consistent with a reverse sense of motion. Changes in elevation are as much as ~1.0 foot (0.30 m) across units 5.2, 5.1, and 4.0. The feature is constrained to an anomalous trough present at the base of units 5.2 and 5.1 between cores DPT 354 to 364. Feature O cannot be traced

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upsection into the overlying loess packages within a resolution of 1.9 feet (0.58 m) (units 3 and 2) and 0.6 feet (0.18 m) for the Upper Peoria Loess (unit 1).

Feature P is near-vertical and coincides with the west-dipping (~10°) stratigraphic boundaries of units 5.2, 5.1, and 4.0 between DPT cores 359 and 369 (Figure 10b). Feature P exhibits normal separation with the westside-down and coincides closely with Blackhawk (2003) Fault 1. Changes in elevation are as much as ~2.0 feet (0.61 m) across the base of units 5.2 and 5.1, and decrease upsection to about 0.5 to 1.0 foot (0.15 to 0.3 m) across unit 4.0. Feature P cannot be traced upsection into the younger loess packages of units 3 to 1 (Roxana Silt and Peoria Loess) within a limit of resolution of ~0.4 feet (0.12 m).

Feature Q is near-vertical, and exhibits an elevation change across the basal boundaries of units 5.2, 5.1, and 4.0 between DPT cores UKK-2-519 to 524 (Figure 10b). The vertical separation is as much as 2.0 feet (0.61 m) across the basal of units 5.2 and 5.1, and decreases upsection to about 1.5 feet (0.46 m) at the intersection with unit 4.0. The basis for the presence of this feature is driven strongly by the large (2 feet or 0.61 m) uncertainties associated with the base of units 5.2 and 5.1 observed in DPT core 519; however, this feature does not vertically separate the flat-lying unit 3 (Roxana Silt) within a resolution of about 0.4 feet (0.12 m). Feature Q lies in a region where no faults have been previously interpreted along line SL-2.

Feature R is vertical and coincides with a subtle elevation change across the base of unit 5.2 between DPT cores UKK-2-549 and 554 (Figure 10b). The vertical separation of Feature R is extensional, as much as 1.0 feet (0.30 m), and is expressed as the east-dipping (<5°) basal contact of unit 5.2. This feature does not warp any overlying stratigraphic unit boundaries within a limit of resolution of about 0.5 feet (0.15 m) (unit 5.1). The feature coincides with an east-dipping reverse fault interpreted by Woolery (personal communication, 2005) between shot points UKK-2-539 and 549 (Figure 9).

Feature S dips about 65° west and is defined by an westside-down elevation change across the west-dipping (~2°) base of units 5.2, 5.1, and 4.0 (Figure 10b). The amount of apparent normal separation across the stratigraphic boundaries is as much as 1.0 feet (0.30 m) (unit 4.0), 1.5 feet (0.46 m) (unit 5.1), and 1.0 feet (0.30 m) (unit 5.2). Feature S does not coincide with any faults interpreted in line SL-2 and does not project into overlying loess packages (Roxana Silt and Peoria Loess) within a resolution of about 0.4 feet (0.12 m).

Feature T dips about 37° west and coincides with possible gently east-dipping (~3°) stratigraphic horizons associated with units 5.2, 5.1, and 4.0 between DPT cores UKK-2-649 and 669 (Plate 10b). This west-dipping feature exhibits a reverse sense of separation that is as much as 2.0 feet (0.61 m) for the base of units 5.1 and 4.0, but considerably less across the deeper basal contact of unit 5.2. The less pronounced nature of the feature across the base of unit 5.2 and 4.0 suggests that this feature may represent the natural variability and undulations of the fluvial stratigraphy within the Metropolis Formation. Feature T does not coincide with faults previously interpreted by Woolery (personal communication, 2005), or Fault 2 of Blackhawk (2003). Lastly, feature T does not project into overlying loess packages (Roxana Silt and Peoria Loess) within a resolution of about 0.4 feet (0.12 m).

Feature U dips about 25° east and coincides with gently (2°) west-dipping strata associated with units 5.2 to 4.0, and possibly the base of unit 3 (Figure 10b). The changes in elevation of units across feature U are stratigraphically inconsistent along its projected length suggesting its projection upsection into the Roxana Silt and Peoria Loess is highly suspect. For example, vertical separations are as much as about 2 feet (0.61 m) across the base of unit 4.0 (unnamed intermediate loess), and as small as 1 foot (0.30 m) across the base of unit 5.2 (Metropolis Formation). The Lower Peoria Loess (unit 2) is flat-lying above this feature and does not reflect any warping within a limit of resolution of about 0.4 feet (0.12 m). The approximate location of feature U coincides with the general location of a feature interpreted by Woolery (personal communication, 2005) between shot points UKK-2-669 and 679, and exhibits a similar sense of vertical separation (Figure 9).

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7.0 POTENTIAL FOR HOLOCENE FAULTING AT THE C-746-U LANDFILL EXPANSION

Available regional and local geologic and geophysical data in western Kentucky provide evidence of steeply dipping, northeast-striking faults lying within the Reelfoot rift that possibly connect with the FAFC of southern Illinois and northwestern Kentucky (Figures 3 and 4). The presence of northeast-trending contemporary microseismicity within this zone of poorly characterized faults suggests that some of the north- to northeast-trending structures may accommodate present-day regional strain, and thus may be similar to faults in the NMSZ (Figure 3). This investigation of Holocene faulting at the C-746-U landfill expansion provides subsurface information by which to assess the presence or absence of Holocene activity on previously interpreted northeast-striking faults (Faults 1 and 2 of Blackhawk, 2003), as well as multiple faults and folds interpreted from previous site-specific seismic lines (Woolery, personal communication, 2005) (Figures 8 and 9). These previously interpreted faults that would intersect the landfill lie within a diffuse band of contemporary microseismicity, and generally coincide with a southwestern projection of the Hobbs Creek and Barnes Creek fault zones in the FAFC of southern Illinois (Figure 4). The inferred faults of Blackhawk (2003) and Woolery (personal communication, 2005) were evaluated with respect to a regional tectonic model in which the near-vertical, northeast-striking faults accommodate oblique dextral strike-slip faulting, including components of extensional and contractional deformation that result in substantial vertical separation of horizontal strata.

This study assumes that if faults underlie the site, material displaced by these inferred faults record discrete brittle deformation in contrast to some localities associated with the 1811-1812 earthquakes, where evidence of past surface rupture is enigmatic along much of the NMSZ. The absence of primary surface rupture with this earthquake sequence may be partly a result of the rupture being broadly distributed through the thick semi-consolidated to unconsolidated saturated deposits in the Mississippi embayment. We suggest that there is only a remote possibility that the deposits encountered in this fault study may not record discrete Holocene fault rupture because the Quaternary section underlying the site is thin (<100 feet thick; 30 m). These relatively thin early to middle Quaternary fluvial materials overlain by late Pleistocene loess have been shown regionally to be displaced by faults in southern Illinois (Nelson et al., 1999: SAIC, 2004) and southeastern Missouri (Harrison et al., 1999; Baldwin et al., in press), indicating that the material underlying the proposed landfill expansion should record brittle deformation, if faulting has occurred in the recent geologic past. Also, the cores collected for this study provide direct evidence for the absence of slickensides, breccia and clay gauge across some of the interpreted fault zones of Blackhawk (2003) and Woolery (personal communication, 2005).

Based on the tectonic model described above and in patterns typical of surface-fault rupture behavior, the five geologic profiles that intersect the previously interpreted northeast-striking faults show that the strata younger than unit 3.0 (Roxana Silt) are undeformed beneath the site. Of the 25 features possibly associated with vertically separated or warped stratigraphic horizons, 20 features do not extend into unit 3.0 (Roxana Silt; Tables 3 and 4), which has an estimated age ranging between 32 and 51 ka at the site (Table 2). As noted in Section 6.0, of the five possible features that intersect the Roxana Silt, it is permissible to extend only three into the overlying Peoria Loess (10 to 25 ka). However, the presence of two of these features (I and J) is highly suspect because of their association with artificial fill, and the third feature (L) does not displace the overlying Upper Peoria Loess (unit 1). Collectively, the findings from this study strongly suggest that the previously interpreted faults at the landfill are not Holocene active.

Only in a few instances is it permissible to interpret fault-like features extending upward into the Roxana Silt (unit 3) and Peoria Loess (unit 2). These interpretations are highly questionable, especially when the features are evaluated with respect to the geologic sections having zero vertical exaggeration, and/or the near-surface sampling conditions (i.e., presence of artificial fill). Nowhere along the profiles do we interpret a clear or distinct separation of the Upper Peoria Loess (unit 1) or the base of the Lower Peoria Loess (unit 2) that unequivocally can be interpreted as fault-related. We argue for the absence of the upward projection of these features into the Peoria Loess when: (1) there is a high degree of uncertainty in the location of basal contacts because of compression, artificial fill, or highly-saturated loess; (2) the fault-like feature has an unrealistically low inclination; and (3) a preponderance of DPT data constrain the majority of the fault-like features to the Metropolis Formation and unnamed intermediate loess (unit 4).

Many of the possible vertical steps interpreted in the Metropolis Formation (units 5.3 to 5.1) also can be explained alternatively by non-tectonic fluvial processes (i.e., channel erosion and deposition). For instance, the base of unit 5.1 typically is abrupt, erosional, and characterized by coarse-grained fluvial deposits overlying fine-grained overbank deposits. This contact often defines the base of a prominent channel that varies in thickness and elevation through scouring and natural stratigraphic undulations. Unit 5.3 also is a gravelly, coarse-grained sand likely associated with Pleistocene braided stream deposits. These types of fluvial deposits often have a natural undulatory surface related to local channel scour, and deposition of mid-channel sand or gravel bars. When buried and viewed in profile, these contacts can appear as vertical steps. We interpret that many of these steps are a result of fluvial erosion, lateral

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accretion, or other fluvial processes, but we cannot absolutely preclude the possibility of fault displacement.

In short, we are unable to unequivocally preclude that some changes in horizon elevation are related to tectonic displacement. Therefore, we conservatively assume that all of the features identified in the sections are of potential tectonic origin. This is especially evident when features I, J and L are considered anomalous due to abrupt, sampling-induced variations in stratigraphic continuity, or compared against the preponderance of DPT data from the direct vicinity of the features that indicate Holocene inactivity (i.e., feature L). Under these conditions and assumptions, unit 4 is the youngest horizon potentially displaced by faulting at the site. Unit 4, an unnamed intermediate loess, is dated at about 53.6 to 75.5 ka, and thus pre-dates the Holocene by several tens of thousands of years. The study findings suggest that the previously interpreted faults of Blackhawk (2003) and Woolery (personal communication, 2005) were active during the late Pleistocene but not during the Holocene, and have vertical displacements typically ranging from about 1 to 3 feet (0.3 to 0.9 m). This late Pleistocene age of possible faulting at the C-746-U landfill expansion more closely correlates with the age of faulting associated with structures comprising the FAFC of southern Illinois (Nelson et al., 1999). Therefore, this fault-rupture hazard investigation indicates that: (1) there is a strong likelihood of no Holocene faulting across the existing and proposed landfill expansion; and (2) the C-746-U landfill is not subject to fault-setback conditions outlined in CFR, Subtitle D, Title 40. A summary of the findings of the DPT-based geologic profiles is provided below.

7.1 Fault 1 and Deformation Zone DZ2-1

Fault 1 of Blackhawk (2003) and deformation zone DZ2-1 of Woolery (personal communication, 2005) are intersected by DPT cross-sections UKK-1C-1C' and UKK-2A-2A' (see Plate 1, and Figures 8 and 9 for locations). Blackhawk (2003) interprets about 20 feet (6.1 m) of vertical displacement of either the Metropolis Formation or Mounds Gravel across this fault, and maps the fault to within 15 to 20 feet (4.6 to 6.1 m) of the ground surface. Alternatively, Woolery (personal communication, 2005) interprets a "half-flower" structure that vertically displaces the Mounds Gravel about 10 feet (3.0 m) and the Metropolis Formation about 2 feet (0.61 m) (Figure 9). In either case, many of the DPT cores would intersect the fault zones, and thus should be expressed in the lower part of the cross-sections, if present.

The DPT core data from these sections depict a possible northeast-trending, buried topographic high (antiform/feature DD) limited mostly to the Metropolis Formation, that may be reflective of tectonic deformation (e.g., folding and faulting associated with a "half-flower" structure inferred by Woolery)

(Figure 10b). The antiform has an overall southerly plunge, and vertical relief estimated to be as much as 5 feet (1.5 m) of the base of unit 5.2, whereas the overlying younger loess sheets of units 3 to 1 (Roxana Silt and Peoria Loess) are relatively horizontal above the tilted fluvial strata of the Metropolis Formation. These stratigraphic and structural relations suggest that, if the antiform (feature DD) is related to tectonic deformation, it pre-dates the Holocene (see Plate 3). Similarly, fault-like features (K, M through P) inferred from these sections are constrained primarily to the Metropolis Formation (units 5.3 to 5.1) and the unnamed intermediate loess (unit 4) suggesting that the features are pre-Holocene in age (Tables 3 and 4). The fault-like features typically exhibit about 1 to 3 feet (0.3 to 0.9 m) of vertical separation of basal contacts within the Metropolis Formation, consistent with both a normal and reverse sense of motion.

We acknowledge that it is permissible to infer near-surface faulting of the Peoria Loess across a few of the features shown in sections UKK-1C-1C' and UKK-2A-2A'; however, we consider this scenario to be unlikely. For instance, features I and J of section UKK-1C-1C' can be inferred to intersect or come close to the base of the Peoria Loess (Figure 10a). The cores used to define features I and J underwent significant compression, which resulted in uncertainty in evaluating the elevations and correlation of stratigraphic horizons within the upper 10 feet (3.0 m). In cores UKK-570 to 590, and directly below this anomalous zone of compression, it is reasonable to infer vertical separation across the basal contacts of units 5.1 and 5.2; but above the base of unit 4, features I and J suspiciously align with the southern and northern margins of a body of artificial fill (Figure 10a). If features I and J represent faults, we interpret a pre-Holocene age of faulting based on: (1) the presence of fill which artificially distorts the basal contacts of the near-surface loess due to compression; and (2) an observed increase in vertical separation upsection along the feature, indicating the amount of displacement is stratigraphically inconsistent. Similarly, we interpret that it is unlikely that feature L (section UKK-2A-2A') extends across the basal contact of unit 2 because of: (1) a moderate inclination (45°), and (2) a direct association with other adjacent fault-like features (M through P) that do not displace the Peoria Loess (Figure 10b).

In summary, the cross-sections intersecting Fault 1 and DZ2-1 depict primarily near-vertical, fault-like features coincident with zones of apparent warping or folding (Figures 10a and 10b). The fault-like features typically exhibit an apparent vertical separation consistent with both normal and reverse components of motion that extends across the basal unit 5.1 and 5.2 contacts. The youngest potentially displaced unit in these sections is the unnamed intermediate loess (unit 4), indicating that the age of Fault 1 (Blackhawk, 2003) and faults interpreted in deformation zones DZ2-1, pre-date deposition of unit 3 (Roxana Silt) at about 32 to 51 ka.

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7.2 Fault 2 and Deformation Zones DZ1-2 and DZ2-2

DPT core data used in constructing sections UKK-1B-1B' and UKK-2B-2B' provide the basis for assessing the presence or absence of Fault 2 (Blackhawk, 2003) and the broad zone of deformation delineated by zones DZ1-2 and DZ2-2 (Woolery, personal communication, 2005) (Figures 8 to 10). Woolery (personal communication, 2005) interprets a "positive" flower structure deforming the Metropolis Formation along faults with as much as 2 to 3 feet (0.6 to 0.9 m) of vertical displacement. The geologic sections prepared from the DPT data and presented without vertical exaggeration exhibit nearly flat-lying stratigraphy across the entire north-central and northeastern part of the landfill (Plate 3). At an exaggerated scale (4x), these same DPT data delineate seven features with vertically separated stratigraphic boundaries. Five of the seven features (features F, T to Q) appear to intersect the Metropolis Formation and the unnamed intermediate loess (unit 4), and the remaining two features (G and U) project upward across the Roxana Silt (unit 3) basal contact (Figure 10a and 10b).

The likelihood of features G and U extending beyond unit 4 is believed to be low. Feature G dips south, would have a reverse sense of motion, and can be interpreted as intersecting the basal contact of unit 3 (Roxana Silt). However, it does not vertically separate the base of the Peoria loess (unit 2), which dips in an opposite direction of the underlying units within a resolution of about 0.4 feet (0.12 m). Profile UKK-1B-1B', without vertical exaggeration, shows that feature G is moderately well expressed across the basal unit 5.2 contact, but is barely discernable across the basal contacts of units 5.1 and 4. These relationships suggest that if feature G is present, it most likely is present only within the Metropolis Formation (Figure 10a). Similarly, it is possible that feature U of section UKK-2B-2B' projects upward into unit 3 (Roxana Silt), but because of its moderately low inclination (about 37°), and a pattern of stratigraphically inconsistent vertically separated contacts (i.e., displacement increases upsection), there is a very low likelihood that feature U has a tectonic origin.

In summary, geologic profile UKK-2B-2B' provides an extensive DPT data set that shadows much of the northern part of the landfill. This section shows laterally continuous, nearly horizontal stratigraphic contacts along its entire length. Where the profile intersects the surface projection of Fault 2 (Blackhawk, 2003) and deformation zone DZ2-2 (Woolery, personal communication, 2005), the stratigraphic information indicates that there is no distinct vertical separation across geologic strata within the Metropolis Formation. This is similarly true with DPT data interpreted in the north-south oriented profile of UKK-1B-1B' and crossing Fault 2, with the minor exception that several subtle perturbations at the base of units 5.1 and 5.2 occur along this section. Estimated amounts of potential vertical displacements

across the inferred fault-like features are as much as 3 feet (0.9 m), consistent with Woolery's (personal communication, 2005) interpretation of the geophysical profiles. Collectively, the sections show: (1) the presence of undeformed, latest Pleistocene to Holocene deposits beneath the central part of the C-746-U landfill, and therefore (2) an absence of Holocene faulting beneath the landfill, and (3) the presence of some possible fault-like features aligned with previously interpreted Fault 2 (Blackhawk, 2003) and DZ2-2 (Woolery, personal communication, 2005)within units older than unit 4 (unnamed intermediate loess dated at 53.6 to 75.5 ka).

7.3 Faults along the Southwestern Perimeter of the Landfill: Deformation Zone DZ1-1

DPT data collected along section UKK-1A-1A' shadow deformation zone DZ1-1 along the southwestern perimeter of the landfill (Plates 1 and 2). Deformation zone DZ1-1 is characterized by a series of steep, north- and south-dipping faults that exhibit both normal and reverse displacement (Woolery, personal communication, 2005). The exaggerated geologic section depicts the gentle south-dipping, undulatory stratigraphic contact of unit 5.2 that projects below the depth of exploration. The overlying strata also have a gentle southerly dip, but at apparent inclinations that progressively decrease upward to the base of unit 4, which has a southerly dip that is parallel with the present-day topographic surface (Plate 1). A total of five possible fault-related features are interpreted on this cross-section, with four of the features (B to E) present only in the Metropolis Formation (units 5.3 to 5.1). Only feature A is interpreted to extend upward into unit 4. However, because this feature is inclined at less than 30°, feature A probably is not related to faulting in this tectonic environment. Within a resolution of about 0.4 feet (0.12 m), none of the five features interpreted in section UKK-1A-1A' is associated with vertical separation of the basal contact of the Lower Peoria Loess (unit 2). Therefore, cross section UKK-1A-1A' shows continuous stratigraphy the faults in deformation zone DZ1-1 interpreted by Woolery (personal communication, 2005). We interpret that these faults have not experienced Holocene fault displacement and thus are judged to be inactive.

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8.0 CONCLUSIONS

This subsurface investigation using 86 DPT cores, each approximately 30 feet (9.1 m) long, provides detailed stratigraphic information for characterizing the locations and age of possible faults previously interpreted beneath the C-746-U landfill. Analysis of these cores, including detailed logging and stratigraphic correlations of more than 2,580 feet (about 790 m, or one-half mile) of core, provide the most comprehensive information to date on near-surface stratigraphy beneath the landfill. The focus of this analysis was on several possible faults previously identified on geophysical profiles, which appear to be the most likely candidates for possible Holocene activity at the site. The locations and ages of the possible faults are constrained by stratigraphic continuity of late Pleistocene loess and fluvial deposits, as well as pedogenic horizons developed in these deposits. The geologic cross-sections developed from the DPT data allow the possible interpretation of as many as four relatively "broad" folds or warps, and 21 features with elevation changes across stratigraphic and/or pedologic boundaries. The 25 potential fault-related features identified during this study represent the most distinct and vertically continuous features within the DPT geologic cross-sections that could be interpreted as faulting or folding. On the basis of the DPT data, there is no evidence that Faults 1 and 2 of Blackhawk (2003), as well as the deformation interpreted by Woolery (personal communication, 2005), have displaced latest Pleistocene to Holocene deposits. Therefore, we interpret that these faults have been inactive during the Holocene (past 11,000 years) and probably during the past 15,000 years. Additional possible deformation-related features could be interpreted elsewhere from the DPT data, but these likely would be present only within units 5.2 and 5.1, and thus would represent pre-Holocene displacement. Therefore, based on the collection, documentation, and analysis of the 86 detailed DPT cores within the C-746-U landfill area, we conclude:

- Previously acquired and interpreted geophysical data from the vicinity of the PGDP collectively indicate this part of western Kentucky is intersected by predominantly moderate to steeply dipping, north-to northeast-striking late Quaternary faults that exhibit normal and reverse displacement. Structural models of the region hypothesize that these faults also have accommodated oblique dextral displacement during the late Quaternary, however, no master strike-slip fault has been identified along which the majority of this hypothesized strain was accommodated.

- Collectively, there are at least seven late Pleistocene distinct stratigraphic and pedogenic horizons present in the upper 30 feet (9.1 m) of geologic material at the C-746-U landfill. The upper three units (i.e., the Upper Peoria Loess, the Lower Peoria Loess, and the Roxana Silt) generally are flat-

lying and mantle pre-existing topography. In contrast, the four lower horizons have rare subtle to abrupt undulations in stratigraphic contacts, which may reflect fluvial depositional processes and/or tectonic deformation.

- Numerical dating of several late Quaternary strata using Optically Stimulated Luminescence (OSL) methods provides well constrained ages on eolian and fluvial deposits beneath the site, including an unnamed loess (53.6 to 75.5 ka), the Roxana Silt (32 to 50 ka), the Lower Peoria Loess (22 to 30 ka) and the Upper Peoria Loess (10 to 25 ka).

- The closely-spaced DPT data provide evidence for the continuity of undeformed late Pliestocene strata (Upper Peoria Loess) beneath the C-746-U landfill, and thus for no Holocene displacement along previously interpreted faults beneath the C-746-U landfill.

- The most recent fault displacement, if present at the site, is constrained to post-date deposition of unit 4, an unnamed loess deposit between the 53.6 and 75.5 ka based on OSL dating at the site.

- The late Pleistocene age of inferred faulting at the site is similar to the youngest age of faulting reported by Nelson et al. (1999) along FAFC northeast-striking faults in southern Illinois.

- This subsurface exploration does not span all zones of deformation interpreted in seismic reflection lines SL-1 and SL-2; however, the DPT core data span the most prominent zones of deformation interpreted by Blackhawk (2003) and Woolery (personal communication, 2005), and thus, collectively suggest that the northeast-striking faults in the direct vicinity of the landfill have not experienced Holocene displacement.

- The interpretation of the DPT data strongly suggests the absence of a surface-fault rupture hazard at the landfill that could significantly impact the design of the proposed and existing facilities.

- On the basis of the findings of this study, and in compliance with 2005 Code of Federal Regulations, Subtitle D, Title 40, Part 258, subpart B (258.13), a setback of 200 feet (60.1 m) from the previously interpreted faults of Blackhawk (2003) and Woolery (personal communication, 2005) is unwarranted.

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Table 2. OSL Laboratory Results: C-746-U Landfill Expansion, Paducah, Kentucky

Core Designation	Section Line	Depth (Feet)	Lab Number	Sample Material	OSL Age (ka)[4]	Unit
UKK-1-215	UKK-1A-1A'	5.8 – 6.0	UIC 1693IR[1]	Silt/Loess	16.6 ± 1.2	Upper Peoria Loess (unit 1)
UKK-1-415	UKK-1B-1B'	5.6 – 5.9	UIC 1698IR	Silt/Loess	19.3 ± 1.4	Upper Peoria Loess (unit 1)
UKK-2-344	UKK-2A-2A'	4.5 – 4.7	UIC 1695IR	Silt/Loess	23.5 ± 1.7	Upper Peoria Loess (unit 1)
UKK-2-344	UKK-2A-2A'	4.5 – 4.7	UIC 1695IRr[2] (Duplicate)	Silt/Loess	22.3 ± 1.6	Upper Peoria Loess (unit 1)
UKK-2-344	UKK-2A-2A'	4.5 – 4.7	UIC 1695IG[3] (Duplicate)	Silt/Loess	20.6 ± 1.5	Upper Peoria Loess (unit 1)
UKK-1-215	UKK-1A-1A'	8.4 – 8.7	UIC 1694IR	Silt/Loess	27.3 ± 1.9	Lower Peoria Loess (unit 2)
UKK-1-415	UKK-1B-1B'	8.1 – 8.4	UIC 1699IR	Silt/Loess	23.5 ± 1.7	Lower Peoria Loess (unit 2)
UKK-2-344	UKK-2A-2A'	7.2 – 7.4	UIC 1696IR	Silt/Loess	27.3 ± 1.9	Lower Peoria Loess (unit 2)
UKK-2-544	UKK-2B-2B'	7.5 – 7.7	UIC 1702IR	Silt/Loess	28.8 ± 2.1	Lower Peoria Loess (unit 2)
UKK-1-215	UKK-1A-1A'	10.3 – 10.5	UIC 1701IR	Silt/Loess	34.6 ± 2.5	Roxana Silt (unit 3)
UKK-1-415A	UKK-1A-1A'	9.4 – 9.6	UIC 1700IR	Silt/Loess	47.2 ± 3.5	Roxana Silt (unit 3)
UKK-2-344A	UKK-2A-2A'	10.8 – 11.0	UIC 1697IR	Silt/Loess	39.6 ± 2.8	Roxana Silt (unit 3)
UKK-2-344A	UKK-2A-2A'	10.8 – 11.0	UIC 1697IRr (Duplicate)	Silt/Loess	41.1 ± 2.9	Roxana Silt (unit 3)
UKK-2-544	UK-2B-2B'	12.1 – 12.3	UIC 1732	Silt/Loess	70.1 ± 5.4	Unnamed Intermediate Loess (unit 4)
UKK-2-544	UK-2B-2B'	13.1 – 13.4	UIC 1733	Silt/Loess	58.1 ±4.5	Unnamed Intermediate Loess (unit 4)

[1] The IR designation indicates excitation by infrared diodes (880 ± 80 nm) by the multiple aliquot additive dose technique (Forman and Pierson, 2002).
[2] The GR designation indicates excitation by green light (514 ± 20 nm) by the multiple aliquot regenerative dose technique (Jain et al., 2003).
[3] The IRr designation indicates excitation by infrared diodes (880 ± 80 nm) by the multiple aliquot regenerative dose technique (Jain et al., 2003).
[4] All errors are at 1 sigma. OSL ages determined at Luminescence Dating Research Laboratory at Univ. of Illinois at Chicago.

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Table 3. Summary Table of Zones of Possible Tilting and Warping - Proposed C-746-U Landfill, Paducah, Kentucky

Possible Large-Scale Structural Features	Cross Section Line	Constrained Between Cores	Structural Style[A]	Direction of Down Warping[B]	Amount of Vertical Separation in Feet (Maximum)	Youngest Unit Boundary Vertically Separated[C]		Estimated Age of Youngest Unit Vertically Separated Ka[D]
AA	UKK-1A-A'	UKK-1-180 to 250	W	S	5	Unit 5.1	Metropolis Formation	>125
BB	UKK-1B-B'	UKK-1-350 to 380	W	N	3	Unit 5.1	Metropolis Formation	>125
CC	UKK-1B-B'	UKK-1-405 to 430	W	N	2.25	Unit 4.0	Unnamed Intermediate Loess	53.6 to 75.5
DD	UKK-2A-A'	UKK-2-319 to 379	F (Antiform)	W and E	5	Unit 4.0	Unnamed Intermediate Loess	53.6 to 75.5

A: W = warping, F = folding
B: N= northside-down, S = southside-down; W = westside-down; E = eastside-down
C: Age of youngest stratigraphic basal boundary affected by possible warping
D: Ka = 1,000 years

Table 4. Summary of Features Having Distinct Elevation Changes in Stratigraphy - Proposed C-746-U Landfill, Paducah, Kentucky

Feature	Cross Section Line (UKK)	Feature Constrained Between Cores	Estimated Amount of Separation Max/Limit of Resolution[A] (ft)	Sense of Vertical Separation (Direction/ Style)[B]	Dip of Feature (H, M, L)[C]	Youngest Unit Boundary Vertically Separated[D]		Estimated Age of Youngest Unit Vertically Separated Ka[E]
A	1A – 1A'	UKK-1-200 to 220	2.0/0.4	S/N	L	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
B	1A – 1A'	UKK-1-205 to 215A	2.0/0.3	N/R	M	Unit 5.1	(Metropolis Formation)	>125
C	1A – 1A'	QKK-1-215A to 220	1.75/0.5	N/N	H	Unit 5.2	(Metropolis Formation)	>125
D	1A – 1A'	UKK-1-220 to 225	1.25/0.3	S/N	H	Unit 5.1	(Metropolis Formation)	>125
E	1A – 1A'	UKK-1-230 to 235	1.75/0.5	S/N	H	Unit 5.2	(Metropolis Formation)	>125
F	1B – 1B'	UKK-1-350 to 380	3.0/0.4	S/R	M	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
G	1B – 1B'	UKK-1-405 to 415	1.75/0.4	N/R	M	Unit 3.0	(Roxana Silt)	32.1 to 50.7
H	1C – 1C'	UKK-1-530 to 555	2.0/0.4	S/R	L	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
I	1C – 1C'	UKK-1-565 to 575	3.25/1.0	S/N	H	Unit 4.0 (2.0/1.0)	(Unnamed Loess)	53.6 to 75.5
J	1C – 1C'	UKK-1-585 to 590	1.25/1.0	N/N	H	Unit 5.1 (2.0/1.0)	(Metropolis Formation)	>125
K	2A – 2A'	UKK-2-304 to 309	1.5/0.4	W/N	H	Unit 5.1	(Metropolis Formation)	>125
L	2A – 2A'	UKK-2-329 to 349	2.0/0.6	E+W/R	M	Unit 2.0	(Lower Peoria Loess)	21.8 to 30.2
M	2A – 2A'	UKK-2-349 to 354	2.0/0.3	W/N	H	Unit 5.1	(Metropolis Formation)	>125
N	2A – 2A'	UKK-2-354 to 359	1.5/0.3	E/N	H	Unit 5.1	(Metropolis Formation)	>125
O	2A – 2A'	UKK-2-354 to 364	1.0/1.9	W/R	M	Unit 4.0	(Unnamed Loess)	53.6 to 75.5

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Feature	Cross Section Line (UKK)	Feature Constrained Between Cores	Estimated Amount of Separation Max/Limit of Resolution[A] (ft)	Sense of Vertical Separation (Direction/ Style)[B]	Dip of Feature (H, M, L)[C]	Youngest Unit Boundary Vertically Separated[D]		Estimated Age of Youngest Unit Vertically Separated Ka[E]
P	2A – 2A'	UKK-2-359 to 369	2.0/0.4	W/N	H	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
Q	2B – 2B'	UKK-2-519 to 524	2.0/0.4	W/N	H	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
R	2B – 2B'	UKK-2-549 to 554	1.0/0.5	E/N	H	Unit 5.2	(Metropolis Formation)	>125
S	2B – 2B'	UKK-2-579 to 589	1.5/0.4	W/N	H	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
T	2B – 2B'	UKK-2-649 to 699	2.0/0.4	E/R	M	Unit 4.0	(Unnamed Loess)	53.6 to 75.5
U	2B – 2B'	UKK-2-669 to 679	2.0/0.4	E/N	L	Unit 3.0	(Roxana Silt)	32.1 to 50.7

A: Limit of resolution of unfaulted unit that lies directly above feature
B: Direction of inferred vertical separation (direction of down-thrown side)/apparent sense of vertical separation N = Normal; R = Reverse
C: H = High-angle (>60°); M = Moderate-angle (≤ 60° to 30° ≥); L = Low-angle (< 30°)
D: Age of youngest basal boundary with vertical separation
E: Ka = 1,000 years
(): Parenthesis indicate possible fault-like feature that comes "anomalously close" to the ground surface but is believed to be a result of DPT sampling complexities

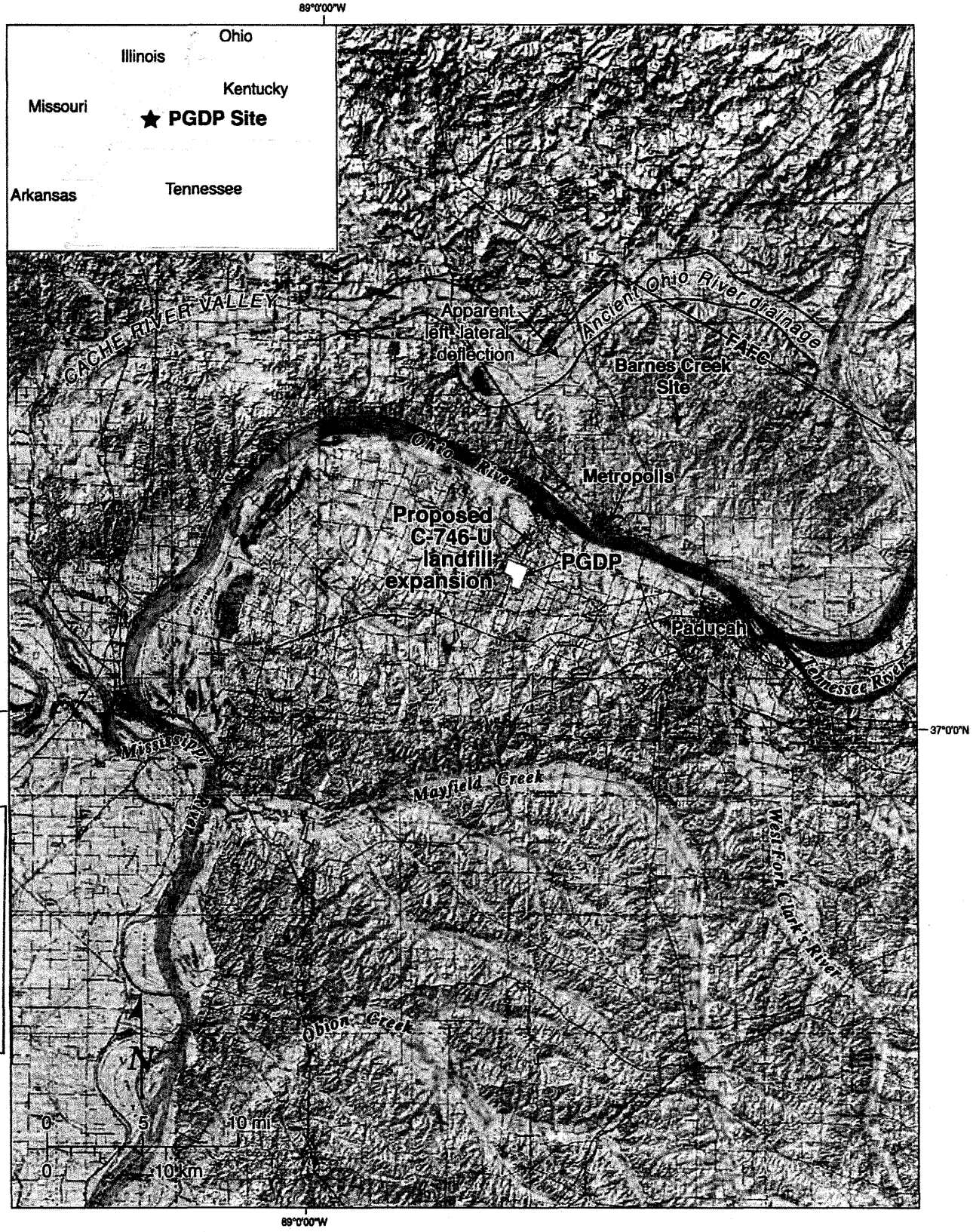

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Figure 1. Location map of Paducah Gaseous Diffusion Plant (PGDP) and surrounding region. Note northeast-trending geomorphic lineaments associated with the westernmost part of the Fluorspar Area Fault Complex (FAFC) in southern Illinois. Also, note the apparent left-lateral deflection of the paleo-Ohio River along the western margin of the FAFC and absence of any deflection of the modern Ohio River along projection of the FAFC. Alternatively, the deflection is across the fault-line scarp of the Lusk Creek fault zone and the deflection represent differences in bedrock erodibility.

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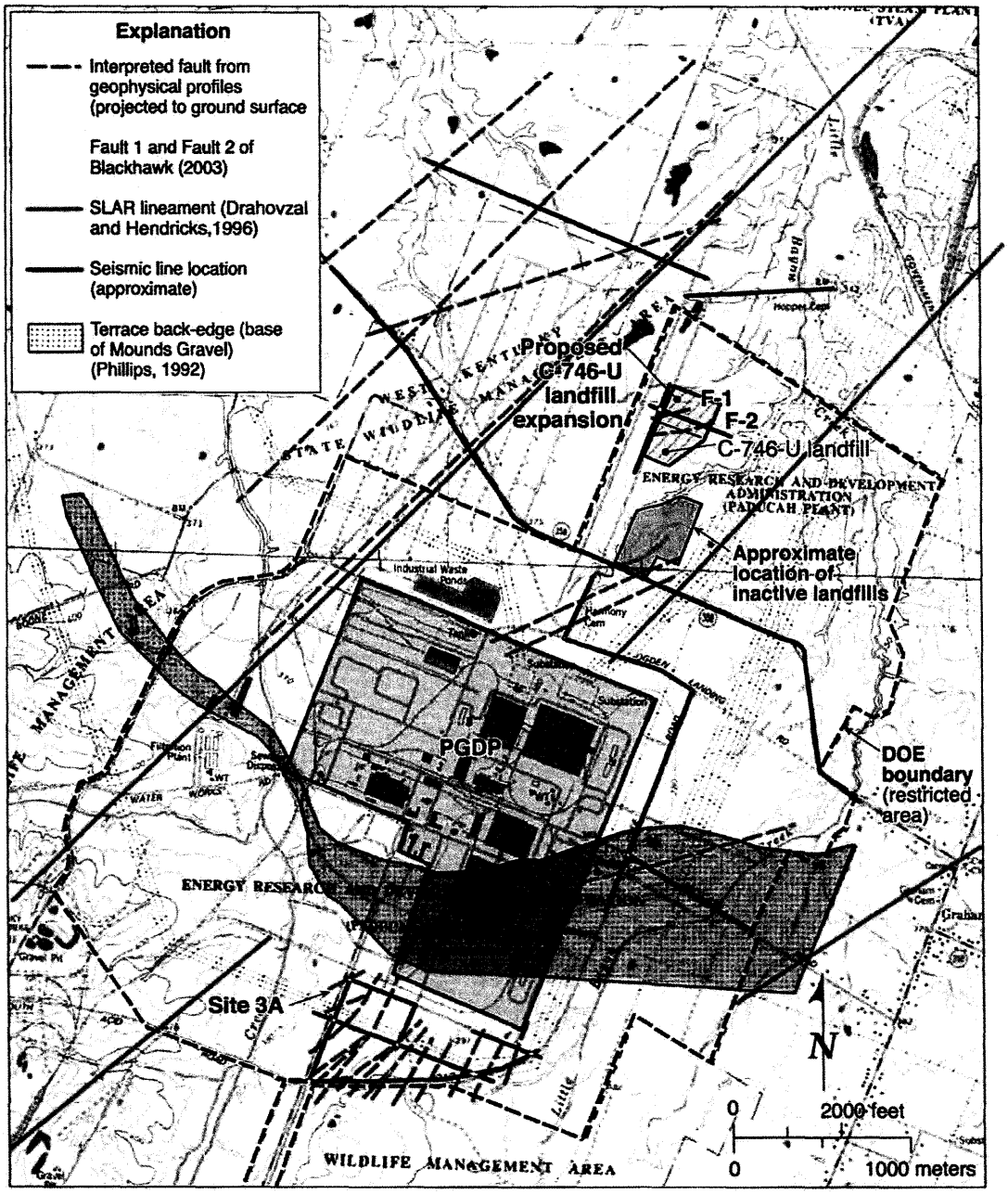

Figure 2. Site map of Paducah Gaseous Diffusion Plant (PGDP) and proposed C-746-U landfill expansion. Seismic line and fault traces considered approximate (taken from Langston and Street, 1998; Woolery and Street, 2002; and SAIC, 2004). SLAR lineaments from Drahovzal and Hendricks (1996). U.S.G.S. topographic base map from Joppa and Heath 7.5-minute quadrangles (1990).

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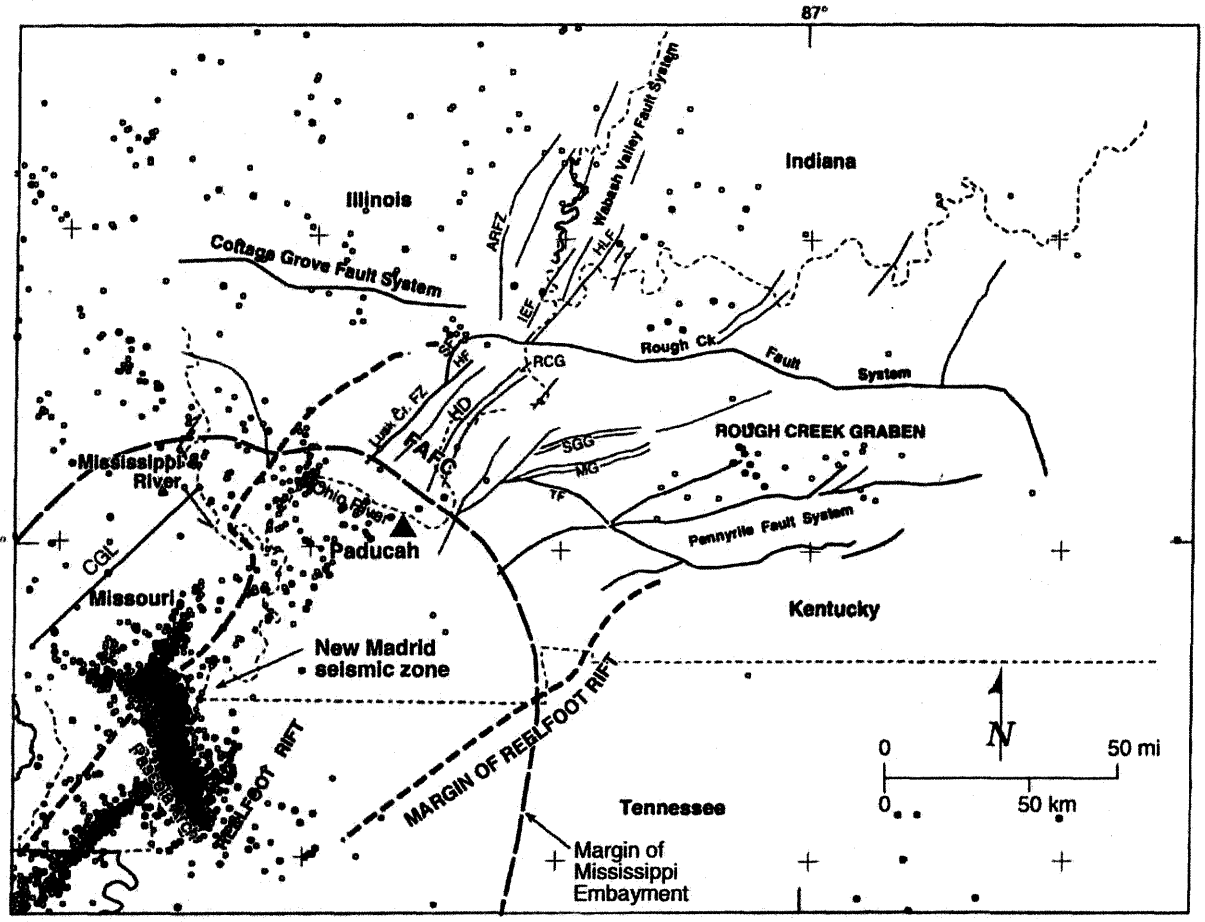

Figure 3. Seismotectonic map showing major geologic structures near Paducah (modified from Potter et al., 1997). Heavy solid lines are faults. Lusk Cr. FZ, Lusk Creek fault zone; HF, Herod fault; SF, Shawneetown fault; HD, Hicks dome; FAFC, Fluorspar area fault complex (shown schematically only - the number of faults is too large to illustrate at this scale); RCG, Rock Creek graben; TF, Tabb fault system; MG, Mexico graben; SGG, Shady Grove graben; ARFZ, Albion-Ridgway fault zone; IEF, Inman East fault; HLF, Hovey Lake fault. Seismicity from 1974 to 2004 (after Rhea et al., 1995; Johnston and Schweig, 1996; post-1992 seismicity from New Madrid earthquake catalog).

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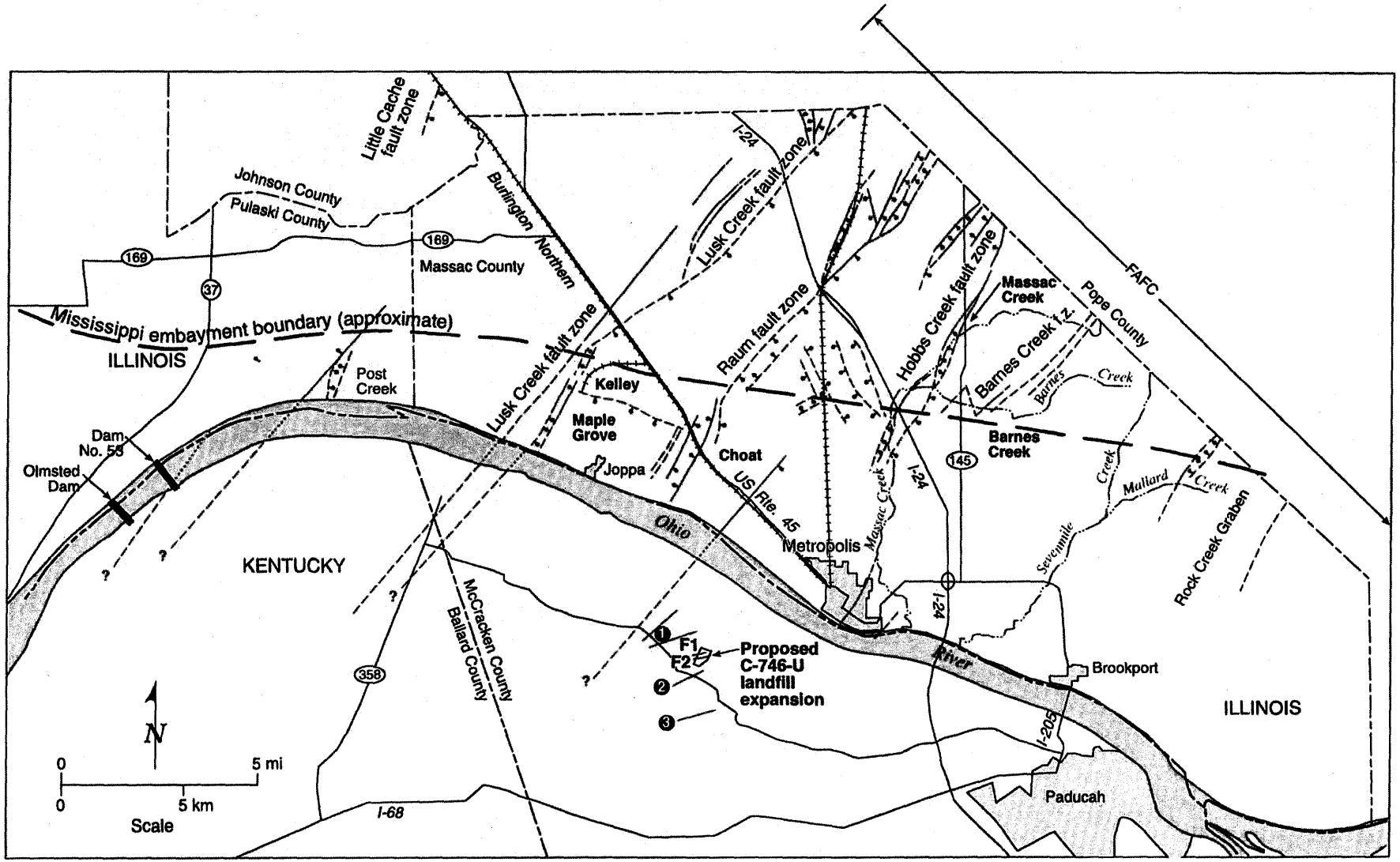

Figure 4. Regional fault map of site vicinity modified after McBride et al. (2002) and Woolery and Street (2002). Balls on downthrown side. Faults numbered 1 through 3 are those of Langston and Street (1998).

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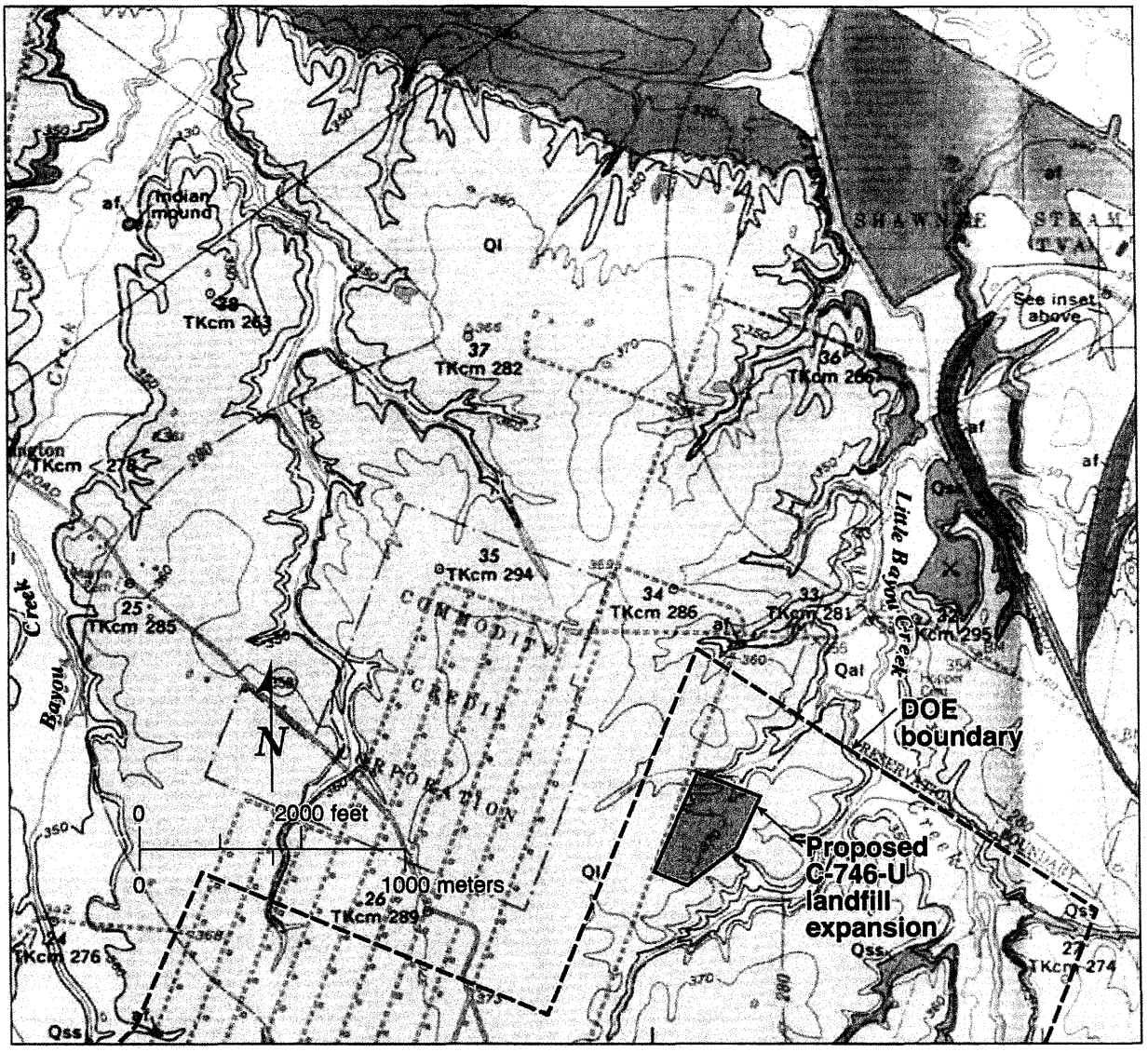

Explanation

Pleistocene and Recent

Qal — Alluvium

sd, sand, adapted in part from soil maps of McCracken County (open-file maps, Soil Conserv. Service Office, Paducah, Ky.). In Little Chain area, Ohio River, adapted from map of Corps of Engineers, U.S. Army (1929–30)

Pleistocene

Ql — Loess

Qal — Silt and sand deposits

QUATERNARY

Pliocene(?) and Pleistocene

QTc — Continental deposits

UNCONFORMITY

Paleocene — Midway Group

Tp — Porters Creek Clay

Upper Cretaceous and Paleocene

Clayton and McNairy Formations

Shown in section only

af — Artificial fill

Includes Indian mounds north of Rossington

TERTIARY(?) AND QUATERNARY

TER-TIARY

CRETACEOUS AND TERTIARY

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Figure 5. Regional geologic map (modified from Finch, 1967).

SYSTEM	SERIES	FORMATION	LITHOLOGY	THICKNESS (IN FT)	DESCRIPTION
QUATERNARY	HOLOCENE AND PLEISTOCENE	ALLUVIUM		0-40	Brown or gray sand and silty clay or clayey silt with streaks of sand.
	PLEISTOCENE	PEORIA LOESS ROXANA SILT LOVELAND SILT		0-43	Brown or yellowish-brown to tan unstratified silty clay.
	PLEISTOCENE	METROPOLIS		3-121	Clay Facies - mottled gray and yellowish brown to brown clayey silt and silty clay, some very fine sand, trace of gravel. Often micaceous.
TERTIARY	PLIOCENE-MIOCENE (?)	MOUNDS GRAVEL			Gravel Facies - reddish-brown clayey, silty and sandy chert gravel and beds of gray sand.
	EOCENE	JACKSON, CLAIBORNE, AND WILCOX FORMATIONS		0-200+	Red, brown or white fine to coarse grained sand. Beds of white to dark gray clay are distributed at random.
				0-100+	White to gray sandy clay, clay conglomerates and boulders, scattered clay lenses and lenses of coarse red sand. Black to dark gray lignitic clay, silt or fine grained sand.
	PALEOCENE	PORTERS CREEK CLAY		0-200	Dark gray, slightly to very micaceous clay. Fine grained clayey sand, commonly glauconitic in the upper part. Glauconitic sand and clay at the base.
		CLAYTON FORMATION		Undetermined	Lithologically similar to underlying McNairy Formation.
UPPER CRETACEOUS		McNAIRY FORMATION		200-300	Grayish-white to dark gray micaceous clay, often silty, interbedded with light gray to yellowish-brown very fine to medium grained sand with lignite and pyrite. The upper part is interbedded clay and sand, and and the lower part is sand.
		RUBBLE ZONE		Undetermined	White, semi-rounded and broken chert gravel with clay.
MISSISSIPPIAN		MISSISSIPPIAN CARBONATES		500+	Dark gray limestone and interbedded chert, some shale.

Figure 6. Schematic stratigraphic column of the PGDP region modified from Nelson et al. (2002) and SAIC (2004). Paleosols developed in the Loveland Silt (Sangamon Geosol), Roxana Silt (Farmdale Geosol) and Peoria Loess are noted by the root-like symbols in the upper half of each loess section.

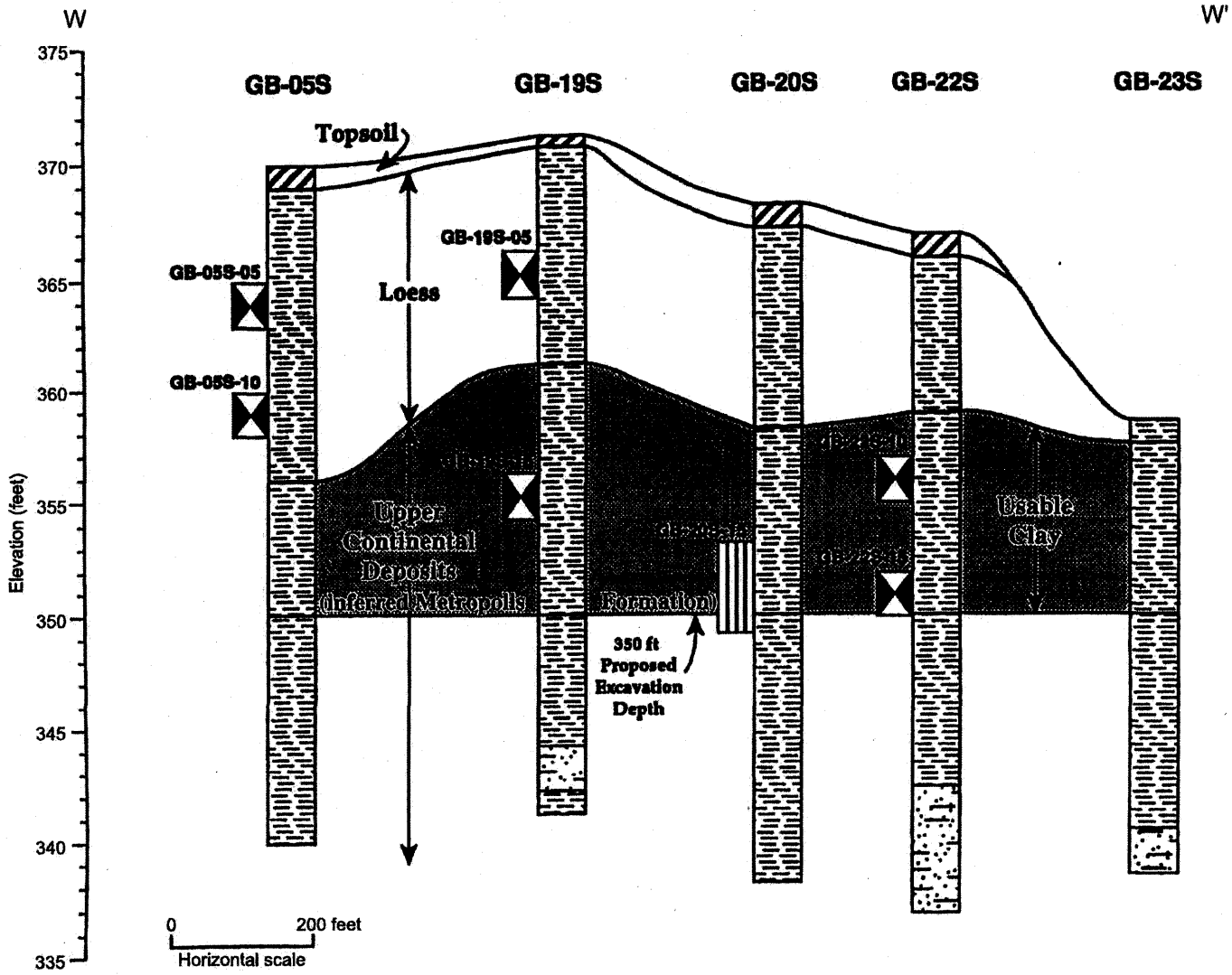

Figure 7. Geologic section from SAIC (1994) which depicts the generalized stratigraphy underlying C-746-U landfill. The topography shown represents the pre-grading slope conditions. See Plate 1 for the section location. Rectangles represent locations of geotechnical samples collected and analyzed by SAIC (1994). Vertical exaggereation approximately 32x.

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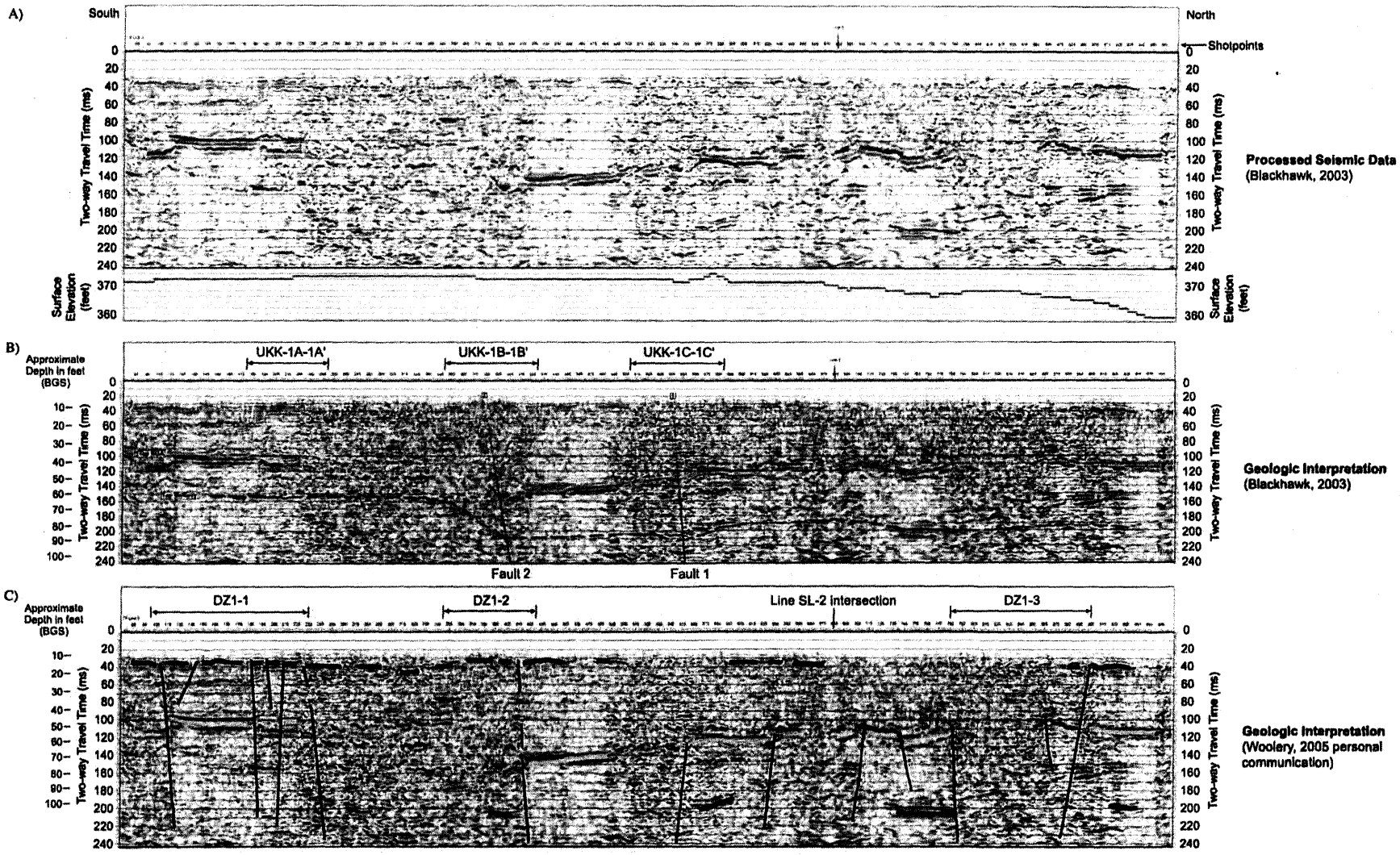

Figure 8. Seismic reflection profile SL-1 of Blackhawk (2003). A) Uninterpreted seismic reflection. B) Blackhawk (2003) interpretation. UKK-1A - 1A' refers to geologic cross section developed from DPT cores (this study). RGA = regional groundwater aquifer. C) Woolery (this study) interpretation DZ1-1, DZ1-2, and DZ1-3 refer to deformation zones of seismic line SL-1. Black subhorizontal lines denote stratigraphy within the Metropolis Formation; yellow colored line denotes the Mounds Gravel or top of the regional groundwater aquifer. Green colored subhorizontal line represents the top of the McNairy Formation. BGS = below ground surface.

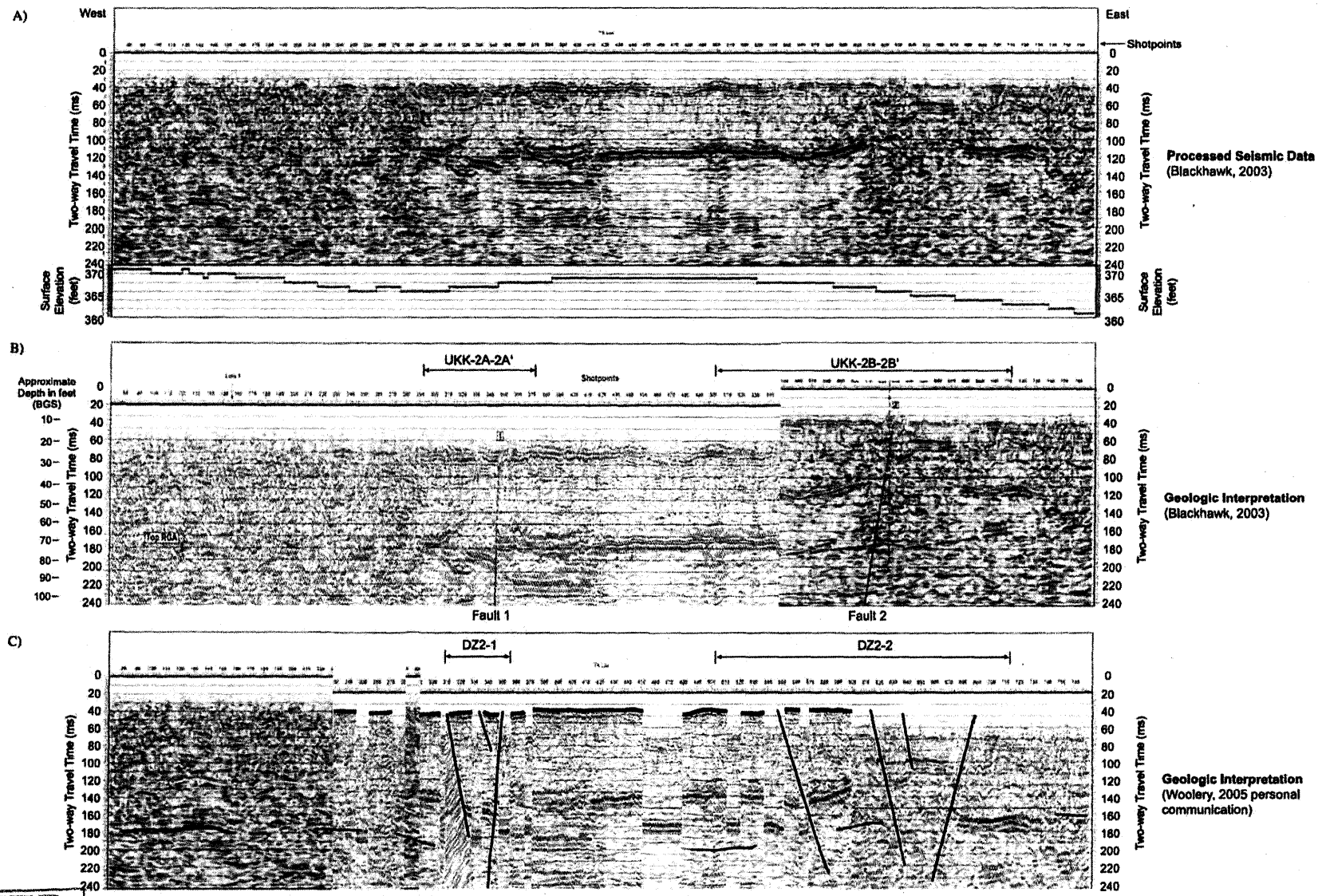

Figure 9. Seismic reflection profile SL-2 of Blackhawk (2003). A) Uninterpreted seismic reflection. B) Blackhawk (2003) interpretation UKK-2A-2A' represents location of geologic cross section based on DPT data (this study). RGA = regional groundwater aquifer. C) Woolery (this study) interpretation DZ2-1 and DZ2-2 and represent deformation zones of seismic line SL-2. Black subhorizontal lines denote stratigraphy within the Metropolis Formation; yellow colored subhorizontal line denotes the Mounds Gravel or top of the regional groundwater aquifer. Green colored subhorizontal line represents the top of the McNairy Formation.

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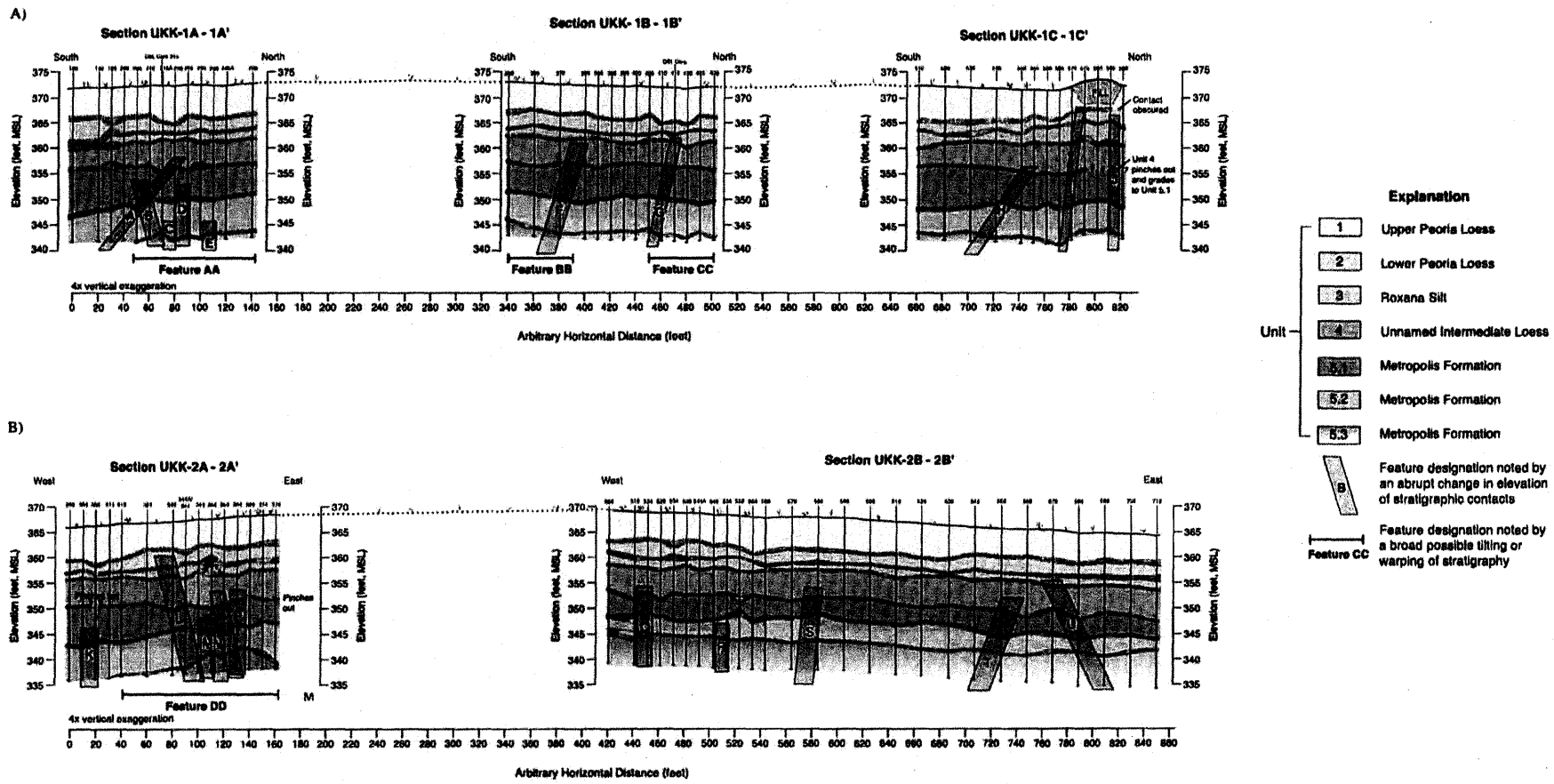
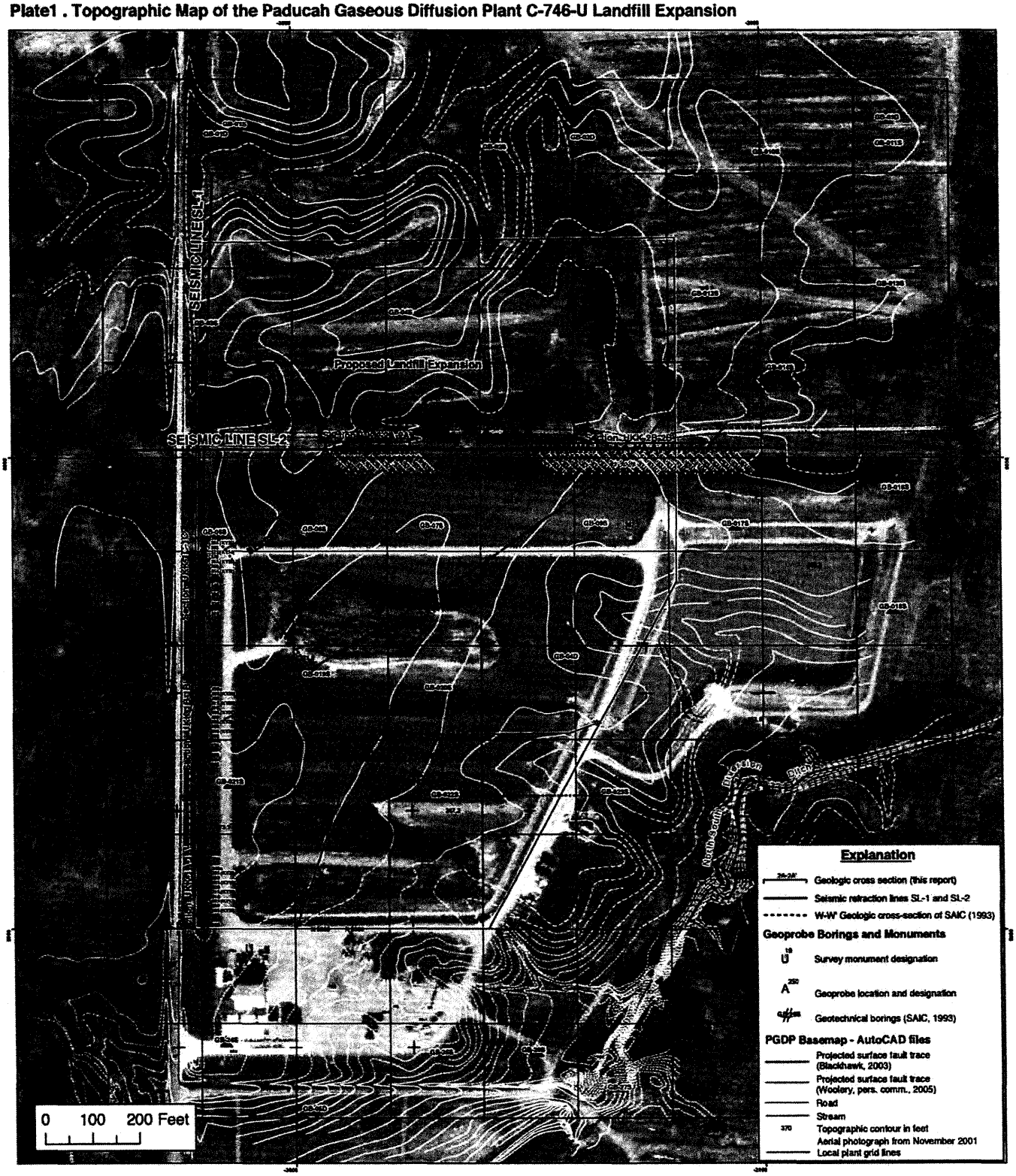


Figure 10. Index figure showing selected features discussed in the text and interpreted from the DPT data; see Plate 1 for locations, and Plates 2 and 3 for further geologic explanation.

1725 Paducah
Revised 07/26/06

Plate1 . Topographic Map of the Paducah Gaseous Diffusion Plant C-746-U Landfill Expansion



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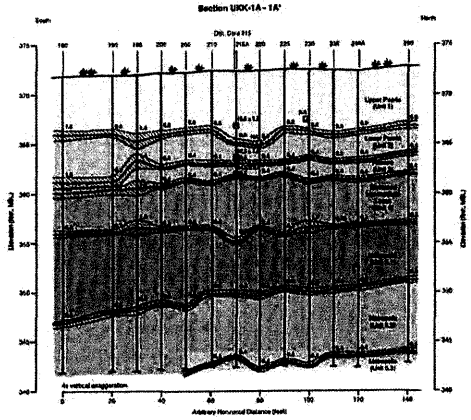
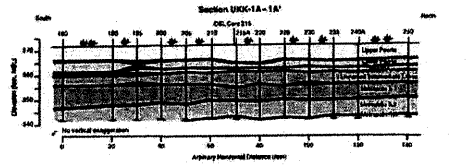
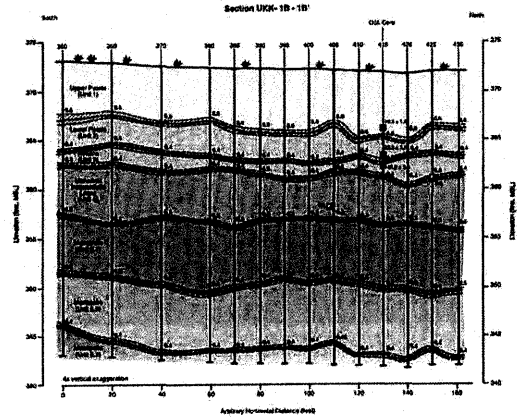
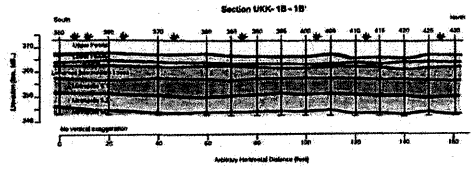








Symbols

- Unit contact
- Contact zone* – contact zone listed next to each boring contact and the outcroppings for determining zone optimum depth-level in section b
- Radiocarbon (C^{14} sample location) – No ages reported because samples did not contain enough carbon for analysis
- 16.8 ± 1.7 Optically stimulated luminescence sample location and age (as with 14c; see Table 2

Notes

1. Boring designations correspond to drill-holes in relation from Ru-1 and Ru-6.
2. Elevations have 5-foot spacing.
3. Vertical exaggeration is 4x (1b-1c).
4. More complete descriptions of stratigraphic units and paleosols provided in section b.
5. Graphic contact zone not accurate.
6. Elevations for the Paducah Gaseous Diffusion Plant constitute system.

Explanation

Unit Descriptions[4]

Upper Peoria – (Unit 1) brown (10YR4/3) to yellowish brown (10YR5/4) CLAYEY SILT (up to 15% clay) to a clean SILT with minor traces of clay. Massive and spaciden (2-4%) with small (<5mm) angular to sub-rounded (dark/black nodules of iron/manganese oxyhydroxides. In places unit has poorly developed (yellow-orange) iron-oxide zones defined as mottles and few nodules. (Pleistocene loess)

Upper section of Unit 1 is overprinted by "modern" and that began developing post deposition of loess (circa 17 ka. Peterson et al. 2002). This soil consists of a thin Ackerman with minor organic accumulation, a distinct eluvial E-horizon, a relatively dark and fluvial horizon, and a Bw-horizon that is noted by a decrease in clay content with little to no mottling.

Lower Peoria – (Unit 1) brownish yellow (10YR6/6) to yellowish brown (10YR 5/4-6/8) SILT to CLAYEY SILT with discontinuous and subparallel visible to light yellow silt laminae. Unit is generally massive, mottled, and soft and compresses readily with the DPT sampling technique. Basal contact of Unit 1 is generally defined by relatively clean silt with lamination overlying a more clay-rich silt (Farmdale Gonsol) with abundant relict root casts and mottling. (Pleistocene loess)

A poorly defined paleosol represents the top of Unit 2. Identified in the cores based on the presence of mottle to moderate iron-manganese oxyhydroxides developed within the upper 0.5 foot of Unit 2.

Peoria – (Unit 2) yellowish brown (10YR5/4) to pale brown (10YR5/4)to SILT with clay and SILTY CLAY with distinct, discontinuous, yellowish-orange thin laminations. Unit 2 also contains prominent clay films along well developed polygonal fractures, a significant clay content compared to overlying loess packages, moderate mottling, and well-developed, clay-filled root casts. Basal contact generally is clear and marked by a thinly laminated yellowish-brown silt with little to no manganese oxides that marks a darker brown to grayish-brown silty clay (interpreted as a buried paleosol) or an older armored loess. (Pleistocene loess)

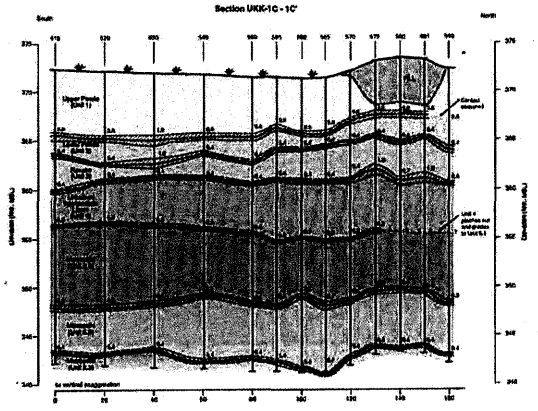
The Farmdale Gonsol and associated mottling and clay development complicate and obscure much of the massive nature of unit 2. Upper part of the Farmdale Gonsol is noted by the concentration of fine- to medium-sized root and manganese oxyhydroxide (5-10%). Prominent dark gray subvertical clay seams (polygonal fractures and root casts) present down section with zones of prominent oxidation and clay film development.

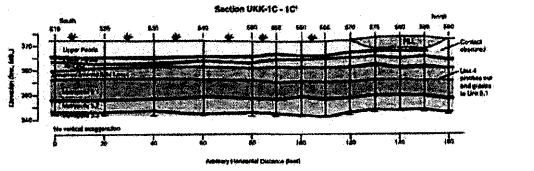
Unconsol (Intermediate Loess – (Unit 3) yellowish brown (10YR5/4) to light brown-pale yellow (10YR6/4) to brown (10YR4/3) SILTY CLAY with thinly laminated silt laminae. A well-developed paleosol present throughout unit 4. Upper part of unit is marked by an increase in clay content and manganese oxide staining and mottle development, associated with paleosol horizons. Subvertical grayish clay-rich seams are found throughout the unit and corresponding to thin yellowish-brown SILTY CLAY to CLAYEY SILT. Unit 3 is strongly mottled, generally moist and soft (silt) to stiff (clay). The basal contact is generally clear and marked by a distinct, paler-tan silty to silty sand section directly overlying a darker clay-rich unit (interpreted as a buried paleosol) consistent with the Sangamon Gonsol. (Pleistocene loess)

Metropolis Formation – (Unit 5.1) This unit is a light brownish gray (10YR6/2) to grayish brown (10YR5/2) CLAY to SILTY CLAY which grades down section to a gray (10YR5/1) to light grayish brown (10YR5/2), or grayish brown (10YR4/2) CLAY with silty to sandy interbeds. Upper part of unit is generally massive with occasional hard silt laminations. Laterally vertical cracks (dry gray clay seams within upper two feet of deposit and interpreted as possible buried pot features associated with the Sangamon Gonsol. The lower part of the unit generally contains thin interbeds of sandy silt, silty sand, silt and clay (homogeneous) oxyhydroxide staining is minor and consists of mottling primarily in the upper section. The basal contact is generally clear. (Pleistocene fluvial deposit)

Metropolis Formation – (Unit 5.2) This unit consists of a reddish yellow (7.5YR6/6) to (5YR) to a strong brown (7.5YR5/6) SANDY CLAY or CLAYEY SAND (20-70% sand) with clay interbeds. Upper contact marked by an increase in silt, sand, gravel, and iron oxide staining. Upper portion of unit contains thin clay interbeds at about a foot below the upper contact with unit 5.1. Unit 5.2 is mostly in very dense, wet, stiff to hard, with little or no iron manganese oxyhydroxide staining. Base of unit stain-grades into a SILT or CLAY, which can be up to 2 feet thick. (Pleistocene fluvial deposit)

Metropolis Formation – (Unit 5.3) This unit is a bedded, brown (7.5YR5/4) to strong brown (7.5YR5/6) SILT to medium-grained SAND and GRAVEL with silt and some reddish-yellow (7.5YR6/6) clay laminations. This unit is moist and is often roughly stained an orange-brown (iron oxide), other subvertical blue-gray clay seams (subvertical ancient cracks or polygonal clay seams possibly associated with the Yarmouth Gonsol, iron and manganese oxyhydroxide staining are other absent or weakly expressed when present. The base of this unit extends beyond the depth of subsurface exploration. (Pleistocene fluvial deposit)





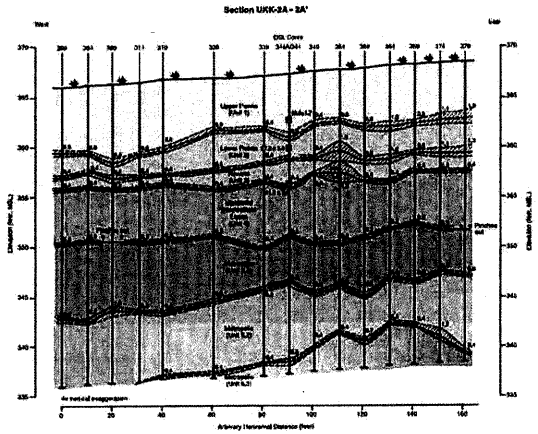
C-746-U LANDFILL EXPANSION
PADUCAH, KENTUCKY

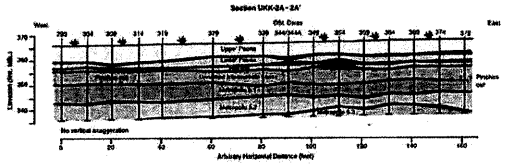
Sections UKK-1A-1A', UKK-1B-1B' and UKK-1C-C'

WLA William Lettes & Associates, Inc.

Plate 2

1795 Paducah





Symbols

- Unit contact
- Contact area[6] — contact area listed next to each boring contact and the methodology for determining area, as described in section 5
- Radiocarbon (C^{14} sample location) — No ages reported because samples did not contain enough carbon for analysis
- 1A.3, 1.2 Optically stimulated luminescence sample location and age (ka with 1σ); see Table 2

Notes

1. Boring designations correspond to drill points in accompanying Sheet S1-1 and S1-2.
2. Shot points have 3 foot spacing.
3. Vertical exaggeration is 4x (1% slp).
4. More complete descriptions of physiographic units and paleosols provided in section 5.
5. Greater contact error not accurate.
6. Elevations are rel. Paducah Cesium DELJoint Plant coordinate system.

Explanation

Unit Descriptions[4]

Upper Peoria Loess – (Unit 1) brown (10YR/5/3) to yellowish brown (10YR/5/6) CLAYEY SILT (up to 10% clay) to a clean SILT with minor traces of clay. Massive and speckled (3-5%) with small (<2mm) angular to subrounded light brown nodules of iron-manganese oxyhydroxides. In places unit has poorly developed (massive stage) transitional zones defined as mottles and fine nodules. (Pleistocene loess)

Upper section of Unit 1 is characterized by "treasem" soil that began developing post deposition of loess (since 12 ka; Forman et al., 2005). This soil consists of a thin A-horizon with minor organic accumulation, a distinct whitish (5-10YR 8-5/4)(pH 8.1) clay-rich A/B and B-soil horizons, and a Cox/Horizon that is noted by a decrease in clay content with little to no mottling.

Lower Peoria Loess – (Unit 2) brownish yellow (10YR/6/6) to yellowish brown (10YR 5/4-5/6) SILT to CLAYEY SILT with discontinuous and substantial reddish to light yellow silt lenses. Unit is generally massive, moist, and soft and compresses readily with the GPT sampling technique. Basal contact of Unit 2 is generally defined by relatively clean silt with lenticular overlying a more clay-rich silt (Farmdale Gravel) with abundant relict root casts and mottling. (Pleistocene loess)

A poorly defined paleosol represents the top of Unit 2. Identified in the cores based on the presence of subtle to moderate iron-manganese oxyhydroxides developed within the upper 0.5 feet of Unit 2.

Roxana Silt – (Unit 3) yellowish brown (10YR/5/4) to pale brown (10YR/6/3) SILT with clay and SILTY CLAY with distinct, discontinuous, yellowish-white thin lenticulars. Unit 3 also contains prominent clay films along well developed polygonic fractures, a significant clay content compared to overlying loess packages, extensive mottling, and soil-developed, simplified root casts. Basal contact generally is clear and marked by a thinly laminated yellowish-brown silt with little to no manganese-oxides that overlie a darker brown to grayish-brown silty clay (interpreted as a buried paleosol) of an older unnamed loess. (Pleistocene loess)

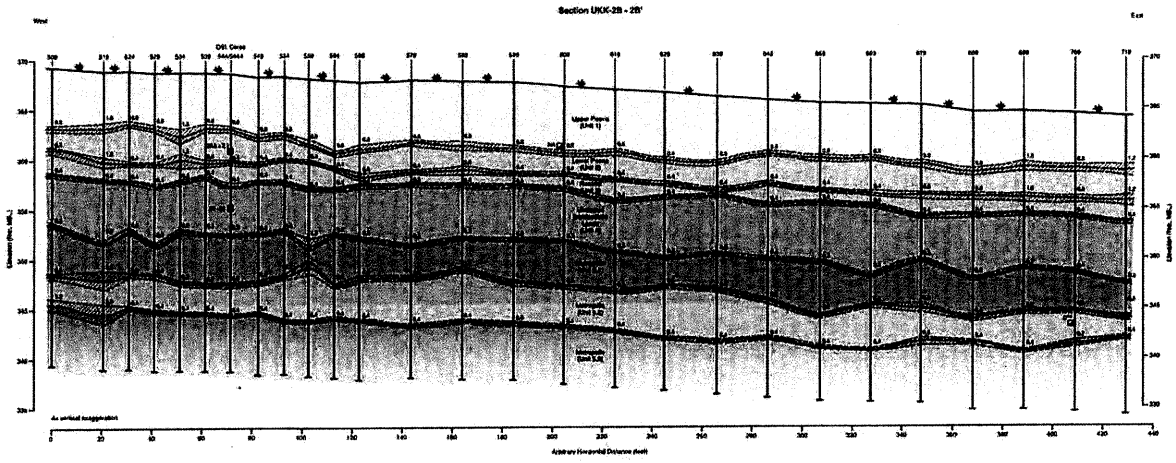
The Farmdale Gravel and associated mottling and clay development overprints and obscures much of the massive nature of unit 3. Upper part of the Farmdale Gravel is noted by the concentration of fine- to medium-sized iron and manganese oxyhydroxides (5-10%). Prominent dark gray subvertical clay seams (polygonic fractures and root casts) present down section with zones of prominent mottling and clay film development.

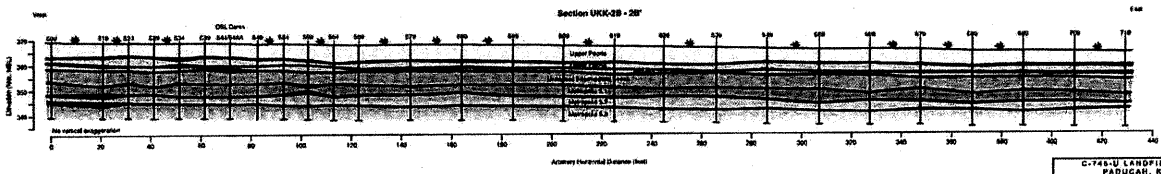
Unnamed Intermediate Loess – (Unit 4) yellowish brown (10YR/5/6) to light brownish yellow (10YR/6/4) to brown (10YR/5/3) SILTY CLAY with fairly laminated silt interbeds. A well-developed paleosol present throughout unit 4. Upper part of unit is marked by an increase in clay content and manganese oxide staining and nodule development, consistent with paleosol features. Subvertical polygon clay-rich seams are found throughout the unit and show mottling softer yellowish brown SILTY CLAY to CLAYEY SILT. Unit 4 is strongly mottled, generally moist and soft (soft to stiff clay). The basal contact is generally clear and marked by a distinct, massive silt to silty sand horizon directly overlying a darker gray clay-rich unit interpreted as a buried paleosol possibly associated with the Sangamon Gravel. (Pleistocene loess)

Metropolis Formation – (Unit 5.1) This unit is a light brownish gray (10YR-6/2) to grayish brown (10YR-5/2) CLAY to SILTY CLAY which grades down section to a gray (10YR-5/1) to light grayish brown (10YR-6/2), or grayish brown (10YR-5/2) CLAY with silty or sandy interbeds. Upper part of unit is generally massive with intermediate level silt lenticulars. Exhibits a vertical dark blue gray clay seams within upper two feet of deposit and interpreted as possible buried soil horizons associated with the Sangamon Gravel. The lower part of the unit generally contains thin interbeds of sandy silt, silty sand, silt and clay. Iron-manganese oxyhydroxide staining is minor and consists of mottling primarily in the upper section. The basal contact is generally clear. (Pleistocene fluvial deposit)

Metropolis Formation – (Unit 5.2) This unit consists of a reddish yellow (7.5YR-6/6 to 5/6) to a strong brown (7.5YR-5/8) SANDY CLAY or CLAYEY SAND (50-70% sand) with clay interbeds. Upper contact marked by an increase in silt, sand, gravel, and iron oxide staining. Upper portion of unit contains thin clay interbeds at about a foot below the upper contact with unit 5.1. Unit 5.2 is noted to vary moist, soft, stiff to hard with little or no iron-manganese oxyhydroxide staining. Base of unit often grades into a SILT or CLAY which can be up to 3 feet thick. (Pleistocene fluvial deposit)

Metropolis Formation – (Unit 5.3) This unit is a darkest, lower (7.5YR-5/1) to strong brown (7.5YR-5/6) fine- to medium-grained SAND and GRAVEL with silt and some reddish yellow (7.5YR-6/6) clay lenticulars. The unit is moist and is often strongly stained an orange-brown from iron oxides. Minor polygonal clay-gray clay seams indicate ancient mottling or polygonal clay seams possible associated with the Yarmouth Gravel. Iron and manganese oxyhydroxide staining are minor apparent or weakly expressed when present. The base of this unit extends beyond the depth of subsurface exploration. (Pleistocene fluvial deposit)





C-745-U LANDFILL EXPANSION
PADUCAH, KENTUCKY

Sections UKK-2A-2A' and UKK-2B-2B'

WLA William Lettes & Associates, Inc | Plate 3

1725 Paducah

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ATTACHMENT 3

JUSTIFICATION FOR THE USE OF BORINGS INSTEAD OF TRENCHING FOR THE HOLOCENE FAULT STUDY

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JUSTIFICATION FOR THE USE OF BORINGS INSTEAD OF TRENCHING FOR THE STUDY

At the time of scoping of the Holocene Fault Study, the investigators and technical oversight personnel evaluated the use of exploratory trenches as a primary tool for identifying fault traces. Trenches were projected to be 10 to 15 ft deep with lengths of hundreds to thousands of ft. The project scoping group rejected exploratory trenches for two primary reasons:

1. Trenches pose inherent risk to excavation workers, the investigators, and the general public.

2. The shallow depth of the water table in some areas would result in standing water in the trenches (making observations difficult, increasing the dangers of trench wall failure, and generating a large waste volume requiring characterization and disposition).

The participants to the scoping agreed that closely-spaced soil borings to 30-ft depth were a preferred approach to identifying fault traces. In addition to significantly decreased health risk and waste volume, the borings allowed observation to 30-ft depth. The increased depth was important because the shallow soils at 10- and 15-ft depths are relatively uniform, making detection of a fault offset difficult. Enclosed with this letter is a list of scoping participants and their affiliations.

The University of Kentucky Research Consortium for Energy and Environment coordinated the investigation which resulted in the Holocene Fault Study. William Lettis and Associates, Inc., was the primary project contractor. The investigation benefitted from the input of professors of the Department of Geological Sciences of the University of Kentucky, Dr. John Nelson of the Illinois Geological Survey, and Dr. David Amick of Science Applications International Corporation.

LIST OF SCOPING PARTICIPANTS AND AFFILIATIONS

The scoping team included:

Dr. John Volpe (KRCEE)
Dr. Ed Woolery (UK Geological Services)
Steve Hampson (KRCEE)
Bruce Phillips (Navarro)
John Baldwin (Lettis & Associates)
Dr. Keith Kelson (Lettis & Associates)
Dr. Dave Amick (SAIC)
Marshall Davenport (Bechtel Jacobs)

Independent Reviewers included:

Dr. Tish Tuttle (Tuttle and Associates)
Dr. John Nelson (Illinois State Geological Survey)
Dr. Roy Van Arsdale (University of Memphis)

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ATTACHMENT 4

Technical Memorandum for the C-746-U Landfill Fault Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-2097&D2, October 2003

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DOE/OR/07-2097&D2

Technical Memorandum for the C-746-U Landfill Fault Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

October 2003

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SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

DOE/OR/07-2097&D2

Technical Memorandum for the C-746-U Landfill Fault Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—October 2003

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
Paducah, Kentucky 42001
managed by
Bechtel Jacobs Company LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-03OR22980

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CONTENTS

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2. PLANNED ACTIVITIES 1

3. SUMMARY OF WORK PERFORMED 2

4. DEVIATIONS FROM PLANNED ACTIVITIES 2

5. DATA ACQUIRED 2

6. SUMMARY OF RESULTS 2

7. REFERENCES 4

APPENDIX FINAL SHEAR-WAVE SEISMIC SURVEY REPORT A-1

ACRONYMS

BJC	Bechtel Jacobs Company LLC
DOE	U.S. Department of Energy
HSW	horizontal shear wave
RGA	Regional Gravel Aquifer
S-Wave	shear (S) wave
SAIC	Science Applications International Corporation

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1. INTRODUCTION

The U.S. Department of Energy (DOE) has completed a fault study at the C-746-U Contained Landfill at the Paducah Gaseous Diffusion Plant to satisfy Condition 8 of the revised landfill permit, issued February 1, 2001.

The seismic reevaluation study shall completely reevaluate the ground motion potential, the potential for structural offset along local faults, and all other seismic risks associated with the New Madrid Seismic Zone, the Wabash Valley Seismic Zone, and local fault zones.

Prior to conducting this fault study, DOE provided a work plan to the Commonwealth of Kentucky (Commonwealth) for review (Feireisel 2003). The Commonwealth subsequently provided conditional approval of the work plan (Ritchie 2003). This Technical Memorandum documents the fault study activities and presents the results (data) from the fault study. The interpretation of the Shear-Wave (S-Wave) Survey is presented in the Appendix to this Technical Memorandum.

The fault study consisted of a horizontal (S-Wave) Survey. An S-Wave Survey is a nonintrusive geophysical method that uses acoustic energy to image the subsurface; it is used to detect anomalies in the shallower portions of the subsurface. A summary of this geophysical technique is presented in the Appendix to this Technical Memorandum.

2. PLANNED ACTIVITIES

The planned S-Wave Survey activities are described, as follows, in Section 2.1.3 of the Technical Specifications portion of the work plan (Feireisel 2003).

> A high-resolution horizontal shear (S) wave (HSW) seismic reflection survey ... with an estimated total footage of 2,908 ft (approximately 1,209 ft. East-West, approximately 1,699 ft North-South). The purpose of this survey is to provide higher resolution data, which may better define potential faulting, from the surface to the top of the Clayton-McNairy Formation. For the purpose of this description it is assumed that the survey will be 96 channel, 48 fold and will be conducted using a geophone spacing of 2 feet, a "vibroseis" and/or hammer generator source and a geophone frequency of 40 Hz.

The conditional approval received from the Commonwealth requires the collection of "full-fold (i.e., 48 fold) data along the entire length of the proposed profile lines ... to insure that the maximum data quality is achieved from the beginning to end of the two lines" (Ritchie 2003). Since the proposed lines extended 200 ft beyond the boundary of the landfill, DOE extended the survey lines by 50 ft at each end to achieve full-fold data within 200 ft of the landfill boundary.

The conditional approval received from the Commonwealth also requires that DOE provide the Commonwealth with a copy of the S-Wave raw data files (SEG-Y format) and a copy of this finalized Technical Memorandum for review (Ritchie 2003). DOE provided the raw data files to the Commonwealth on August 21, 2003, and has agreed to provide this Technical Memorandum to the Commonwealth.

3. SUMMARY OF WORK PERFORMED

Science Applications International Corporation (SAIC) and its subcontractor, Blackhawk GeoServices, performed the S-Wave Survey. SAIC is under subcontract to Bechtel Jacobs Company LLC (BJC), DOE's Management and Integration contractor.

The S-Wave Survey was conducted from May 22 through 26, 2003, along two perpendicular lines that intersect northwest of the landfill. A total of 3,196 linear ft of data were collected (1,398 ft along the East-West line and 1,798 ft along the North-South line). The survey was conducted using the Bay Geophysical MicroVibrator S-Wave source, a 96-channel seismograph, and 40 Hz horizontal component geophones. The geophones were placed at 2-ft intervals, and "shots" (using the MicroVibrator energy source) were taken at 2-ft intervals. Figure 1 illustrates the locations of both S-Wave Survey lines. Blackhawk GeoServices processed the data, and their report is contained in the Appendix to this Technical Memorandum. The Blackhawk GeoServices report contains detailed information regarding the data acquisition, data processing, and interpretation of results.

4. DEVIATIONS FROM PLANNED ACTIVITIES

There were no deviations from the work plan, as conditionally approved.

5. DATA ACQUIRED

The results of S-Wave Survey are presented in the Appendix to this Technical Memorandum. The Appendix consists of the report prepared by Blackhawk GeoServices. It contains processed data from both survey lines.

6. SUMMARY OF RESULTS

The goal of this study was to determine if geologically young faulting is present beneath the C-746-U Landfill. The study was completed as planned. The S-Wave reflection data reveals two zones of deformation, which are interpreted as potential faults. In both zones, the deformation extends from the bedrock up to and through the Regional Gravel Aquifer (RGA). The RGA generally is thought to be Quaternary to late Tertiary in origin; therefore, the deformation occurred within the past few million years. The RGA is, however, covered by approximately 45 ft of even younger sediments. Because there are no strong seismic reflectors observed in these shallower sediments, it could not be determined, using the S-Wave reflection technique, if these potential faults extend into the younger units.

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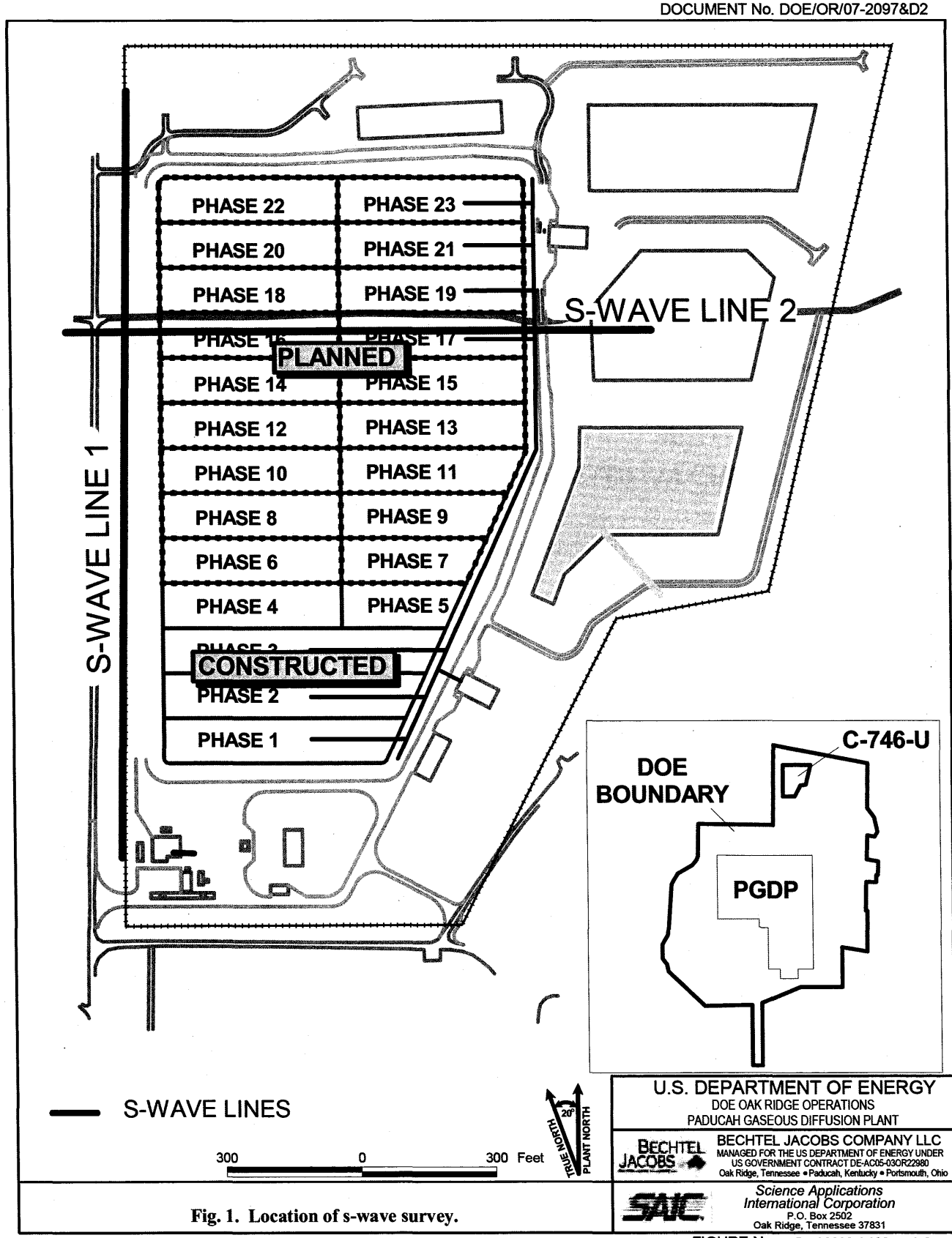

Fig. 1. Location of s-wave survey.

FIGURE No. c5ac90000sk122y-saic3.apr
DATE 08-13-03

7. REFERENCES

Feireisel 2003. Feireisel, Dianna. April 15, 2003. Acting Site Manager, U.S. Department of Energy, Paducah, KY, letter to Robert H. Daniell, Director, Division of Waste Management, Kentucky Department for Environmental Protection, Frankfort, KY.

Ritchie 2003. Ritchie, Charles W., P.E. May 2, 2003. Environmental Engineer II, Solid Waste Branch, Division of Waste Management, Natural Resources and Environmental Protection Cabinet, Frankfort, KY, letter to Dianna Feireisel, Acting Site Manager, U.S. Department of Energy, Paducah, KY.

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APPENDIX

FINAL SHEAR-WAVE SEISMIC SURVEY REPORT

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FINAL SHEAR-WAVE SEISMIC SURVEY REPORT
C-746-U LANDFILL SEISMIC ASSESSMENT
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY

Blackhawk GeoSciences SE Project Number 3915SAI

Prepared For:
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

BLACKHAWK
GeoServices
Southeast Region

FINAL SHEAR-WAVE SEISMIC SURVEY REPORT
C-746-U LANDFILL SEISMIC ASSESSMENT
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY

Blackhawk GeoSciences SE Project Number 3915SAI

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) is the lead agency at the Paducah Gaseous Diffusion Plant (PGDP). The general location of PGDP is presented in **Figure 1**. The U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky, pursuant to the Federal Facility Agreement (FFA), regulate environmental restoration activities at PGDP.

Over the past year, representatives from the Commonwealth of Kentucky, DOE, and their support staffs have developed a field investigation program to address seismic issues associated with the C-746-U Landfill. This site is located on DOE property, northeast of the present security fence **(Figure 2)**.

Blackhawk GeoServices (BHG), in partnership with our subsidiary, Bay Geophysical, performed a horizontal shear-wave (s-wave) seismic reflection survey at the C-746-U Landfill from May 22 to May 26, 2003. The work was performed under subcontract number 4400069187 with Science Applications International Corporation (SAIC).

For this study, s-wave seismic reflection data were acquired along two survey lines (Lines 1 and 2) totaling approximately 3,200 linear feet of surface coverage. The locations of the survey lines relative to PGDP and permanent geographic features are shown in **Figure 2**. For production work, key seismic equipment used to collect the data included:

- Bay Geophysical MicroVibrator,
- 96-channel OYO DAS-1 Seismograph,
- 40-Hz OYO SMC70 horizontal component geophones.

This report summarizes all data acquisition and field methods used to conduct the investigation and includes sections on data processing, interpretation, conclusions and recommendations.

1.1 PROJECT OBJECTIVES

The purpose of the C-746-U Landfill seismic reflection survey is to identify potential subsurface anomalies indicating the presence of young/shallow faulting. Specifically, the target zone of the s-wave study extends from as near to the ground surface as possible to an approximate depth of 50 feet below ground surface (bgs).

1.2 GEOLOGIC SETTING

The shallow stratigraphy at the C-746-U Landfill site consists of variable layers of sand, silt, and clay. The Upper Continental Recharge System is the shallowest stratigraphic unit, extending from the surface to a depth of approximately 45 feet below ground level. This unit is composed of loess and other fine-grained continental deposits, and is Quaternary in age. Beneath this lies a thick layer of sand and gravel, known as the Regional Gravel Aquifer. This gravel deposit extends from approximately 45 feet to 80 feet below ground surface (bgs). The Cretaceous age McNairy Formation, composed of sands, silts, and clays, lies beneath the Regional Gravel Aquifer and extends down to a depth of approximately 325 feet bgs, where Mississippian age Limestone bedrock is encountered.

The key reflectors at the Landfill site include:

- A strong reflection from the top of the Regional Gravel Aquifer
- A moderate to poor reflection from the Regional Gravel Aquifer/ Top McNairy Interface

Although the McNairy/Mississipian Limestone interface provides a large acoustic contrast, it lies at a depth well below the level of this investigation, and no reflector from this interface is expected.

The s-wave survey focused on identifying faulting between the surface and the top of the Regional Gravel Aquifer. Based on the geologic setting, the seismic surveys completed recently at the southern side of the PGDP and mapping in the Fluorspar Area Fault Complex of Massac County, Illinois (located just across the Ohio River from Paducah, Kentucky), if faulting is present at the PGDP, it would be expected to trend northeast and consist mostly of high-angle normal faults that outline horsts and grabens (Nelson 1998).

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2.0 DATA ACQUISITION

This section describes the seismic methods and field procedures used to conduct the C-746-U Landfill investigation including survey control, source testing, and production parameters.

2.1 GENERAL

Seismic Reflection Technique

Seismic reflection profiling is a standard technique employed by the oil and gas exploration industry. The use of this technique in shallow engineering and environmental projects has been a relatively recent phenomenon, as the formerly high production costs and serious computing requirements were prohibitive. Advances in microelectronics have led to engineering seismographs and PC-based processing that now permit the cost-effective use of reflection seismic methods in a wide variety of applications (Steeples and Miller 1988).

Details of the general seismic reflection technique can be found in many comprehensive texts, such as Sheriff and Geldart (1995); therefore, only a brief synopsis of the basic principles is presented here, with particular emphasis on the characteristics of shear waves.

The seismic reflection technique can be divided into two categories based on the type of seismic energy used. Compressional, or p-waves, propagate through the earth as a series of compressions and rarifications and are identical to ordinary sound waves. As shown on the left side of **Figure 3**, particle motion for p-waves is parallel with the direction of propagation. Shear waves, or s-waves, propagate through the earth by distorting the shape of the medium through which they are passing. The right portion of **Figure 3** shows that particle motion in s-waves is perpendicular to the direction of wave propagation. An important feature of shear waves is that, unlike p-waves, they will not propagate through liquids or gases, as these materials have no shear strength. This makes them particularly valuable for the detection of voids, fractures, and faults.

Civil engineers have been using shear wave velocities since the 1940's to determine elastic moduli of near surface materials, which are linked to material properties of rock and, thus, to the safety of construction works such as dams or tunnels (Garotta 1999). Geophysicists, on the other hand, have moved cautiously to the use of shear waves. The oil and gas (O&G) industry experimented with shear wave techniques in the 1970's and 1980's, but has for the most part discontinued their use except for special applications. This primarily was because p-waves did a better job for targets on the order of several thousand feet below ground surface. Shear wave propagation through the earth generally is limited to a few hundred times their wavelength before attenuating below detectable levels (Helbig 1984). For the O&G industry, this is a serious limitation.

The application of shear wave reflection techniques to shallow subsurface investigations began in the 1990's. For these applications, the limitations imposed by the attenuation of shear waves over distance no longer are applicable. On the contrary, for engineering and environmental applications, s-waves provide higher resolution and resolve shallower targets than p-waves. Primarily, this is because s-wave velocities are slower than p-wave velocities, resulting in greater subsurface resolution, and s-waves generally are not affected by shallow groundwater tables, which results in greater resolution, particularly in low-velocity unconsolidated sediments like those at PGDP.

Seismic Reflection

The basic principles of the reflection technique are illustrated in **Figure 4**. The seismic reflection method involves projecting acoustic energy down from the surface, and then recording the acoustic energy back at the surface as it reflects off of formations at depth. Seismic energy also is refracted and diffracted at boundaries in the subsurface, in accordance with Snell's Law. One of the main design considerations for a successful seismic reflection survey is the ability to separate the reflected energy from the other arrivals in processing.

A seismic reflection occurs when an acoustic wavefront encounters an impedance boundary in the subsurface. Seismic impedance depends on both the velocity and density of a rock, and impedance boundaries occur where these rock properties change abruptly, usually due to changes in lithology. The reflection coefficient, R, across an interface, is expressed by a function relating the acoustic impedance of adjacent layers. R determines the relative amplitude of the reflected wavelet.

$$\mathbf{R} = \frac{\sigma_2 \mathbf{V}_2 - \sigma_1 \mathbf{V}_1}{\sigma_2 \mathbf{V}_2 + \sigma_1 \mathbf{V}_1}$$

where, R = reflection coefficient,
σ_1, σ_2 = mass density of the material on each side of the interface, and
V_1, V_2 = p-wave velocity on each side of the interface.

The sign of the reflection coefficient determines the polarity of the reflected wave. The magnitude of the reflection coefficient is critical to obtaining usable data. The seismic reflection technique will not work if the acoustic contrast is not sufficient to produce a clear reflection, regardless of the survey parameters or processing techniques employed. The ability of the seismic reflection method to detect an individual sedimentary bed is not only a function of the acoustic impedance at the top and bottom of the bed, but also depends on the layer thickness. The minimum resolvable bed thickness often is quoted as 1/4 to 1/8 of the wavelength of the seismic reflection. Wavelength is inversely proportional to frequency.

That is:

$v = f\lambda$

where, v = acoustic propagation velocity,
f = frequency, and
λ = wavelength.

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Wavelength controls vertical resolution and obviously is dependent on frequency and velocity, with shorter wavelengths resolving smaller subsurface features than longer wavelengths. Generally, shear waves travel at roughly half the velocity of p-waves; therefore, for a given frequency, shear waves will have approximately half the wavelength, translating to twice the resolution.

Shear wave velocities in the PGDP area have been determined by previous downhole surveys performed at the site. **Table 2-1** presents shear wave velocities determined by cross-well testing at various locations around the PGDP facility. **Figure 5** presents s-wave and p-wave velocity data from borehole DB02 that were acquired with a P-S Suspension logger. From **Figure 5**, it's evident that s-wave velocities above the water table (~20 feet bgs) are roughly half the velocity of p-waves, whereas below the water table, p-wave velocities increase significantly to the approximate velocity for water [~5,000 feet per

second (ft/s)] and the s-wave velocities generally remain unchanged. Below the water, this translates to an s-wave velocity that is roughly 4 times slower than the p-wave velocity.

TABLE 2-1
LOCAL S-WAVE VELOCITIES (FT/S) FROM CROSS-WELL MEASUREMENTS

Depth (ft).	Site			
	Z-1/Z-3	Z-5/Z-7	Z-9/Z-12	Z-13/Z-16
5			620	490
10	770	600	625	
15		630	815	
20		735	855	
25		1070	890	1220
30			975	1300
35	1015		975	
40	1020	1180	915	1330
45	1035	1280	990	
50	1025			
55	1180?		980	
60		1125		
65	1115	1105	990	
70		1065		1470
75			1185	1330
80		1225	1205	1500
85				1320
90		1310	1250	1070
95		1260		1190
100		1360	1210	1510
105		1245		
110		1180	1105	1100
115		1515	1160	1090
120		1470		
125		1290		
130				
135		1200		

At the Landfill site, shear wave interval velocities in the sedimentary layers above bedrock are less than 2,000 feet per second. The frequencies put into the ground by the MicroVibrator ranged from 40-300 Hertz (Hz) and recoverable frequencies ranged from 40-280 Hz. **Table 2-2** compares the frequencies, velocities, and wavelengths for the site area, with consideration to the data acquisition parameters used and recovered signal frequencies.

TABLE 2-2

VELOCITY, FREQUENCY, AND WAVELENGTH RELATIONSHIPS FOR RESOLUTION OF POST-PALEOZOIC FAULTS

Velocity ft/s	Frequency Hz	Wavelength ft	Vertical Offset Mapping Limit (1/4 λ), ft	Vertical Offset Detection Limit (1/8 λ), ft
1,000	40	25.0	6.3	3.1
1,000	80	12.5	3.1	1.6
1,000	120	8.3	2.1	1.1
1,000	180	5.6	1.4	0.7
1,000	240	4.2	1.0	0.5
2,000	40	50.0	12.5	6.3
2,000	80	25.0	6.3	3.1
2,000	120	16.6	4.2	2.1
2,000	180	11.1	2.8	1.4
2,000	240	8.3	2.1	1.0
3,000	40	75.0	18.8	9.4
3,000	80	37.5	9.4	4.7
3,000	120	25.0	6.3	3.1
3,000	180	16.7	4.2	2.1
3,000	240	12.5	3.1	1.6

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When a reflecting boundary exists, it's important to optimize the field procedure and acquisition parameters to ensure the quality of the final processed data. Choosing the best field parameters involves determining the relative importance of several competing objectives, such as site constraints, equipment capabilities, and processing needs.

In all geophysical surveys, the objective is to extract the usable data (i.e., in this case, reflections from various lithologic boundaries) from the unwanted background information (geologic and ambient noise). In reflection seismology, it's desirable to record high frequency, high signal-to-noise ratio reflection events from the boundary of interest. The frequency of a reflection event is largely determined by the source input frequency and the filtering effect of the ground. Often, the target reflector frequency is similar to that commonly recorded for coherent noise (in particular, the noise from ground roll), making it difficult or impossible to selectively filter out the noise. Isolation of the reflection events requires careful design of field acquisition parameters, such as the source/receiver geometry, choice of source and receiver types, as well as recording parameters, such as sampling rate and filter settings.

In general, s-wave data is more difficult to assess in the field than p-wave data. The primary reason for this is the predominance of Love waves on the shot records, which are usually strong enough to mask all other arrivals below first breaks. Love waves are surface waves involving transverse motion parallel to the surface of the ground and have velocities intermediate between the s-wave velocity at the surface and the s-wave velocity in deeper layers **(Figure 6)**. Because these waves are trapped in the near surface layer or weathering layer, they attenuate slower than other seismic waves and often are the strongest events on the record. Love waves are not seen on p-wave data and are unique to the shear wave reflection method.

Figure 7 presents a raw s-wave production shot from Line 1 (Shotpoint 196.5). The seismic source is located between channels 48 and 49. The first breaks on this record are direct arrivals near the source and become refractions at the longer offsets. Beneath the first breaks, high amplitude Love waves can be seen propagating throughout the record. Fortunately, this coherent, source-generated noise can be mitigated with a number of field and processing tools. In the field, the application of a 100 Hz Low-Cut filter revealed the underlying reflectors. During data processing, velocity filtering or statistical noise attenuation algorithms were applied to the data to remove this unwanted signal. In the figure, the geophone at position 74 was disconnected intentionally to track geometry.

Figure 8 presents the same shot record from Line 1, after Love wave mitigation. This record demonstrates the relationships between the s-wave reflection and refraction events within the zone from 60-120 milliseconds (msec) and several s-wave reflectors that previously were obscured by Love waves. Note that ground roll (Rayleigh waves) and the airwave are absent, since Rayleigh waves are surface waves that travel in the vertical plane, and s-waves will not propagate through gases, respectively. The refraction event, highlighted in brown, is always the first to arrive at the long offset geophones and usually makes up the bulk of the first breaks. Refractions are characterized by linear moveout across the shot records, that is, they appear as straight segments. The reflection events, which dominate the areas highlighted in green, are characterized by a hyperbolic moveout. Multiple reflections, though not clearly evident in this shot record, result from a double bounce of acoustic energy between, for example, the surface and a hard layer **(Figure 9)**. Multiples display nearly the same hyperbolic moveout as primary reflections and are typically easy to recognize. Some multiples do stack in on the final sections, and any interpreters working with these data need to be aware of their presence.

2.2 DESIGN OF SURVEY PARAMETERS

A summary of the production data acquisition parameters is provided in Section 2.5 and **Table 2-3**. For this phase of the project, the receiver group interval was 2 feet, with one 40-Hz horizontal component geophone located at each station. Shot records contain 96 live channels in a symmetric split spread configuration, except at the beginning and end of each line, where the MicroVibrator was rolling on and off of the spread. Data were recorded with a 0.5-msec sample rate and a record length after correlation of 1 second. The source parameters were determined by on-site testing.

2.2.1 Source Testing

The MicroVibrator used on this project is patented to Bay Geophysical. It weighs approximately 300 pounds and is coupled to the ground by several large spikes (or smaller spikes as conditions warrant). It generates a sweep by oscillating a mass through a user-defined range of frequencies, which are transmitted into the ground.

Typically, the advantages of using a vibratory source for reflection work include a higher signal-to-noise ratio when compared to impulsive sources, such as the hammer and cylinder, weight-drops, or dynamite. This is due to the statistics of the correlation process and the ability to control the frequencies put into the ground. Another advantage is that particle motion amplitudes are much lower with vibratory sources, greatly reducing or eliminating damage to any nearby surface structures. This is because the energy of a vibratory source is input into the ground over a relatively long time interval.

Vibratory sources function by holding a plate on the ground and vibrating the plate through a user-defined range of frequencies, known as a "sweep." The length of the sweep, peak force, and frequency range can be changed in the field. At the instant the vibrator begins its sweep, the seismograph begins recording the signals received from the geophones. The seismic signal created by the sweep is received by the geophones and stored in the seismograph. By correlating the recorded signals from the geophones with the known sweep generated by the vibrator, a seismic trace is obtained.

Source testing at the Landfill site was limited, since a recent shear wave survey conducted at the PGDP already had determined most of the field parameters. Due to the presence of the thick Regional Gravel Aquifer, some short experiments with the sweep were conducted. The gravel layer was expected to absorb more high frequencies than previously observed at the southern portion of the PGDP; therefore, tests were conducted using 30–240 Hz and 30-300 Hz sweeps. No significant changes in data quality were observed, so the decision was made to proceed with data acquisition using the parameters from the previous survey at the PGDP (40-300 Hz). This sweep had produced excellent data quality on the previous shear wave surveys at PGDP.

2.3 SITE-SPECIFIC PROBLEMS

Conditions in the field were ideal for seismic data acquisition. Lines 1 and 2 ran parallel to the landfill fence on the west and north sides. These areas were swaths of mowed grass, and surface soil conditions were uniform throughout most of each line. Both lines extended across dirt roads and into thicker grass in the northwest corner of the survey area. Topography was gentle, and conditions were generally dry, except for a few wet spots in the low areas.

Only one site-specific problem became apparent during the course of data acquisition. It was observed early on that a relatively high-frequency "buzz" could be seen ahead of the first breaks on the shot records. The "buzz" was broadband, ranging from approximately 180 to 250 Hz. At first it was suspected that there may be underground utilities beneath Line 1, but this was determined by SAIC not to be the case. The source of the noise remained a mystery until data acquisition extended away from the fence. Geophones placed on that part of the line beyond the extent of the landfill fence were noise-free. The "buzz" was observed once again on Line 2 when the active spread became adjacent to the fence. After further investigation, it was determined that the landfill fence was carrying a current that fluctuated, but sometimes reached as high as 500 milliamps. The current probably was being induced into the fence by overhead powerlines leading into the PGDP facility. Since geophones are sensitive to electrically induced noise, it is likely that the current in the fence was the source of this "buzz". The induced noise from the fence was, however, quite low in amplitude and would have caused only a slight degradation of the data, if any.

2.4 HEALTH AND SAFETY (H&S)

The C-746-U Landfill seismic survey was conducted under the Health and Safety Plan prepared by SAIC. SAIC personnel provided health and safety coverage. The survey was completed safely.

2.5 PRODUCTION PARAMETERS AND LINE INFORMATION

The nominal spread configuration is graphically represented in **Figure 10**. Production parameters for the two seismic lines are summarized in **Table 2-3**.

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TABLE 2-3

NOMINAL SEISMIC REFLECTION ACQUISITION PARAMETERS

Shot Spacing	2 feet
Geophone Group Interval	2 feet
Nominal CMP Fold	48
Maximum Offset	95 feet
Minimum Offset	1 feet
Spread Geometry	Symmetric Split Spread 48/48 – (190 foot total active array)
Seismograph	2 OYO DAS-1 Recorders (Master/Slave)
Number of Channels	96
Sample Rate	0.5 ms
Record Length	1.0 second
Field Filters	3/18 – Out Hz/dB
Seismic Source	Bay MicroVibrator, - 300 lbs of peak ground force 40 to 300 Hz, Linear, 8 second sweep, 4 sweep/station
Geophones	1 X 40 OYO SMC70 40 Hz Shear Wave phone
Cables	48 pair cables with Amphib Heads, 4' takeouts, 24 takeouts / cable
Rollbox	I/O Inc. RLS-240M

CMP - Common Mid Point (Having the same midpoint between source and detector.)

Table 2-4 lists the lines surveyed and their number of stations. The lines also are shown on the seismic line location maps **(Figures 2 and 3)**.

TABLE 2-4

SUMMARY OF LINE AND STATION NUMBERS

Line Name	First Station	Last Station	# of Stations	Line Feet
1	76	976	900	1,798
2	76	776	700	1,398

2.6 PRODUCTION PROCEDURES

A Kentucky-licensed surveyor surveyed Lines 1 and 2 under the supervision of SAIC. At that time, stations were staked and XYZ coordinates shot on 100-foot centers, plus at the line intersection. Supplemental elevation shots were made at high and low surface areas along each line. All XYZ coordinates were used by the seismic data processor to position the data and perform statics analysis and datum corrections.

At the start of each line, the source (the MicroVibrator) was positioned at the first receiver station. A total of 9 cables with 24 geophones per cable (216 channels) were connected to the OYO DAS-1 seismographs via a roll box, which is mounted in the recording vehicle. When the source is moved one station past the first midpoint of the spread (between geophones 48 and 49), the roll box is incremented one channel, thereby maintaining the source at the midpoint position of the active 96 channel spread. In order to survey the entire line, the 9 cables were leap-frogged along the line until the last station was reached. After the operator in the recording vehicle incremented the channel on the roll box, the

MicroVibrator began its sweep sequence, and the seismographs began recording simultaneously. The synthetic sweep was recorded on auxiliary channel 2 in the master seismograph for correlation with the recorded data from the geophones. The uncorrelated data was written to the hard drive and to 4 mm data tape. Correlated records were generated and written to tape after the completion of a line.

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3.0 DATA PROCESSING

The C-746-U Landfill seismic reflection data were processed using UNIX-based ProMax® software. The processing flow is based on a standard common midpoint (CMP) reflection processing sequence with modifications for specific conditions at the survey site. Each line was processed individually, while keeping all area-based parameters the same for uniformity. **Table 3-1** below shows each step in the processing sequence leading to the final stacks used for interpretation.

TABLE 3-1
DATA PROCESSING FLOW

Sequence	Process Applied	Relevant Parameters
1	Convert SEG-Y to Internal Format & Correlate	
2	Geometry Definition & Trace Edit	
3	True Amplitude Gain Recovery	
4	Surface Consistent Amplitude Recovery	
5	Surface Consistent Spiking Deconvolution	Operator: 80 msec; Noise 0.01%
6	Spectral Enhancement	30-300 Hz
7	Elevation & Datum Statics	Datum: Intermediate Floating; Vc = 3,000 ft/s
8	CMP Gather	
9	Velocity / Mute Analysis - Pass 1	
10	NMO Correction and Mute Application	
11	Surface Consistent Auto-Statics	50-300 msec Static Gate
12	Velocity / Mute Analysis - Pass 2	
13	NMO Correction and Mute Application	
14	Surface Consistent Auto-Statics	50-300 msec Static Gate
15	Surface Wave / Linear Noise Attenuation	
16	AGC Scaling	100 msec Gate
17	Velocity / Mute Analysis - Final Pass	
18	NMO Correction and Mute Application	
19	Surface Consistent Auto-Statics	50-300 msec Static Gate
20	CMP Consistent Trim Statics	1 msec Maximum Shift
21	CMP Stack	
22	Final Datum Correction	Datum: 500 ft; Vc = 3,000 ft/s
23	Spectral Balancing	40-280 Hz
	FINAL STACKS	
24	F-X Predictive Enhancement Filtering	
	ENHANCED STACKS	
25	Finite-Difference Time Migration	95% Smoothed RMS/Interval Velocities
	MIGRATED SECTIONS	
26	Time to Depth Conversion	
	DEPTH SECTIONS	

CMP - Common Mid Point (Having the same midpoint between source and detector.)
NMO - Normal Move Out (Normal move out is the increase in arrival time of a seismic reflection event resulting from an increase in the distance from source to detector, or from dip to reflector.)
AGC - Automatic Gain Control (Automatic gain control alters the amplification factor of the amplifier in accordance with the amplitude of the input signal.)

Data processing includes compressing the frequency-modulated signal (correlation) to a signal similar to that observed with explosives or other impulsive seismic sources. The geometry and coordinates of all sources and receivers on the seismic profile then are input to the computer and bad data traces are edited out (geometry and trace edit). An attempt is made to reverse the localized filtering effects that near-surface materials cause on the seismic signal (deconvolution and amplitude recovery).

Effects of surface topography and variations in the upper layers of the earth are applied to the data (datum and automatic statics). Nonlinear effects of the data acquisition geometry (velocity analysis and normal moveout correction) are accounted for and removed in order to correctly image subsurface features. Directional filters are applied to the source (shot) records to eliminate unwanted signals generated by the seismic sources (surface wave / linear noise attenuation). Statistical data sets are sorted and then summed by subsurface reflection point (common midpoint stack). The data are spectrally whitened to adjust amplitudes of all frequency components and filtered to keep those reflection frequencies with the best signal/noise ratio (spectral balance).

Good sources for explaining seismic data processing can be found in *Seismic Data Processing* by Yilmaz, 1997.

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4.0 INTERPRETATION

The C-746-U interpreted seismic sections are presented as **Figures 11 and 12**, and a fault interpretation map is presented as **Figures 13**. Uninterpreted s-wave seismic sections for Lines 1 and 2 are presented in **Appendix A**. These seismic sections are displayed in Variable Density format, with blue reflectors corresponding to amplitude peaks and red reflectors corresponding to amplitude troughs. The vertical axis is time, with an approximate depth scale located on the left side of the section. The depth scale is derived from a combination of locally measured s-wave velocities, stacking velocities and nearby well control. Also note that the top of the data occurs at roughly 20 msecs. This is a result of processing the data to a datum of 400 feet.

The locations of interpreted faults on **Figure 13** are based on anomaly locations at the top of the Regional Gravel Aquifer (RGA).

4.1 GENERAL CHARACTERISTICS

In spite of the ideal surface conditions, data quality is significantly lower on the C-746-U lines than has been seen in the previous study at the PGDP. Since all the equipment was functioning properly, and the acquisition parameters were identical to those used on the previous survey (which was located less than 5 miles away), it appears that the geology at the C-746-U Landfill site is just not as amenable to seismic imaging as the previous work at the PGDP. Nearby well control indicates that we can expect only a few good reflectors in this area. The previous work at PGDP has shown that gravels and firm sands adjacent to silts and clays produce the largest reflection events above the bedrock limestone.

As discussed below, the interpreted horizons have been identified as the Top RGA (highlighted in yellow) and the Top McNairy (highlighted in green). Interpreted faults are shown in red, with faults numbered from east to west.

The seismic data at the C-746-U Landfill site is less constrained by ground truth than the previous work at the PGDP. The nearby well control is shown on **Figure 13**, and generally lies to the north and west of the two seismic lines. Two wells, GB-01D and MW-367, lie in close enough proximity to the seismic lines that they can be used to identify reflection events in the seismic sections.

The Boring log from Well GB-01D is found in Appendix A. This well is located approximately 50 feet off the north end of Line 1. This log shows a rather uniform sequence of silty clay and clayey sand down to 42 feet below ground surface. Strong reflectors within this interval are not to be expected. From 42–78 feet bgs, the stratigraphy changes over to sand (the Regional Gravel Aquifer), with a thin gravel streak at 61 feet bgs. Reflectors can be expected at the top and bottom of this sand, and possibly from the gravel streak.

The boring log from Well MW-367 also is included in Appendix A. This well lies approximately 100 feet north of Shotpoint 632. The log shows a similar sequence of silts and clays down to 50 feet bgs, where the stratigraphy changes to sand and then gravel. The sand/gravel sequence ends at 80 feet bgs, and returns to a clay which marks the top of the McNairy Formation.

The other well control in the area (shown on **Figure 13)**, is too far away to utilize directly in the interpretation, but generally shows that the top of the Regional Gravel Aquifer maintains a level of roughly 45 feet below ground surface. The thickness of the unit is variable, but averages around 30 feet

thick. Interestingly, well GB-01D is the only well where sand predominates in the RGA; all of the other wells show a preponderance of gravel in this interval.

4.2 HORIZON IDENTIFICATION

Both seismic sections (**Figures 11 and 12**) are dominated by a strong reflector that shows a fair amount of structural relief. On Line 1 (**Figure 11**), this reflector occurs at 115 msecs on the north end of the section and descends in an irregular fashion to a time of 145 msecs at Shotpoint 430. Tracing this strong reflector over shotpoints 230-415 is difficult, and then a strong, flat-lying reflector appears on the south side of the section at 100 msecs.

S-wave velocities at the PGDP site show a gradual increase in velocity from about 600 ft/s at the surface to 1000 ft/s at approximately 50 ft. Below that, the s-wave velocity data show a gradual increase in velocities from about 1,000 ft/s to approximately 2,000 ft/s at a depth of approximately 370 feet bgs. The stacking velocities used to process lines 1 and 2 confirm this trend. Using the average s-wave velocity above the specific depth of a horizon provides an "expected" two-way travel time to that formation. (Note that an additional 20 msec must be added after multiplying by 2, to account for the time lag induced by the datum and correction velocity.) Using this method, it appears that the strong reflection event described above corresponds to the top of the Regional Gravel Aquifer in Well GB-01D, which, as stated earlier, should produce the largest reflection event in the section.

Using the same approach, the Top McNairy/Base RGA reflection event should come in at approximately 190 msecs on the north end of Line 1. Hints of reflectors occur at this level, but they are discontinuous and hard to correlate across the section. The Top McNairy Horizon is a dashed green line across the section to reflect the uncertainty in the interpretation.

Line 2 (**Figure 12**) also is dominated by a strong reflector at the 110-130 msec level. This reflector exhibits some structural relief, and is difficult to pick in shotpoint intervals 620-680 and 75-300. Using the methodology described above with Well MW-367 confirms that the strong reflection event corresponds to the top of the Regional Gravel Aquifer. Again, the Top McNairy/Base RGA reflector is ill-defined, but a dashed green line connects hints of reflectors at this level.

4.3 FAULTING

The previous seismic assessment at the southern side of the PGDP concluded that faulting was present in the Paleozoic basement limestone, and that some of the faults extended into the younger overlying sediments. The previous work shows that faulting generally trends northeast-southwest in this area. For most of the faults, relative movement along the main fault plane is normal, with the downthrown side to the east. These normal faults, along with their associated splays, either form a series of narrow horst and graben features or divide the local sediments into a series of rotated blocks. Both are consistent with extensional regional tectonics and faulting observed in the Fluorspar Area Fault Complex of Massac County, Illinois, located just across the Ohio River.

At the C-746-U Landfill Site, 2 potential faults have been interpreted, and are shown in **Figure 13**. On the s-wave profiles, the interpretation was completed on migrated data. Potential faults are identified primarily by disrupted reflectors in areas where the Top of the Regional Gravel Aquifer (RGA) shows structural changes.

Since faults in this area are known to trend NE-SW, it is useful to start from the intersection of the two seismic lines and work south on Line 1 and west on Line 2. Overlaying the sections at their tie point shows that from the line intersection, the top of the RGA drops off slightly in elevation to the east and

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south. In particular, the Top RGA reflector makes a sudden dip to the east at shotpoint 353 on line 2 and shows a similar sudden dip to the south at shotpoint 555 on Line 1. These structural features in the Top RGA reflector are interpreted to show disrupted bedding along a fault trending NE-SW, and movement is consistent with normal faulting with the downthrown side to the northwest. This fault is labeled as number 1 on the sections and fault interpretation map.

Continuing south on Line 1, the next structural feature in the Top RGA reflector is the abrupt termination of the event at approximately shotpoint 400. Here the Top RGA reflector is obscured, only to reappear 50 msecs (~20 feet) higher at shotpoint 225. An attempt has been made to interpret the Top RGA through this interval, but the reflector is dashed to denote the uncertainty in the interpretation. Regardless, this area shows the largest lateral variation in Top RGA reflector depth on the two seismic sections. The presence of a fault within this zone is likely. A similar, though less dramatic, shallowing of the Top RGA reflector occurs near shotpoint 625 on Line 2. Both features are consistent with movement along a normal fault with the downthrown side to the northwest. This interpreted fault is labeled as number 2 on the seismic sections and fault interpretation map.

The data only allows for the identification of those faults associated with structural changes.

5.0 CONCLUSIONS

The shear wave seismic reflection survey at the C–746-U Landfill Site images the Top of the Regional Gravel Aquifer (RGA) with reasonable success. The Top McNairy/Base RGA horizon also is present, but discontinuous and difficult to correlate across the sections. The limited data quality appears to be a function of geology, since equipment was functioning normally and acquisition parameters were identical to those used at the previous PGDP survey (less than 5 miles away). Surface conditions at the Landfill site were excellent.

Nearby well control is sparse, but shows that few good reflectors can be expected in this area. Wells GB-01D and MW-367 provide ground truth, allowing identification of reflecting horizons. Potential faulting is identified by disrupted reflectors and associated structural features. Two faults are interpreted using this criterion. More faults may be present in the area of investigation, but the more subtle manifestations of faulting cannot be identified with reasonable certainty in this dataset.

Figure 13 shows the interpreted faults at the Landfill Site. Faults are posted on this figure where they intersect the Top Regional Gravel Aquifer (RGA) reflector.

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6.0 CERTIFICATION

All geophysical data analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by Blackhawk GeoServices senior geophysicists.

October 27, 2003

Jeffrey B. Hackworth
California Registered Geophysicist GP979
Manager, Blackhawk GeoServices, Southeast Region
Oak Ridge, Tennessee

Date

* This geophysical investigation was conducted using sound scientific principles and state-of-the-art technology. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing, interpretation, and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review.

A geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations, or ordinances.

7.0 REFERENCES

Garrota, R., 1999, Shear Waves from Acquisition to Interpretation, SEG Distinguished Instructor Series, No. 3, Society of Exploration Geophysicists.

Helbig, K., 1984, *Shear Waves—What they Are and How they can be Used*, Proceedings of the SEG Shear-Wave Symposium.

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Sheriff, R.E., and Geldart, L.P., 1995, History, theory, and data acquisition, Exploration Seismology, Volume 1, Cambridge University Press.

Steeples, Don W., and Miller, Richard D., 1988, *Seismic reflection methods applied to engineering, environmental, and groundwater problems*, Proceedings of SAGEEP, Golden, CO., pp. 409-460.

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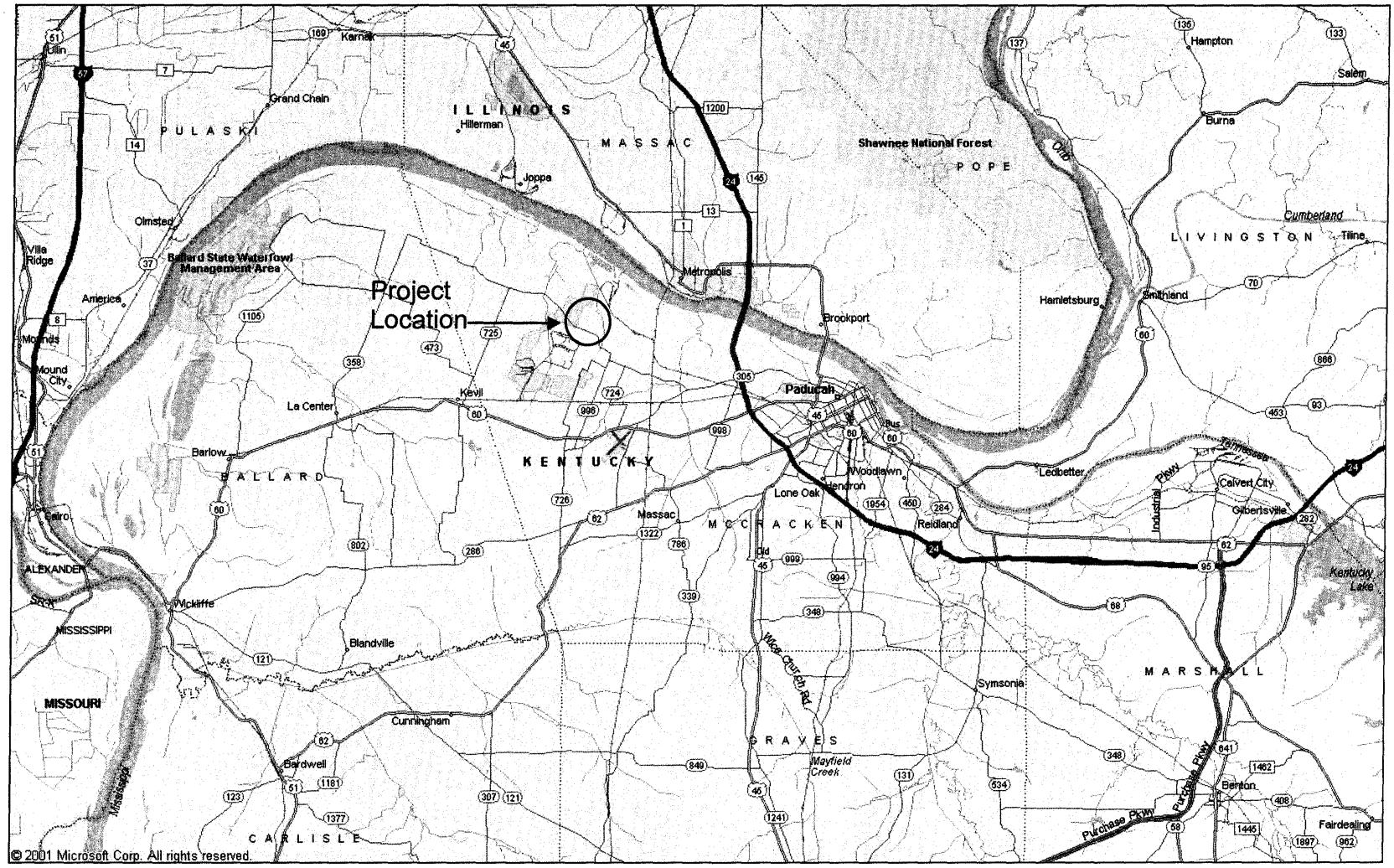

Scale: miles

0 2 4 6 8 10 12

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Site Location Map

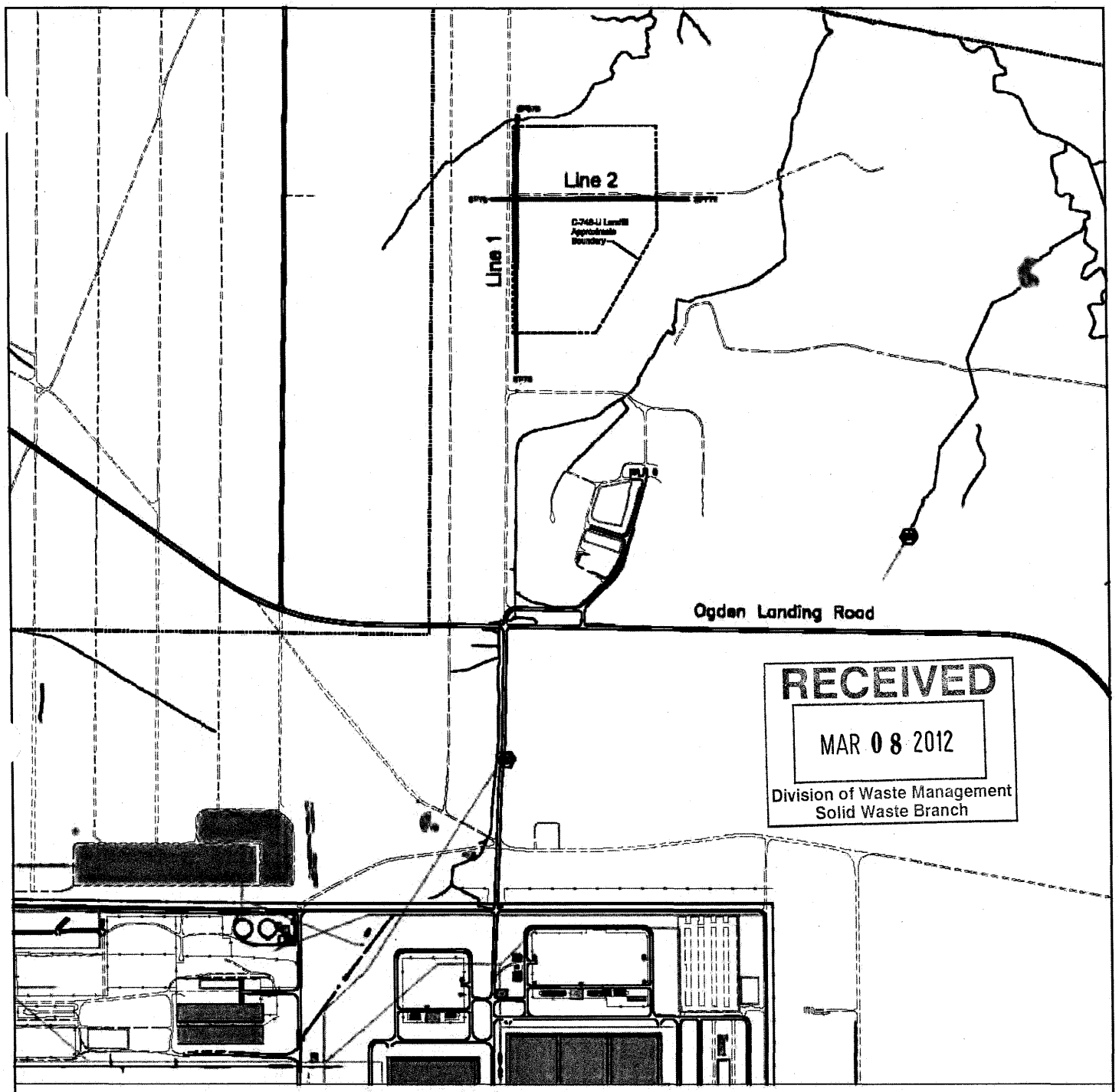
Paducah Gaseous Diffusion Plant

Paducah, Kentucky

Figure: 1

Project: 3915SAI

\projects\3915sai\SiteMap.cdr



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Explanation

S-Wave Seismic Lines

Streams & Ditches

0 1000 2000

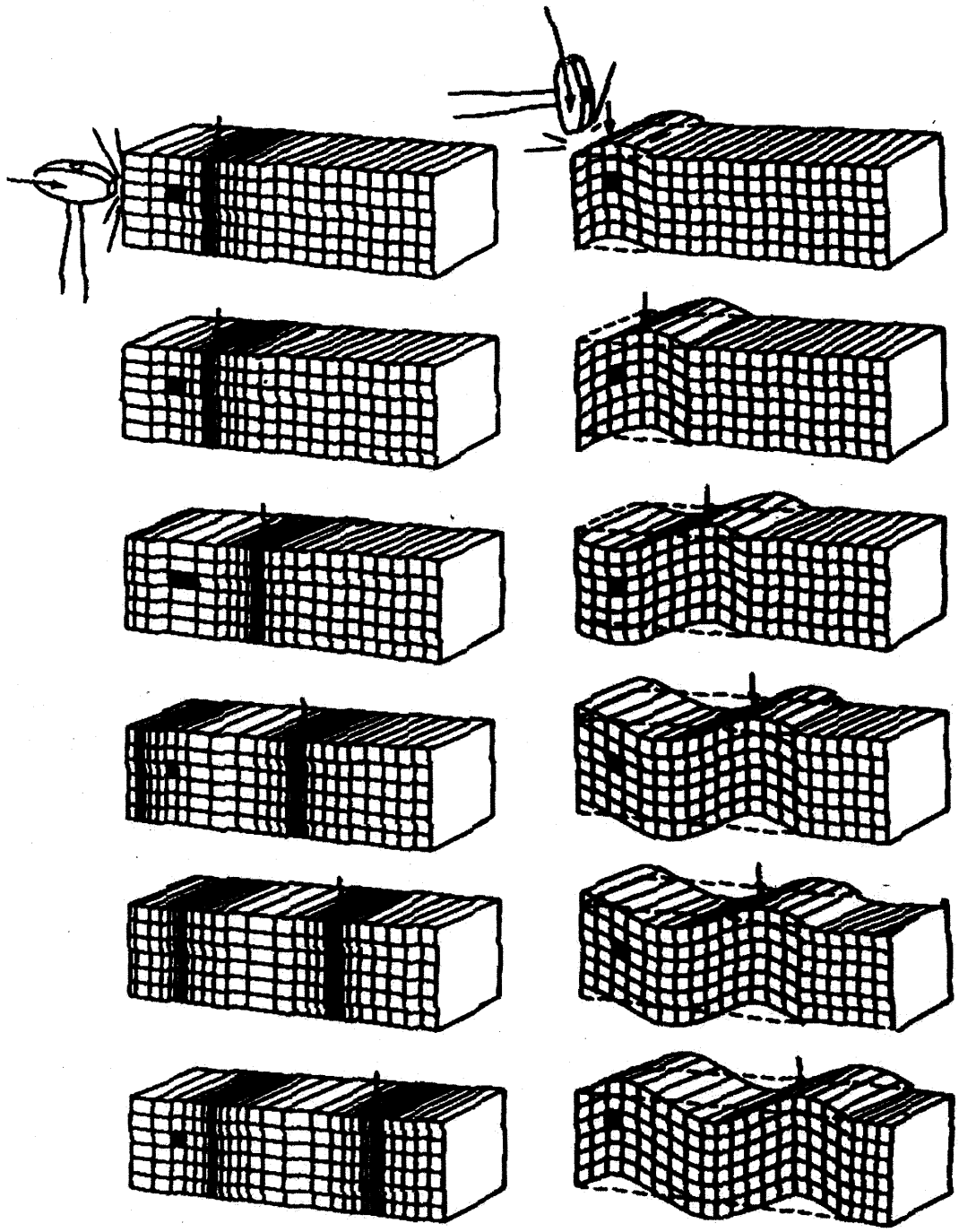
Scale in Feet
1" = 1000'

N

BLACKHAWK GeoServices Southeast Region

SAIC
Oak Ridge, Tennessee

Figure No. 2	Seismic Line Location Map C-746-U Landfill Seismic Assessment Paducah Gaseous Diffusion Plant
Project No. 3915SAI	
File No. Sebbeme_Phase2_F2.dwg	
Date: October, 2003	*Paducah, Kentucky*



(A)
Compressional (P) Waves

(B)
Shear (S) Waves

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Southeast Region

Motion during passage of Compressional and Shear Waves

Figure: 3

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|projects\3915sai\Hammer.cdr

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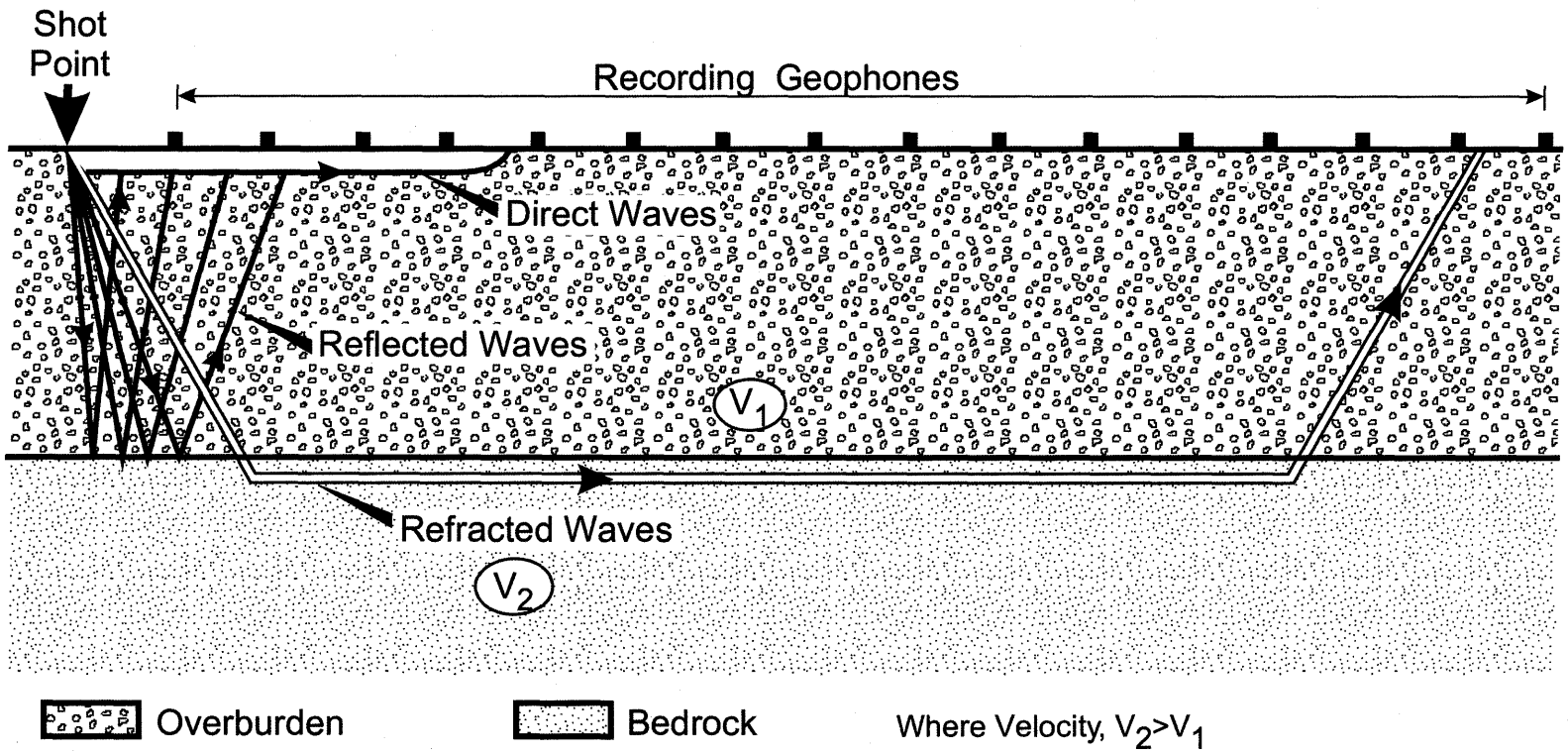

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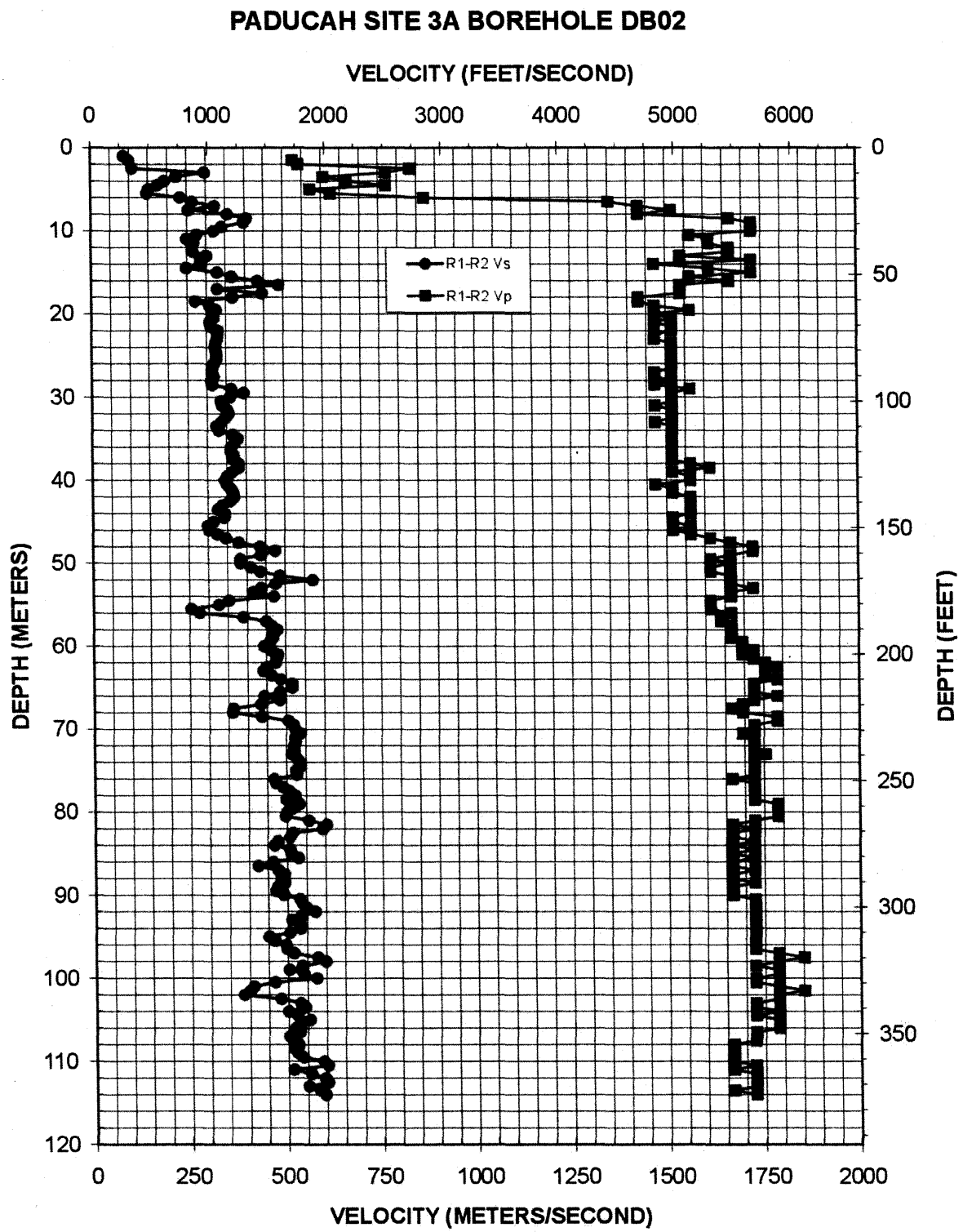
Seismic Raypath Geometry

Figure: 4

Project: 3915SAI

\projects\3915sai\Raypath.cdr



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P-S Suspension Log Velocities

Paducah Gaseous Diffusion Plant

Paducah, Kentucky

Figure: 5

Project No. 3915SAI

3915sai\PGDP_suspension_log.cdr

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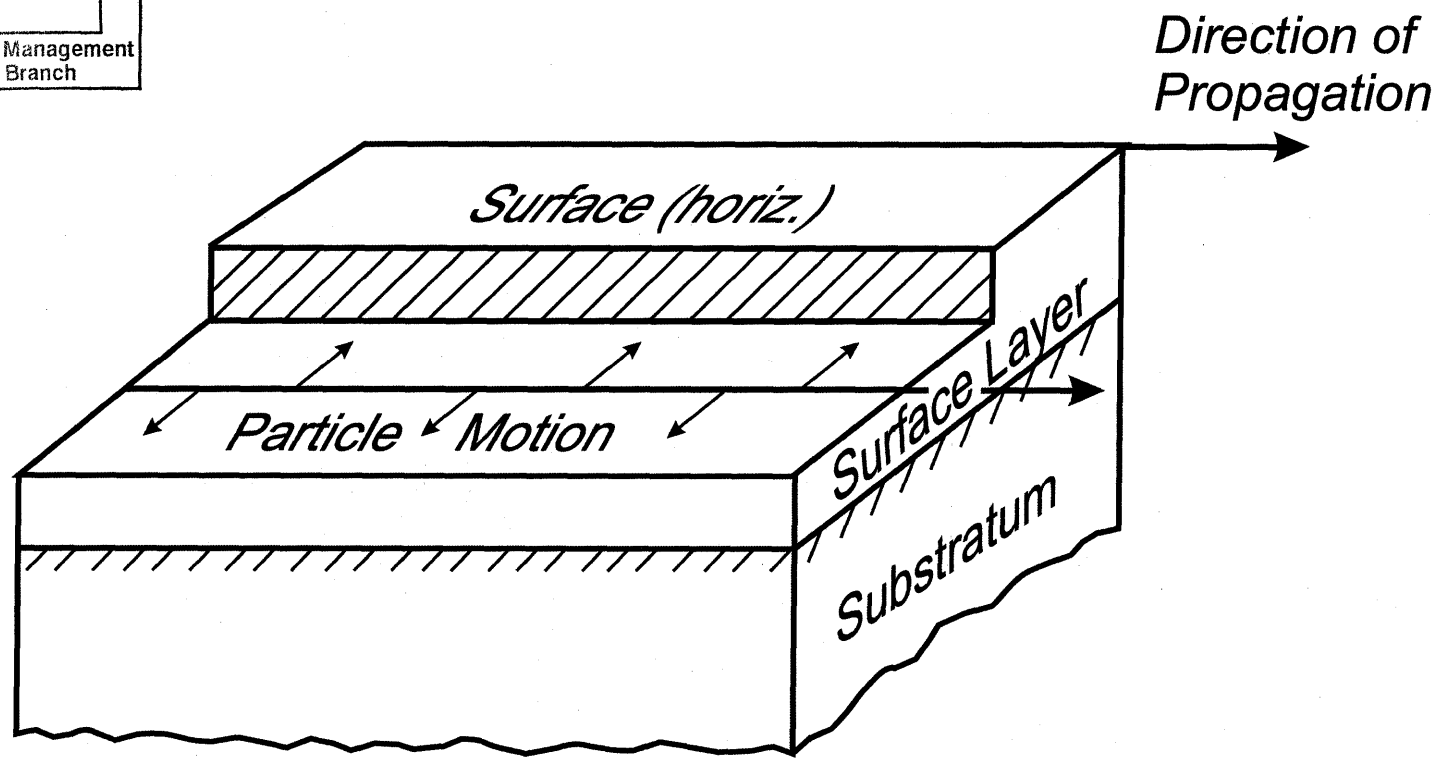

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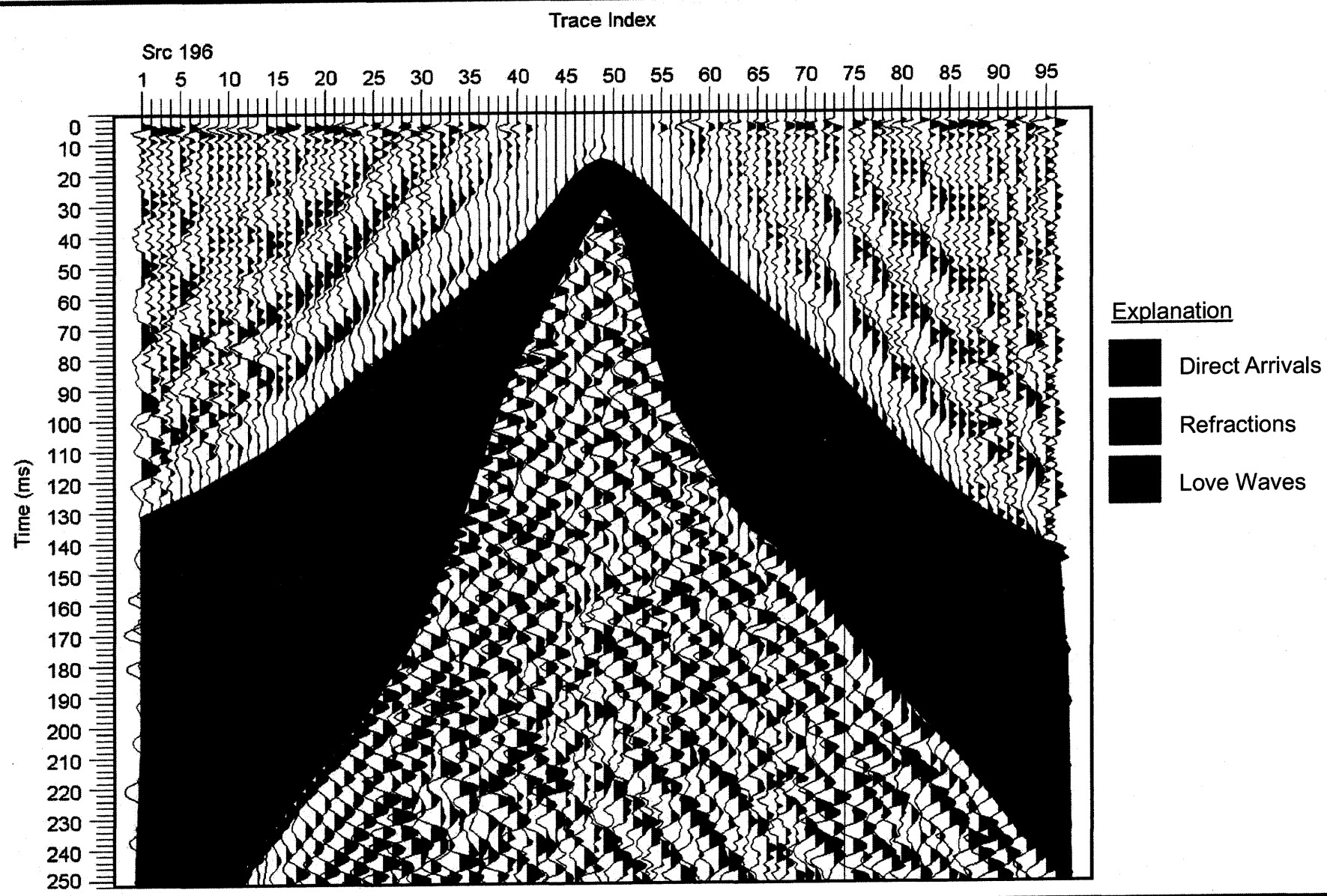
Love Waves
Traveling Along a Surface Layer

Figure: 6

Project: 3915SAI

|projects\3915sai\LoveWave.cdr



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Raw Shot Record
Line 1, SP 196.5
Paducah Gaseous Diffusion Plant
Paducah, Kentucky

Figure: 7

Project: 3915SAI

|projects\3915sai\RawShot.cdr

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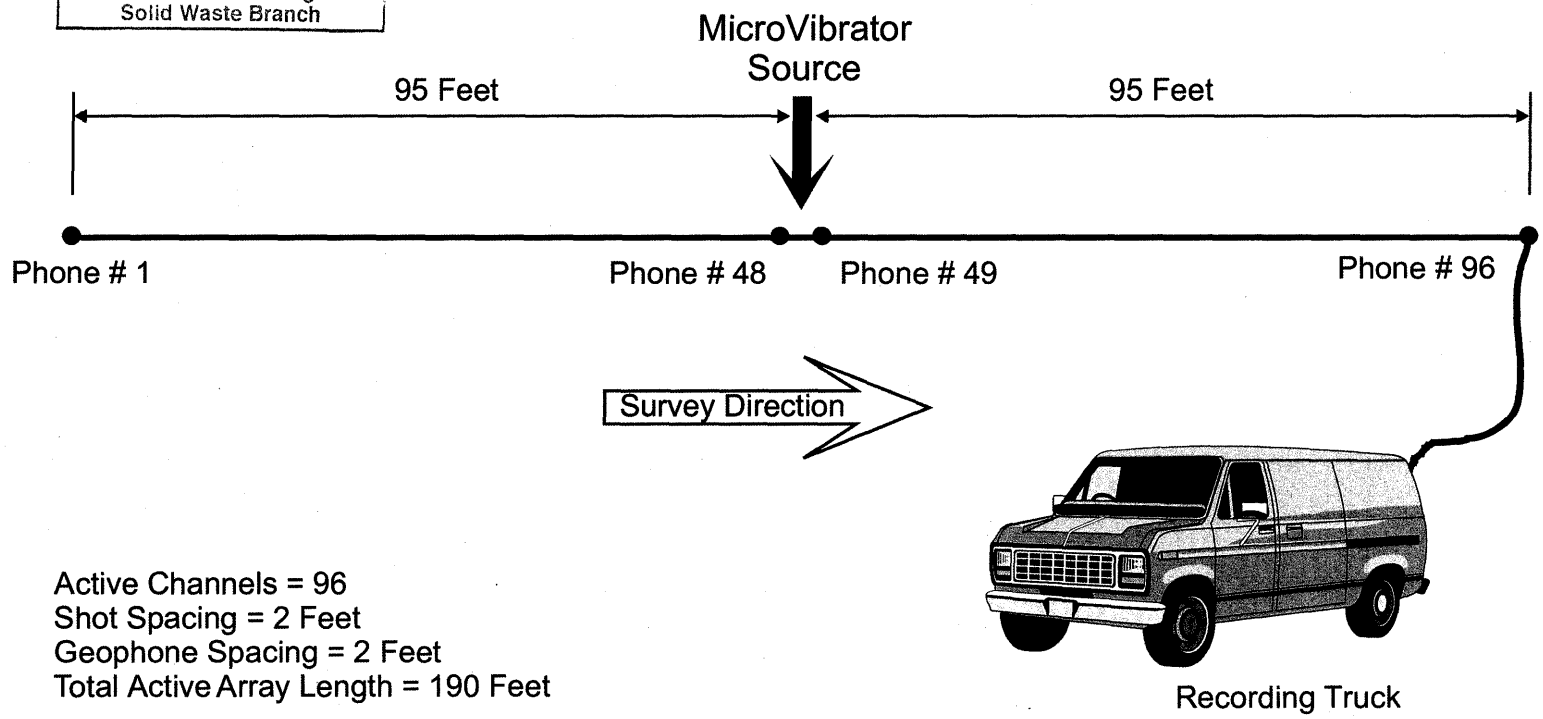

Active Channels = 96
Shot Spacing = 2 Feet
Geophone Spacing = 2 Feet
Total Active Array Length = 190 Feet

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Diagram of Nominal
Shear Wave Acquisition Geometry
Paducah Gaseous Diffusion Plant
Paducah, Kentucky

Figure: 10

Project: 3915SAI

|projects\3915sai\SpreadReflec.cdr

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY
LANDFILL AREA

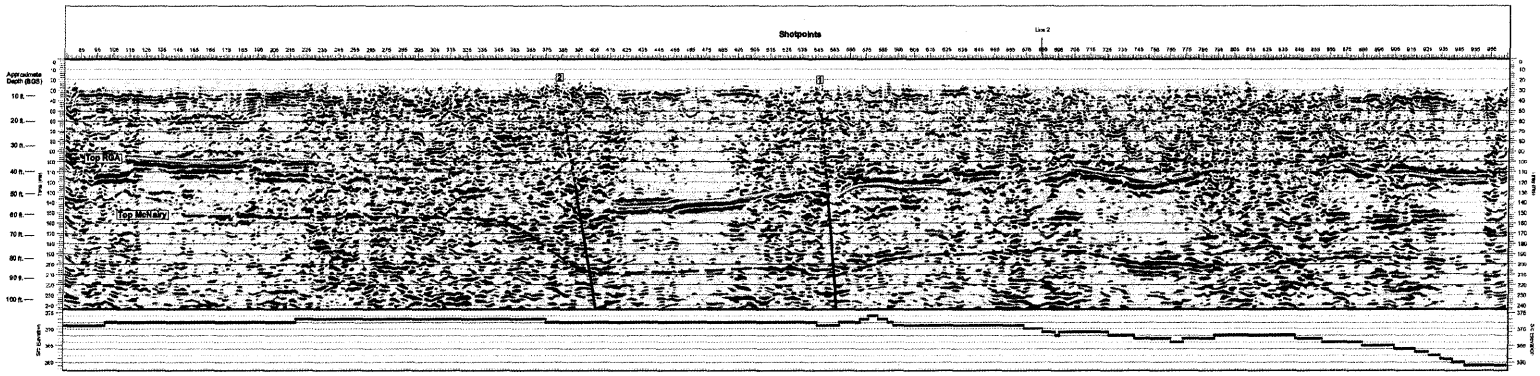
LINE 1
SP 75-975

SHEAR WAVE
MIGRATED SECTION
DIRECTION: S--->N

SEISMIC DATA ACQUISITION:

RECORDED BY:	BAY GEOPHYSICAL
DATE:	MAY 2003
RECORDING INSTRUMENT:	GTC DAS
FIELD FORMAT:	SEG-D 8048
SAMPLE RATE:	0.5 msec
SAMPLE INTERVAL:	0.5 msec
RECORD LENGTH:	1000 msec
SOURCE:	BAY MICROVIBRATOR
SOURCE ARRAY:	(40-300 Hz) 4 SWEEPS CENTERED ON THE HALF STATION
SOURCE INTERVAL:	2 ft.
RECEIVER INTERVAL:	2 ft.
STANDARD SPREAD:	96 - 1 - > 1 96 ft. 1 - 48 - > 48 - 96 chs

FIGURE 11



PROCESSING SEQUENCE

SEG Y to internal Format Conversion
Geometry and Trace Edit
True amplitude scan Recovery
Surface Consistent Gain Recovery
Surface Consistent Spiking Deconvolution
Operator: 80 msec - Noise: 0.01%
Surface Consistent Static Solving
Shallow & Datum Statics
Vc: 5000 f/s
DATUM: 95 Processing/FMO
CDP Gather
PASS 1: NMO/Velocity/Mute Analysis
PASS 1: NMO Correction & Mute Application
PASS 1: Surface Consistent Automatic Statics
50-350 msec Stack Data
PASS 2: Velocity/Mute Analysis
PASS 2: NMO Correction & Mute Application
PASS 2: Surface Consistent Automatic Statics
50-350 msec Stack Data
ADD Scaling: 100 msec Data
Autoinstructive Wave - Linear Noise Attenuation
PASS 3: Velocity/Mute Analysis
PASS 3: NMO Correction & Mute Application
PASS 3: Surface Consistent Automatic Statics
50-500 ms Stack Data
CDP Consistent Trim Statics
1 msec. Maximum Shift
Common Depth Point Stack
Post Stack Migration to Fixed Datum
Surface: 0 ft
Vc: 3000 ft
Spectral Whitening: 45-350Hz
FX Predictive Filter Enhancement
Finite Difference Time Migration
99% Uncorrelated Random Velocities
ADD Trace Scaling

Depths are a best fit approximation derived from measured S-Wave Velocities, Stacking Velocities and nearby well control.

BLACKHAWK Geophysics, Inc.

Figure: 11
Project: 7915SAI

PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY
LANDFILL AREA

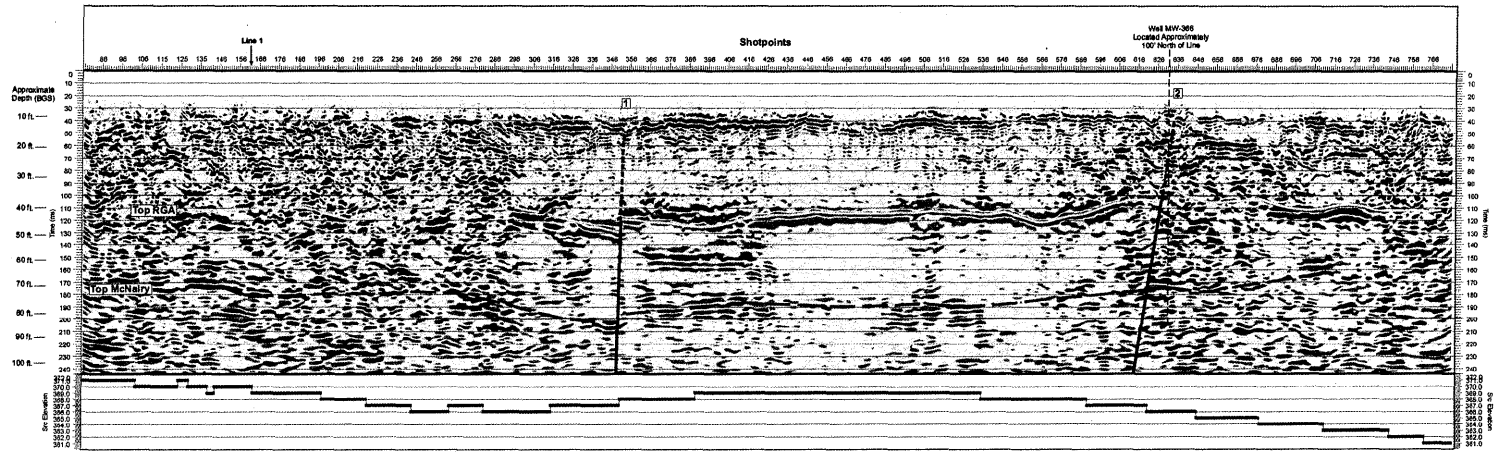
LINE 2
SP 76-776

SHEAR WAVE
MIGRATED SECTION
DIRECTION: W-->E

SEISMIC DATA ACQUISITION

RECORDED BY:	BAY GEOPHYSICAL
DATE:	MAY 2003
RECORDING INSTRUMENT:	OYO GAS
FIELD FORMAT:	SEG-D 8048
# OF CHANNELS:	96
SAMPLE INTERVAL:	0.5 msec
RECORD LENGTH:	1000 msec
SOURCE:	BAY MICROVIBRATOR (40-300 Hz)
SOURCE ARRAY:	4 SWEEPS CENTERED ON THE HALF STATION
SOURCE INTERVAL:	2 ft.
RECEIVER INTERVAL:	2 ft.
STANDARD SPREAD:	65 - 1 - x - 1 95 ft. 1- 48 -x- 49 - 96 cts

FIGURE 12



PROCESSING SEQUENCE

SEG-Y to Internal Format Conversion
Geometry and Trace Edit
True Amplitude Gain Recovery
Surface Consistent Gain Recovery
Surface Consistent Spiking Decon
Operator: 80 msec. ; Noise 0.01%
Spectral Enhancement: 30-300 Hz
Elevation & Datum Statics
Vr: 3000 ft/s
Datum: Int. Processing/NMO
CDP Gather
PASS 1: Velocity/Mute Analysis
PASS 1: NMO Corrections & Mute Application
PASS 1: Surface Consistent Automatic Statics
50-300 msec Statics Gate
PASS 2: Velocity/Mute Analysis
PASS 2: NMO Corrections & Mute Application
PASS 2: Surface Consistent Automatic Statics
50-300 ms Statics Gate
AGC Scaling: 100 msec. Gate
Surface/Source Wave - Linear Noise Attenuation
PASS 3: Velocity/Mute Analysis
PASS 3: NMO Corrections & Mute Application
PASS 3: Surface Consistent Automatic Statics
50-300 ms Statics Gate
CDP Consistent Trim Statics
1 msec. Maximum Shift
Common Depth Point Stack
Final Datum Correction to Flat Datum
Datum: 400 ft.
Vc: 3000 ft.
Spectral Whitening: 40-280 Hz
F-X Predictive Filter Enhancement
Finite Difference Time Migration
95% Smoother RMS/Interval Velocities
AGC Trace Scaling

Depths are a best fit approximation derived from measured S-Wave Velocities, Stacking Velocities and nearby well control.

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Figure: 12
Project: 3915BAI

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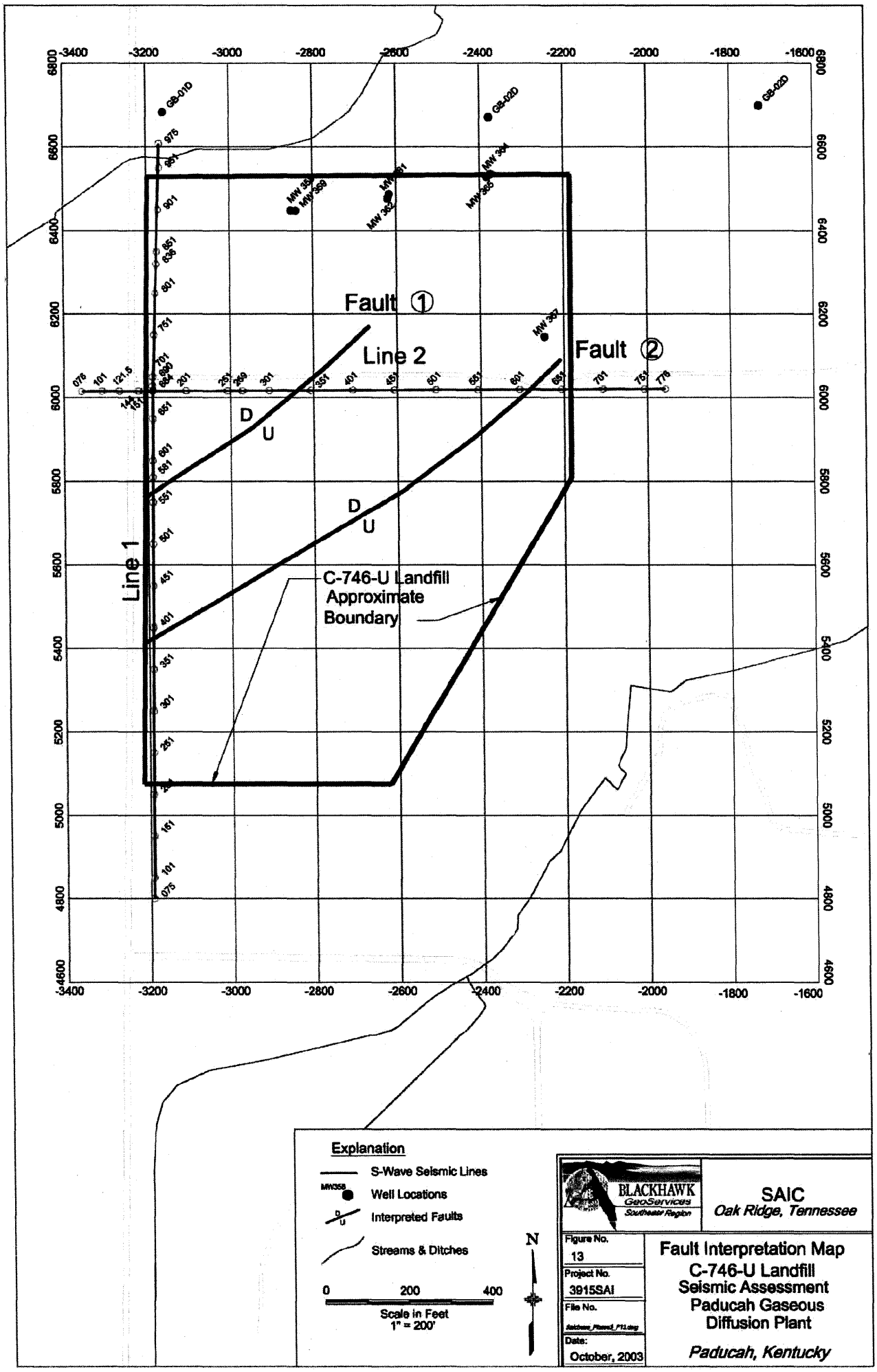
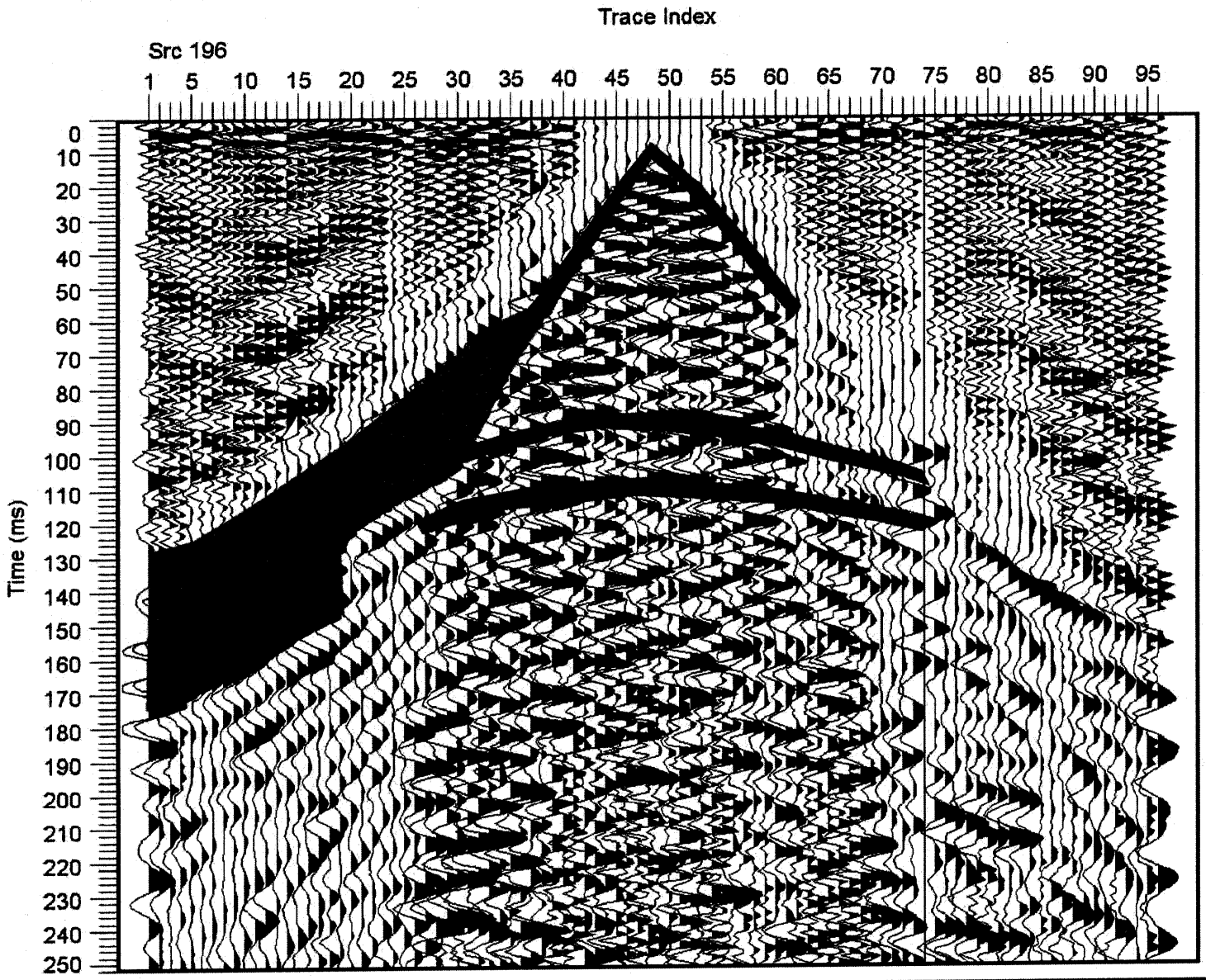

Fault ①
Fault ②
Line 1
Line 2
D
U
D
U
C-746-U Landfill
Approximate
Boundary
GB-01D
GB-02D
GB-02D
MW 367
Explanation
S-Wave Seismic Lines
Well Locations
Interpreted Faults
Streams & Ditches
0 200 400
Scale in Feet
1" = 200'
N
BLACKHAWK
GeoServices
Southeast Region
SAIC
Oak Ridge, Tennessee
Figure No.
13
Project No.
3915SAI
File No.
Date:
October, 2003
Fault Interpretation Map
C-746-U Landfill
Seismic Assessment
Paducah Gaseous
Diffusion Plant
Paducah, Kentucky



Explanation

- Refractions
- Reflections
- Direct Arrivals

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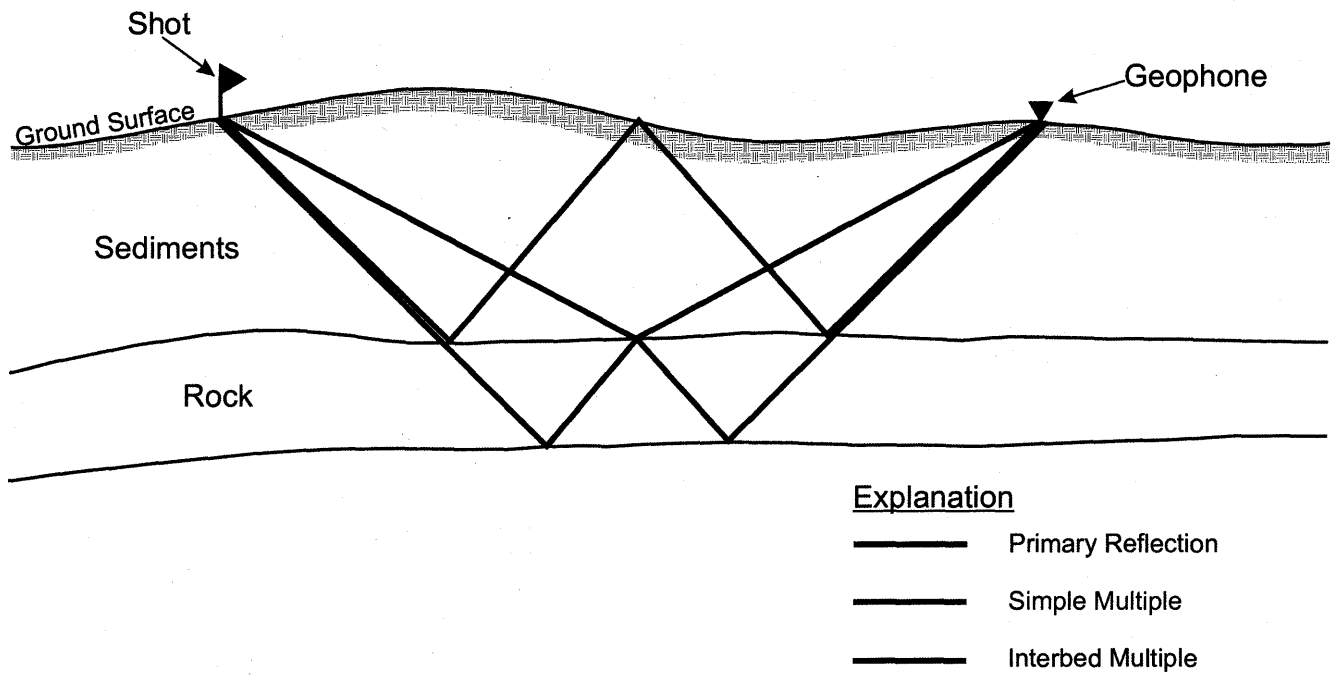
Shot Record After Love Wave Mitigation
Line 1, SP 196.5
Paducah Gaseous Diffusion Plant
Paducah, Kentucky

Figure: 8

Project: 3915SAI

|projects\3915sai\ShotLove Wave.cdr



BLACKHAWK GeoServices Southeast Region

Raypaths of Simple and Interbedded Multiples in the Seismic Reflection Data

Paducah Gaseous Diffusion Plant

Paducah, Kentucky

Figure: 9

Project: 3915SAI

|projects\3915sai\Spreads.cdr

APPENDIX A

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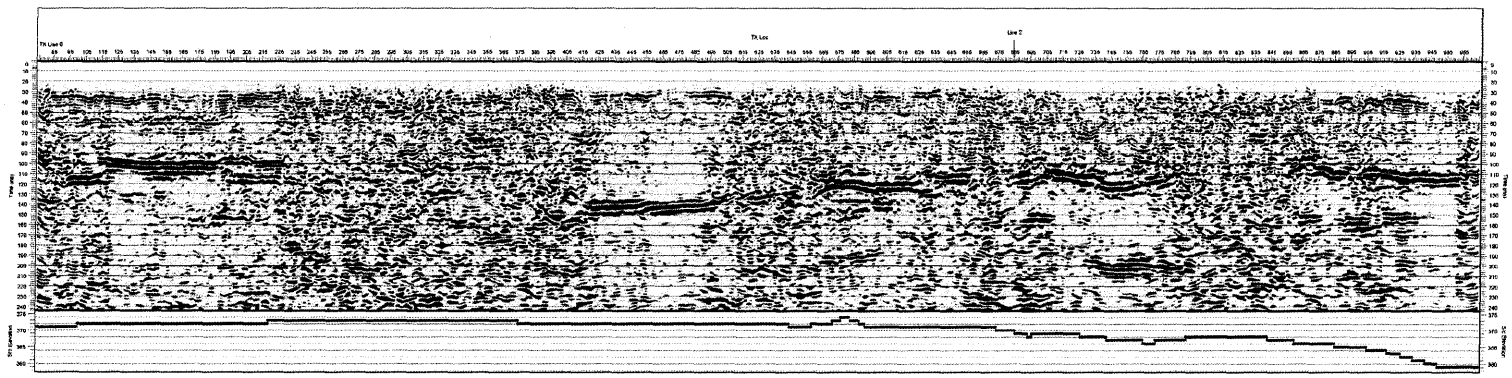
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY
LANDFILL AREA

LINE 1
SP 75-975

SHEAR WAVE
MIGRATED SECTION
DIRECTION: S—>N

SEISMIC DATA ACQUISITION

RECORDED BY:	BAY GEOPHYSICAL
DATE:	MAY 2000
RECORDING INSTRUMENT:	1210 DAS
FIELD FORMAT:	SEG-D 8048
# OF CHANNELS:	48
SAMPLE INTERVAL:	0.5 msec
RECORD LENGTH:	1000 msec
SOURCE:	BAY MICROVIBRATOR
SOURCE ARRAY:	(40-300 Hz) 4 SWEEPS, CENTERED ON THE HALF STATION
SOURCE INTERVAL:	2 ft
RECEIVER INTERVAL:	2 ft
STANDARD SPREAD:	96 : 1 : > 1.25 ft h: 48 m: 48 : 96 chs



PROCESSING SEQUENCE

SEG-Y to Internal Format Conversion
Geometry and Trace Edit
True Amplitude Gain Recovery
Surface Consistent Gain Recovery
Surface Consistent Spiking Decon
Operator: 80 msec ; Noise 0.01%
Spectral Enhancement - 30-300 Hz
Static Solution Datum
Vc: 5000 ft/s
Datum: Pt. Pleasant/NAD
CDP Gather
PASS 1 Velocity/Mute Analysis
PASS 1 NMO Correction & Mute Application
PASS 1 Surface Consistent Automatic Statics
50-300 msec Static Data
PASS 2 Velocity/Mute Analysis
PASS 2 NMO Correction & Mute Application
PASS 2 Surface Consistent Automatic Statics
50-300 msec Static Data
ADO Scaling: 150 msec Gate
Surface/Source Wave - Linear Noise Attenuation
PASS 3 Velocity/Mute Analysis
PASS 3 NMO Correction & Mute Application
PASS 3 Surface Consistent Automatic Statics
30-300 Hz Static Data
CDP Correlation Trim Statics
1 msec Maximum Shift
Common Depth Point Stack
Final Datum Correction/Tail Datum
Vc: 5000 ft/s
Datum: 2000 ft
Spectral Whitening 40-250 Hz
FX Predictive Filter Enhancement
Finite Difference Time Migration
Split Secondary RMS/Interval Velocities
ADO Trace Scaling

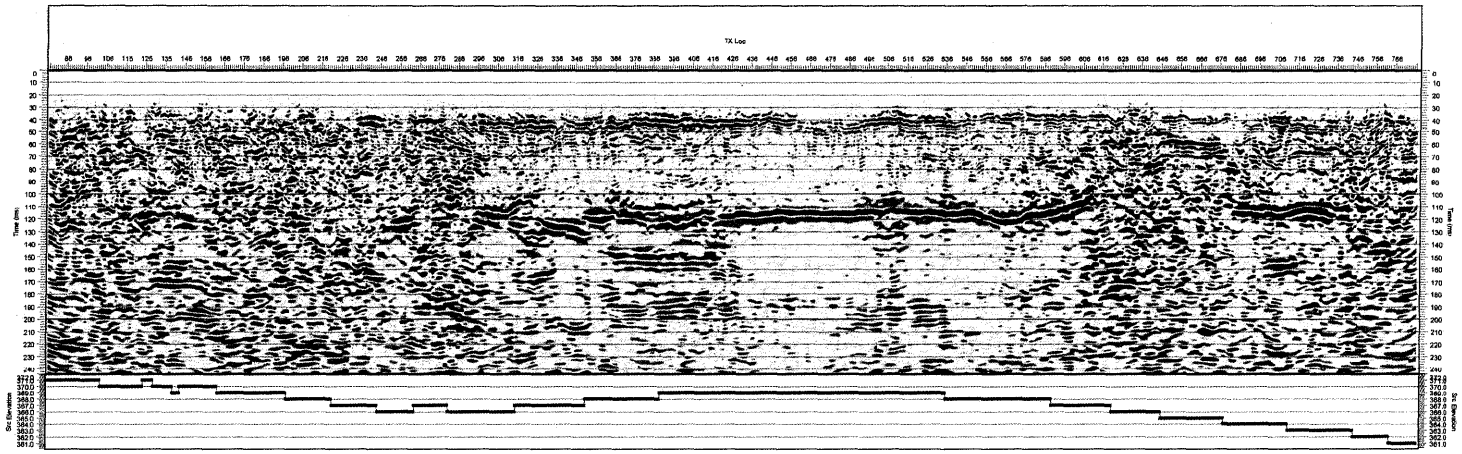
PADUCAH GASEOUS DIFFUSION PLANT
PADUCAH, KENTUCKY
LANDFILL AREA

LINE 2
SP 76-776

SHEAR WAVE
MIGRATED SECTION
DIRECTION: W—>E

SEISMIC DATA ACQUISITION

RECORDED BY:	BAY GEOPHYSICAL
DATE:	MAY 2003
RECORDING INSTRUMENT:	OYO DAS
FIELD FORMAT:	SEG-Y 8046
# OF CHANNELS:	96
SAMPLE INTERVAL:	0.5 msec
RECORD LENGTH:	1000 msec
SOURCE:	BAY MICROVIBRATOR (40-300 Hz)
SOURCE ARRAY:	4 SWEEPS CENTERED ON THE HALF STATION
SOURCE INTERVAL:	2 ft.
RECEIVER INTERVAL:	2 ft.
STANDARD SPREAD:	96 - 1 - x - 1 95 ft. 1 - 48 - x - 49 - 96 chs



PROCESSING SEQUENCE

SEG-Y to Internal Format Conversion
Geometry and Trace Edit
True Amplitude Gain Recovery
Surface Consistent Gain Recovery
Surface Consistent Spiking Decon
Operator: 80 msec.; Noise 0.01%
Spectral Enhancement - 30-300 Hz
Elevation & Datum Statics
Vc: 3000 ft/s
Datum: ht. Processing/NMO
CDP Gather
PASS 1: Velocity/Mute Analysis
PASS 1: NMO Corrections & Mute Application
PASS 1: Surface Consistent Automatic Statics
50-330 msec Statics Gate
PASS 2: Velocity/Mute Analysis
PASS 2: NMO Corrections & Mute Application
PASS 2: Surface Consistent Automatic Statics
50-300 ms Statics Gate
AGC Scaling- 100 msec. Gate
Surface/Source Wave - Linear Noise Attenuation
PASS 3: Velocity/Mute Analysis
PASS 3: NMO Corrections & Mute Application
PASS 3: Surface Consistent Automatic Statics
50-300 ms Statics Gate
CDP Consistent Time Statics
1 msec. Maximum Shift
Common Depth Point Stack
Final Datum Correction to Flat Datum
Datum: 400 ft
Vc: 3000 ft
General Whitening: 40-280 Hz
FX Predictive Filter Enhancement
Finite Difference Time Migration
85% Smoother RMS/Interval Velocities
AGC Trace Scaling

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BORING LOG

GB-01D

SAIC

Sheet 1 / 2

Client Martin Marietta Energy Systems, Inc. **Project** Solid Waste Landfill Subsurface Investigation at PGDP

Location W 3159.2 - N 6682.8 **Started** 11/02/93 **Completed** 11/03/93

Drilling Contractor GEOTEK **Ground Elevation** 360.2 ft. **Total Depth** 88 ft.

Drill Method and Equipment Mobile M-61, 8.5" OD Hollow Stem Augers

Driller Joe Wilkinson **Logger** Glenn Zinter

DEPTH BELOW SURFACE (FT)	ELEV (FT/MSL)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE RECOVERY	SPT RESULTS 6"-6"-6"-6" (N)	LITHOLOGY	USCS	LITHOLOGIC DESCRIPTION	COMMENTS background reading HNu = 0 ppm Rad β/γ = 40 cpm α = 0 cpm
							OL	**ORGANIC SILTY LEAN CLAY** gray-brown (10 YR 5/2)	
				60%	1-3-5-7 (8)		CL	**SLIGHTLY SILTY CLAY** (Silt 10-15%), mottled lt. gray (10 YR 7/1) and brown-yellow (10 YR 6/8), trace scattered black grains, damp	HNu = 0 β/γ = 40, α = 0
				75%	2-4-7-9 (11)				HNu = 0 β/γ = 40
-5.0	355.0			60%	2-5-7-8 (12)				HNu = 0 β/γ = 40
				80%	3-6-7-8 (13)				HNu = 0
				90%	4-4-7-9 (11)				HNu = 0 β/γ = 60
-10.0	350.0			90%	5-6-9-9 (15)				HNu = 0 β/γ = 50
				40%	7-13-13-23 (26)			**LEAN CLAY WITH SILT** (Silt 25%), trace sand, lt. gray (10 YR 7/2) with interbeds of clay, yellow-brown (10 YR 5/4)	HNu = 0 β/γ = 60, α = 0
-15.0	345.0			90%	10-6-6-11 (12)				HNu = 1 β/γ = 40
				95%	3-5-6-16 (11)			Same as above with hematite lined vertical fracture 14.0-14.5 ft.	HNu = 1 β/γ = 40
				95%	4-4-4-7 (8)			**LEAN CLAY WITH SILT** (Silt 20%), mottled lt. gray (10 YR 7/2) and brown-yellow (10 YR 6/6)	HNu = 0 β/γ = 40
-20.0	340.0			80%	4-4-7-7 (11)				HNu = 1 β/γ = 40
				100%	7-7-11-17 (18)		ML	**SILT WITH SAND AND CLAY** (Sand 20%, Silt 15-20%), trace fine gravel, yellow-red (5 YR 5/6), moist	HNu = 5 β/γ = 40
-25.0	335.0			100%	5-9-11-16 (20)				HNu = 4 β/γ = 60, α = 0
				100%	5-8-11-12 (19)				HNu = 4 β/γ = 70, α = 0
				100%	3-7-9-14 (16)				HNu = 3 β/γ = 60
-30.0	330.0			95%	5-9-10-12 (19)		SC	**CLAYEY SAND** (Clay 40%), very fine grained to fine grained, micaceous, yellow-red (7.5 YR 5/6)	HNu = 1 β/γ = 60
				100%	7-5-6-8 (11)		CL	**SANDY LEAN CLAY** (Sand 40%), yellow-red (7.5 YR 5/6), moist	HNu = 0 β/γ = 40
-35.0	325.0			100%	4-5-6-8 (11)				HNu = 0 β/γ = 40, α = 0
				60%	4-9-4-3 (13)			Same as above with trace coarse gravel, wet	HNu = 0
-40.0	320.0			80%	3-5-10-15 (15)				HNu = 0 β/γ = 40, α = 0

BORING LOG

GB-01D

SAIC

Sheet 2 / 2

Client Martin Marietta Energy Systems, Inc. **Project** Solid Waste Landfill Subsurface Investigation at PGDP

DEPTH BELOW SURFACE (FT)	ELEV (FT MSL)	SAMPLE TYPE	SAMPLE NUMBER	SAMPLE RECOVERY	SPT RESULTS 6"-6"-6"-6" (N)	LITHOLOGY	USCS	LITHOLOGIC DESCRIPTION	COMMENTS background reading HNu = 0 ppm Rad β/γ = 40 cpm α = 0 cpm
				100%	2-3-3-5 (6)		CL	**SANDY LEAN CLAY** trace organics, yellow-red (5 YR 5/6), wet	HNu = 0 β/γ = 40, α = 0
				60%	3-4-6-10 (10)		SP	**POORLY GRADED SAND** fine-medium grained, micaceous, yellow-red (5 YR 5/6), saturated	HNu = 0 β/γ = 50, α = 0
-45.0	315.0			75%	1-2-4-5 (6)				HNu = 0 β/γ = 40, α = 0
				40%	1-1-1-2 (2)			Same as above, trace gravel at 47.5 ft.	HNu = 0 β/γ = 50, α = 0
				60%	1-1-1-1 (2)				HNu = 0 β/γ = 40, α = 0
-50.0	310.0								
				30%	1-1-1-1 (2)				HNu = 0 β/γ = 40, α = 0
				25%	2-2-3-5 (5)				HNu = 0 β/γ = 40
-55.0	305.0			50%	1-3-3-4 (6)			Same as above, gravelly at 55.5 ft.	HNu = 0 β/γ = 50
				100%	2-4-5-8 (9)			Same as above, medium-coarse grained, red-yellow (7.5 YR 6/8)	HNu = 0 β/γ = 80
				90%	2-3-4-5 (7)				HNu = 0 β/γ = 60
-60.0	300.0								
				100%	8-18-41-46 (59)		GC	**SANDY GRAVEL WITH CLAY** 50% gravel, 30% poorly graded sand, 20% clay, brown (7.5 YR 5/4)	HNu = 0 β/γ = 40
				100%	3-5-11-12 (16)		SW	**WELL GRADED SAND** medium-coarse grained, micaceous, trace gravel, trace organics, red-yellow (7.5 YR 6/6), saturated	HNu = 0 β/γ = 60
-65.0	295.0			70%	10-11-15-18 (26)				HNu = 0 β/γ = 60
				60%	2-4-7-9 (11)				HNu = 0 β/γ = 60
				100%	3-4-8-18 (12)				HNu = 0 β/γ = 60
-70.0	290.0								
				100%	4-6-8-9 (14)				HNu = 0 β/γ = 60
				100%	2-3-4-4 (7)				HNu = 0 β/γ = 60
-75.0	285.0			100%	3-4-7-6 (11)		SP	**POORLY GRADED SAND** medium-coarse grained, brown (7.5 YR 5/6), saturated	HNu = 0 β/γ = 80
				100%	10-3-7-8 (10)				HNu = 0 β/γ = 60
				100%	4-7-12-7 (19)		CL	**SLIGHTLY SILTY LEAN CLAY** (Silt 10%), lt. gray (10 YR 7/1) with thin, horizontal organic laminations, micaceous	HNu = 0 β/γ = 60
-80.0	280.0			100%	6-9-9-19 (18)				HNu = 0 β/γ = 60
				100%	9-10-13-12 (23)				HNu = 0 β/γ = 60
-85.0	275.0			100%	10-22-27-19 (49)			Same as above with trace thin sand laminations, very fine grained, gray (10 YR 6/1), micaceous	HNu = 0 β/γ = 60
			GB-01D-86	100%	4-6-7-23 (13)				

Total Depth 88 ft.

RECEIVED
MAR 08 2012
Division of Waste Management
Solid Waste Branch

LITHOLOGIC LOG

BORING/WELL NO.: MW-367

Facility:	Site:
Client: Environmental Restoration Division	
Contractor: (	Drill Contractor: Miller
Driller: Harley Uychanch	
Start Time: 1330/8 Feb 02	End Time: 2/8/02 1600
Borehole Dia(s): 8 1/4	
Drill Method/Rig Type: HSA / CME-85	Total Depth:
Logged By: Brad Baker	Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (cpm)	FIELD MEASUREMENTS Beta/Gamma (cpm)	FIELD MEASUREMENTS VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
0			4.5'/5.0' 90%				Silty CLAY (CL), silt ~40%, clay ~60%; trace v. fine sand; Brown 7.5YR 4/2; leafy organics present; subrounded; v. poorly sorted; soft; moist		4 1/4" ID HSA w/ CME 5 ft sampler
1									
2							Silty CLAY (CL); silt ~40%, clay ~60%; trace v. fine sand; Pale Brown 10YR 6/3; variegated yellowish brown and lt gray; subrounded; v. poorly sorted; soft; moist		
3									
4									
5									
6			3'/5' 60%				SILT w/ some clay (MH) silt ~70%, clay ~30%; trace v. fine sand; Pale Brown 10YR 6/3 variegated yellowish brown and lt gray; subrounded; v. poorly sorted; soft; moist		
7									
8									
9									
10									
11			4'/5' 80%				SILT w/ some clay (MH) silt ~75%, clay ~25%; trace v. fine sand; Pale Brown 10YR 6/3 variegated yellowish brown and lt. gray; subrounded; v. poorly sorted; stiff; moist		10.0-15.0 ft run lith description 10-14.0 ft.
12									
13									

A1182A/26JUL97

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW-367

Facility:

Site:

Client: Environmental Restoration Division

Contractor: (

Drill Contractor: Miller

Driller: Harley Upchurch

Start Time: 1330 / 8/6/02

End Time:

Borehole Dia(s):

Drill Method/Rig Type: HSA / CME-85

Total Depth:

Logged By: Brad Baker

Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (cpm)	FIELD MEASUREMENTS Beta/Gamma (cpm)	FIELD MEASUREMENTS VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
14								X	See previous pg for 10.0-14.0 ft lithology
15			5'/5' 100%				SILT w/ some clay (MH), silt ~75%, clay ~25%, trace v. fine sand; Pale Brown 10YR 6/3 variegated yellowish brown and lt. gray; subrounded, v. poorly sorted; stiff; moist		RECEIVED MAR 08 2012 Division of Waste Management Solid Waste Branch
16									
17									
18									
19									
20			5'/5' 100%				Clayey SILT (ML); clay ~40%, silt ~60%, Lt Gray 10YR 7/1 variegated yellow; subrounded, v. poorly sorted; stiff; moist		
21									
22									
23									
24									
25			4.6'/5.0 92%				SILT w/ some clay (ML) silt ~75%, clay ~25%, Yellow 10YR 7/6 variegated lt. gray; subrounded, v. poorly sorted; stiff; moist		
26									
27									

A11824/26JUN92

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW-367

Facility:

Site:

Client: Environmental Restoration Division

Contractor:

Drill Contractor: Miller

Driller: Harley Hyschovich

Start Time: 1330 / 18 Feb 02

End Time:

Borehole Dia(s):

Drill Method/Rig Type: HSA / CME-85

Total Depth:

Logged By: Brad Baker

Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (cpm)	FIELD MEASUREMENTS Beta/Gamma (cpm)	FIELD MEASUREMENTS VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
28			4.6'/5.0'				SILT w/ some clay (ML) silt ~75%, clay ~25%; Yellow 10YR 5/6 varigated lt. gray; subrounded; v. poorly sorted; stiff; moist		25.0 - 30.0 ft run 25.0 - 29.6 ft recovered
29			92%						
30							SILT w/ some clay (ML) silt ~75%, clay ~25%; Yellow 10YR 5/6 varigated lt. gray; subrounded; v. poorly sorted; stiff; moist		
31			4.5'/5.0'						
32			90%						
33									
34									
35									

A1183A/28JUL97

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW367

Facility: PGDP

Site: C-746 U LANDFILL

Client: Environmental Restoration Division

Contractor: SAIC

Drill Contractor: MGS

Driller: D. BISHOP

Start Time: 1432 3/7/02

End Time: 1710 3/7/02

Borehole Dia(s): 8 1/4

Drill Method/Rig Type: 8 1/4 HSA, CME 5' SPOONS, CME-75

Total Depth: 85

Logged By: V. MULLINS

Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (cpm)	Beta (cpm)	Gamma (cpm)	VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
35								CLAY, SILTY (40%), TRACE FINE SAND, VERY STIFF, MOTTED BROWNISH YELLOW (10YR 6/6) AND LIGHT BROWNISH GRAY (10YR 6/2), MOIST, LESS SILT UPPER 2 FT		RECEIVED MAR 08 2012 Division of Waste Management Solid Waste Branch
36										
37	35' 40		5.0/5.0							
38										
39										
40								CLAY, SAND (20%) WELL SORTED, SUB-ROUNDED, FINE GRAINED, MOIST, VERY STIFF, MOTTED LIGHT YELLOWISH BROWN (10YR 6/6) AND YELLOWISH BROWN (10YR 6/6), TRACE MICA		
41										
42	40' 45		5.0/5.0							
43										
44										
45								45-49.5 CLAY, SANDY (40%), FINE GRAINED, WELL SORTED, SUB-ROUNDED, VERY STIFF, MOIST, MOTTED STRONG BROWN (7.5YR 5/6) AND GRAY (7.5YR 6/1) TRACE BLACK, TRACE MICA		
46	45' 50		5.0/5.0							
47										
48										

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW367

Facility: PGDP

Site: C-746 U LANDFILL

Client: Environmental Restoration Division

Contractor: SAIC

Drill Contractor: MAS

Driller: D. BISHOP

Start Time: 1432 3/7/02

End Time: 1710 3/7/02

Borehole Dia(s): 8 1/4

Drill Method/Rig Type: 8 1/4 HSA, CME 5' SPOONS, CME-75

Total Depth: 85

Logged By: V. MULLINS

Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (ppm)	FIELD MEASUREMENTS Beta/Gamma (ppm)	FIELD MEASUREMENTS VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
49–50							49.5–50.0 CLAY SANDY (4YR) FINE, WELL SORTED, SUBROUNDED, STRONG BROWN (7.5YR 5/8) ~~AND LITTLE LIGHT~~		BROWNISH GRAY (10YR 6/2), MOIST
50–55	50–55		2.0/5.0				SAND FINE TO MEDIUM GRAINED, WELL SORTED, SUBROUNDED, TRACE MICA, MOIST; LIGHT YELLOWISH BROWN (10YR 6/4) IN END CAP GRAVEL; COARSE SAND TO MEDIUM PEBBLE GRAVEL, WET, LIGHT YELLOWISH BROWN (10YR 6/4)		
55–60	55–60		28"/5.0'				GRAVEL, FINE SAND TO VERY COARSE PEBBLE GRAVEL, VERY POORLY SORTED, SUBANGULAR TO SUBROUNDED, TRACE ROUNDED, CHERT, QUARTZ, TRACE MICA, SATURATED, STRONG BROWN (7.5YR 5/6)		
60–62	60–62		15/5.0				SAME AS ABOVE		

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW367

Facility: PGDP

Site: C-746 U LANDFILL

Client: Environmental Restoration Division

Contractor: SAIC

Drill Contractor: MAS

Driller: D. BISHOP

Start Time: 1432 3/7/02

End Time: 1710 3/7/02

Borehole Dia(s): 8 1/4

Drill Method/Rig Type: 8 1/4 HSA, CME 5' SPOONS, CME-75

Total Depth: 85

Logged By: V. MULLINS

Protection Level: D

Depth (ft)	Sample Interval	Sample Number	Recovery (ft)	Field Measurements: ALPHA (cpm)	Beta/Gamma (cpm)	VOC's (ppm)	Lithologic Description	Graph Log	Comments
63									
64									
65									
66	65-70		22"/5.0'				SAND COURSE (60%) GRAVEL (40%), GRAVEL TO VERY COARSE PEBBLE GRAVEL, VERY POORLY SORTED, SUBANGULAR TO SUBROUNDED, SATURATED, STRONG BROWN (7.5YR 5/8), TRACE ROUNDED CHERT, QUARTZ		RECEIVED MAR 08 2012 Division of Waste Management Solid Waste Branch
67									
68									
69									
70									
71	70-75		28"/5.0				SAME AS PREVIOUS SAMPLE		
72									
73									
74									
75									
76	75-80						NO RECOVERY		

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE:

LITHOLOGIC LOG

BORING/WELL NO.: MW367

Facility: PGDP

Site: C-746 U LANDFILL

Client: Environmental Restoration Division

Contractor: GAIC

Drill Contractor: MAS

Driller: D. BISHOP

Start Time: 1432 3/7/02

End Time: 1710 3/7/02

Borehole Dia(s): 8 1/4

Drill Method/Rig Type: 8 1/4 HSA, CME 5' SPOONS, CME-75

Total Depth: 85

Logged By: V. MULLINS

Protection Level: D

Depth (ft)	SAMPLE Interval	SAMPLE Number	SAMPLE Recovery (ft)	FIELD MEASUREMENTS ALPHA (ppm)	FIELD MEASUREMENTS Beta/Gamma (ppm)	FIELD MEASUREMENTS VOC's (ppm)	LITHOLOGIC DESCRIPTION	GRAPH LOG	COMMENTS
77							NO RECOVERY		
78									
79									
80									
81			1.5/5.0				IN END CAP CLAY GRAVEL (30%) FINE TO MEDIUM GROUND, SUBANGULAR, STIFF, MOTTLED BROWNISH YELLOW (10YR 6/8) AND LIGHT GRAY (10YR 7/1)		
82									
83									
84									
85							TD 85.0 FT BGS		

DATA RECORDED BY: DATE: DATA CHECKED & REVIEWED BY: DATE: