COMMONWEALTH of VIRGINIA

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HAZARDOUS WASTE MANAGEMENT

POST-CLOSURE CARE PERMIT

PERMITTEES: **Radford Army Ammunition Plant**

BAE Systems Ordnance Systems Inc.
Route 114, P.O. Box 1
Radford Army Ammunition Plant
Radford, VA 24141-0100

US Army Radford Army Ammunition Plant
Route 114, P.O. Box 2
Radford Army Ammunition Plant
Radford, VA 24141

EPA I.D.#: **VA1210020730**

Pursuant to Chapter 14, Section 10.1-1426, Code of Virginia (1950), as amended and regulations promulgated thereunder by the Department of Environmental Quality (hereinafter referred to as the Department), a Post-Closure Permit is issued to the United States Army and BAE Systems Ordnance Systems Inc. (hereinafter referred to as the Permit and the Permittees), for the post-closure care of two closed hazardous waste management units (HWMU) of one hazardous waste disposal facility: Unit 5, and Unit 16. The facility is located in Montgomery and Pulaski Counties at Route 114, PO. Box 1, Radford, Virginia, 24141-0100.

HWMU-5 is a former lined surface impoundment (Neutralization Pond) located at latitude 37°11'12" North and longitude 80°32'15" West. HWMU-16 is a closed hazardous waste landfill located at latitude 37°11'49" North and longitude 80°31'26" West.

These two UNITs, 5, and 16, at the above facility are currently limited to the following activities: maintenance and monitoring of one closed hazardous waste surface impoundment (5) and one hazardous waste landfill (16).

Permit Appendices A through **K of Attachment 1** (applying to both units), **Permit Appendices A** through **K of Attachment 2** (applying to Unit 5), and **Permit Appendices A** through **H of Attachment 3** (applying to Unit 16). If the Permit and the above attachments conflict, the Permit conditions shall prevail. The Permittees shall also comply with all applicable regulations contained in the Virginia Hazardous Waste Management Regulations (VHWMR), 9 VAC 20-60, and the Resource Conservation and Recovery Act (RCRA) – **40** *Code of Federal Regulations* (**CFR**) Parts **260-266, 268, 270-273, 279-282**, **148**, and **124**. Applicable regulations are those which are in effect on the date of final administrative action on this Permit as well as any self-implementing statutory provisions and related regulations which are automatically applicable to the Permittees' hazardous waste management activities, notwithstanding the conditions of this Permit.

This Permit is based on the administrative record and the assumption that the information submitted by the Permittees and contained in the administrative record is complete and accurate. The Permittees' failure in the application or during the permit issuance process to fully disclose all relevant facts, or the Permittees' misrepresentation of any relevant facts at any time, shall be grounds for the termination or modification of this Permit pursuant to **40 CFR 124.5** and **40 CFR 270.40** through **270.43**, and also may be grounds for an enforcement action. The Permittees shall inform the Department of any deviations from or changes to the information provided in the application which might affect the ability of the Permittees to comply with applicable regulations and/or permit conditions, or which alter any of the conditions of the Permit in any way.

This Permit is effective as of August 16, 2014 and shall remain in effect

until August 16, 2024 unless revoked and reissued in accordance with **40 CFR 124.5, 40 CFR 270.40**, and **40 CFR 270.41**, terminated in accordance with **40 CFR 124.5** and **40 CFR 270.40**, or continued in accordance with **40 CFR 270.51**.

July 17, 2014
Date Signed

Leslie A. Romanchik

Leslie A. Romanchik
Hazardous Waste Program Manager
Office of Waste Permitting and Compliance

HAZARDOUS WASTE MANAGEMENT POST-CLOSURE CARE PERMIT

TABLE OF CONTENTS

LIST OF ATTACHMENTS

The following Attachments are incorporated, in their entirety, by reference into this Permit. These incorporated attachments are enforceable conditions of this Permit. Some of the documents contain excerpts from the Permittees' Hazardous Waste Permit Application. The Department has, as deemed necessary, modified specific language excerpted from the permit application. Additional modifications are prescribed in the permit conditions (**Modules I through VII**), and; thereby, supersede the language of the Attachments. Facility operations shall be in accordance with the contents of the Attachments and this Permit.

ATTACHMENT 1

- Appendix A- FACILITY LOCATION MAPS
  - Appendix A.1- Facility Location Map
  - Appendix A.2- Geological/Stratigraphic Map
  - Appendix A.3- Fracture Trace Map
  - Appendix A.4- Site (Unit) Location

- Appendix B- CONTINGENCY PLAN
  - Appendix B.1.- Tables and Figures
  - Appendix B.2.- Agreements

- Appendix C- CLOSURE NOTICES AND POST-CLOSURE PLANS
  - Appendix C.1- UNIT Post-closure Notices
  - Appendix C.2- UNIT Post-closure Plan for Units 5, 7, and 16

- Appendix D- FACILITY CONTACT REPRESENTATIVE

- Appendix E- SECURITY PROVISIONS AND MAINTENANCE

- Appendix F- INSPECTION REQUIREMENTS
  - Appendix F.1- Example Semi-annual Inspection Log
  - Appendix F.2- RAAP Benchmark Location Map

- Appendix G- PERSONNEL AND TRAINING
  - Appendix G.1- Outline of Training Program
  - Appendix G.2- Job Description Summary
  - Appendix G.3- Personal Training Summary

Appendix J- STATISTICAL PROCEDURES
- Appendix J.1- Cochran's Approximation to the Behrens-Fisher Student's t-Test
- Appendix J.2- Suggested Minimum Samples
- Appendix J.3- References

Appendix K- METHODOLOGY FOR GW MONITORING WELL ABANDONMENT

ATTACHMENT 2

Unit 5 Information

ATTACHMENT 3

Unit 16 Information

Appendix A -UNIT HYDROLOGICAL AND GEOLOGICAL INFORMATION
  Appendix A.1- Unit Topographic Map and Well Location Map
  Appendix A.2- Geologic Cross Sections
  Appendix A.3- Potentiometric Surface Maps

Appendix B- (RESERVED)Appendix C- DESCRIPTION OF WASTES

Appendix D- CONTINGENCY PLAN
(*Refer to Permit Attachment 1 Appendix B*)

Appendix E- COMPLIANCE (SEMIANNUAL) GROUNDWATER MONITORING CONSTITUENT LIST

Appendix F- INITIAL GROUNDWATER BACKGROUND DATA

Appendix G- GROUNDWATER PROTECTION STANDARDS

Appendix H- BORING LOGS AND WELL CONSTRUCTION DIAGRAMS: Unit 16

Appendix I- GEOPHYSICAL INVESTIGATION AND SURVEY

DEFINITIONS

For the purpose of this Permit, terms used herein shall have the same meaning as those in 9 VAC 20-60-12, 9 VAC 20-60-14, and 9 VAC 20-60-17, unless this Permit specifically states otherwise; where terms are not otherwise defined, the meaning associated with such terms shall be as defined by a standard dictionary reference or the generally accepted scientific or industrial meaning of the term.

a. *All citations* to 40 CFR Parts 124, 260, 261, 262, 263, 264, 265, 266, 268, 270, 273, and 279 are as adopted by reference in the VHWMR at 9 VAC 20-60-124, -260, -261, -262, -263, -264, -265, -266, -268, -270, -273, and –279.

b *Area of Concern (AOC) -*
An area at the Facility or an off-site area, which is not at this time known to be a solid waste management unit, where hazardous waste and/or hazardous constituents are present or are suspected to be present as a result of a release from the Facility.

c *Plume Monitoring Wells -*
Those groundwater monitoring wells designated by Permit Conditions V.D.1.a and V.D.2.a, and located as shown in Appendix A.1 of Permit Attachment 2 for Unit 5 and Appendix A.1 of Permit Attachment 3 for Unit 16, respectively.

d. *Days -*
Except as otherwise provided, calendar days.

e *Department -*
The Virginia Department of Environmental Quality or the Department (with the address as specified in Permit Condition I.E.(3).

f *Director -*
Director of the Virginia Department of Environmental Quality, his designee or authorized representative.

g. *Exceedance -*
Any measured concentration greater than established standard. May be verified by resampling.

h *Facility or site -*
All contiguous property under the control of the owner or operator seeking a permit (except for Permit Condition I.B.), for which the definition in 40 CFR Section 260.10 shall apply. For the purposes of this Permit this includes all Radford AAP property that was identified in the physical description (including structures, appurtenances, and improvements) as set forth in Permit Module III.

i. Hazardous Constituent –

Any constituent identified in Appendix VIII of 40 CFR Part 261, or any constituent identified in Appendix IX of 40 CFR Part 264 and Appendix VII of 40 CFR Part 261.

j. Hazardous Waste Management Unit (HWMU) -

Contiguous area of land on which or in which hazardous waste is placed, or the largest area in which there is a significant likelihood of mixing hazardous waste constituents in the same area.

k. Independent Samples -

Samples collected after a new volume of purged water has completely passed through the filter pack. Sampling interval is calculated based upon aquifer characteristics.

l. Permit -

The Permit issued by the Virginia Department of Environmental Quality, pursuant to Chapter 14, Article 4, Title 10.1, Code of Virginia (1950), as amended, and the Virginia Hazardous Waste Regulations (9 VAC 20-60-10 et seq).

m. Permitted Hazardous Waste Management Unit (HWMU) -

The portion of the facility consisting of former surface impoundments or hazardous waste landfill including all contiguous areas of land on which or in which hazardous waste may have been place placed, or the largest area in which there is a significant likelihood of mixing hazardous waste constituents in the same area, as described in Appendix A of Permit Attachment 1.

n. Permittees -

United States Army (owner) and BAE Systems, Ordnance Systems Inc. (operator) are the Permittees.

o. Point of Compliance -

Vertical plane at the hydraulically downgradient limit of the waste management unit.

p Point of Compliance Wells -

Those groundwater monitoring wells at the hydraulically downgradient limit of the Regulated Unit as designated by Permit Conditions V.D.1.a and V.D.2.a, and located as shown in Appendix A.1 of Permit Attachment 2 for Unit 5 and Appendix A.1 of Permit Attachment 3 for Unit 16, respectively.

q Regulated Unit -

Any hazardous waste management unit for treatment, storage, or disposal regulated under the Virginia Hazardous Waste Management Regulations.

r Release -

Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment.

s *Solid Waste Management Unit (SWMU)-*

Any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at a facility at which solid wastes have been routinely and systematically released.

t. *All definitions* contained in **40 CFR Sections 124.2**, **260.10**, **264.141**, **270.2** and 9 VAC 20-60-12 are hereby incorporated by reference into this Permit. Any of the definitions used above, (a) through (s), shall supersede any definition given in **40 CFR Sections 124.2**, **260.10**, **264.141**, **270.2** and 9 VAC 20-60-12. Where terms are not defined in the regulations or the Permit, the meaning associated with such terms shall be defined by a standard dictionary reference or the generally accepted scientific or industrial meaning of the term.

MODULE I.

STANDARD CONDITIONS

This Permit has been developed for Radford Army Ammunition Plant (Radford AAP) Units 5 and 16 to ensure compliance with all appropriate reporting and monitoring requirements as defined by 9 VAC 20-60-10 et seq. for the closed hazardous waste management unit 5 located in Montgomery County and unit 16 located in Pulaski County at latitude 37°11'12" to 49" North and longitude 80°33'15" to 31'26" West. Hazardous waste management at the Facility addressed by this Permit is currently limited to the following activity: maintenance and monitoring of one closed hazardous waste surface impoundment (Unit 5) and one closed hazardous waste landfill (Unit 16) containing hazardous wastes and various laboratory chemicals as specified in this Permit.

The **Permit Conditions I.A** through **I.H**, **I.J**, and **I.L** in this module apply to both units, Unit 5 and Unit 16.

I.A. EFFECT OF PERMIT

This Permit authorizes only the management of hazardous waste expressly described in this Permit and does not authorize any other management of hazardous waste. Compliance with this Permit generally constitutes compliance, for the purposes of enforcement, with Chapter 14, Section 10.1-1426, Code of Virginia (1950), as amended. Issuance of this Permit does not convey property rights of any sort or any exclusive privilege; nor does it authorize any injury to persons or property, an invasion or other private rights, or any infringement of State or local laws or regulations. Compliance with the terms of this Permit may not constitute a defense to any action brought under Chapter 14, Section 10.1-1455, Code of Virginia (1950), as amended, or any other law governing protection of the public or the environment.

I.B. PERMIT ACTIONS

This Permit may be modified, revoked and reissued, or terminated for cause as specified in **40 CFR 124.5**, **40 CFR 270.30(f)**, and **270.40** through **43**. The filing of a request for permit modification, revocation and reissuance, or termination or the notification of planned changes or anticipated noncompliance on the part of the Permittees do not stay the applicability or enforceability of any permit condition.

I.C. SEVERABILITY

The provisions of this Permit are severable, and if any provision of this Permit or the application of any provision of this Permit to any circumstance is held invalid, the application of such provision to other circumstances and the remainder of this Permit shall not be affected thereby.

I.D. DEFINITIONS

For the purpose of this Permit, terms used herein shall have the same meaning as those in **40 CFR Sections 124.2**, **260.10**, **264.141**, and **270.2**, 9 VAC 20-60-12, 9 VAC 20-60-14, and 9 VAC 20-60-17, unless this Permit specifically states otherwise; where terms are not otherwise defined, the meaning associated with such terms shall be as defined by a standard dictionary reference or the generally accepted scientific or industrial meaning of the term.

I.E. REPORTS, NOTIFICATIONS, AND SUBMISSIONS TO THE DIRECTOR

(1) The Department will review the plans, reports, schedules and other documents (hereinafter collectively referred to as "submission") submitted which require the Department approval. The Department will notify the Permittees in writing of the Department's approval or disapproval of each submission.

(2) In the event of the Department disapproval in whole or in part of any submission, the Director shall specify the deficiencies in writing. Document review and approval shall be in accordance with **Permit Section I.L** (Review & Approval of Submissions).

(3) Two (2) complete copies of all reports, notifications or other submissions which are required by this Permit to be sent or given to the Director of the Department shall by any method, provided they arrive at the Department of Environmental Quality by the date on which they are due. These submissions should be addressed to:

Director
Department of Environmental Quality
Attn: Ms. Leslie Romanchik, Assistant Division Director
Waste Permitting
PO Box 10009
Richmond, VA 23240-0009
(804) 698-4129

Street address:
629 East Main Street
Richmond, Virginia 23219

and one (1) copy to:
Director
Blue Ridge Regional Office
3019 Peters Creek Road
Roanoke, Virginia 24019
(540) 562-6700

(4) Each submission required under the schedule of compliance or required by this Permit (with the exception of data reports) is, upon approval by the Director, incorporated into this Permit. Any noncompliance with approved submissions shall be deemed noncompliance with this Permit.

I.F. SIGNATORY REQUIREMENTS

All reports or other information requested by the Director shall be signed and certified as specified by **40 CFR 270.11**.

I.G. DOCUMENTS TO BE MAINTAINED AT THE FACILITY SITE

The Permittees shall maintain at the facility, until post-closure care is completed and certified by the owner/operator and an independent professional engineer registered in Virginia, the following documents (as amended, revised and/or modified):

- Personnel training documents and records required by **40 CFR 264.16** and this Permit.
- Annually adjusted cost estimate for facility post-closure care required by **40 CFR 264.142(b)**.
- Operating record required by **40 CFR 264.73**, **Permit Condition II.G.1.** and **Permit Module III**.
- Inspection schedules and logs required by **40 CFR 264.15(d)** and **Appendix F** of **Permit Attachment 1**.
- Groundwater sampling and analysis plan required by **40 CFR 264.92** and this Permit.
- Groundwater monitoring results required by **40 CFR 264.73(b)(6)** and this Permit.
- All other documents required by **Permit Conditions I.H.9** and **I.H.12. through I.H.15.**

I.H. DUTIES AND REQUIREMENTS

I.H.1. Duty to Comply

The Permittees shall comply with all conditions of this Permit, except to the extent and for the duration such noncompliance is authorized by an emergency permit (see **40 CFR 270.61**). Any other permit noncompliance constitutes a violation of Title 10.1, Code of Virginia (1950), as amended, and regulations promulgated there under and is grounds for enforcement action, permit termination, revocation and reissuance, modification, or denial of a permit renewal application.

I.H.2. **Permit Expiration**
This Permit and all conditions herein will remain in effect beyond the permit's expiration date if the Permittees have submitted a timely, complete application in accordance with **40 CFR 270.10(h)** and through no fault of the Permittees, the Director has not issued a new permit, as set forth in **9 VAC 20-60-270.B.5**.

I.H.3. **Duty to Reapply**
If the Permittees wish to or is required to continue an activity regulated by this Permit after the expiration date of this Permit, the Permittees shall apply for and obtain a new permit as specified below.

(1) The Permittees shall submit a new and complete application for a new permit at least 180 days before the permit expires, unless a later date has been approved by the Director.

(2) Pursuant to **40 CFR 270.10(h)**, the Director shall not grant permission for an application to be submitted later than the existing Permit's expiration date.

I.H.4. **Need to Halt or Reduce Activity Not a Defense**
It shall not be a defense in an enforcement action to argue that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this Permit.

I.H.5. **Duty to Mitigate**
In the event of noncompliance with the Permit, the Permittees shall take all reasonable steps to minimize or correct any adverse impact on the environment resulting from noncompliance with this Permit, and shall carry out such measures as are reasonable to prevent significant adverse impacts.

I.H.6. **Proper Operation and Maintenance**
The Permittees shall at all times properly operate and maintain all facilities and systems of the treatment and controls (and related appurtenances) which are installed or used by the Permittees to achieve compliance with the conditions of this Permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls; including appropriate quality assurance/quality control procedures. This provision requires the operation of back-up or auxiliary facility or similar systems only when necessary to maintain compliance with the conditions of the Permit.

I.H.7. Duty to Provide Information

The Permittees shall furnish the Director within a reasonable time, any relevant information the Director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this Permit, or to determine compliance with this Permit. The Permittees shall also furnish the Director, upon request, copies of records required by this Permit.

I.H.8. Inspection and Entry

The Permittees shall allow the Director or an authorized representative, upon the presentation of credentials and other documents as may be required by law to:

(1) Enter at reasonable times upon the Permittees' premise where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this Permit;

(2) Have access to and copy, at reasonable times, any records kept under conditions of this Permit;

(3) Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this Permit; and

(4) Sample or monitor, at reasonable times, for the purpose of assuring Permit compliance or as otherwise authorized by **9 VAC 20-60-10 et seq.**, any substance or parameters at any location.

I.H.9. Monitoring and Records

(1) Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity. The method used to obtain a representative sample of the waste to be analyzed must be the appropriate method from **Appendix I to 40 CFR Part 261** or an equivalent method approved by the EPA. Laboratory methods must be those specified in Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, **SW-846** (3rd edition, September 1986, as updated) (also see **Appendix E** of **Permit Attachment 2** and **Appendix E** of **Permit Attachment 3** for Unit 5 and Unit 16, respectively.

(2) The Permittees shall retain at the Facility or a designated repository, records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for any continuous monitoring instrumentation, copies of all reports and records required by this Permit, and records of all data used to complete the application for this Permit for the duration of the post-closure period. The Permittees shall maintain records from all groundwater monitoring wells and associated static water level surface elevations for the duration of the post-closure care period. These periods may be extended by the Director at any time and are automatically extended during the course of any unresolved enforcement actions.

(3) Records of monitoring information shall specify:

- The date, exact place, and time of sampling or measurements;
- The individual(s) who performed the sampling or measurements;
- The date(s) the analyses were performed;
- The individual(s) who performed the analyses;
- The analytical techniques or methods used; and
- The results of such analyses.

I.H.10. Reporting Planned Changes
The Permittees shall give written notice to the Director as soon as possible of any planned physical alterations or additions to the permitted Facility which will or has the potential to affect the Regulated Units or the associated groundwater monitoring system. This written notice shall include a detailed description of all incidents of noncompliance reasonably expected to result from the proposed changes.

I.H.11. Anticipated Noncompliance
The Permittees shall give advance notice to the Director of any planned changes in the permitted Facility or activity which may result in noncompliance with the Permit requirements.

I.H.12. Twenty-four Hour Reporting
The Permittees shall report to the Director any non-compliance which may endanger human health or the environment. Information shall be provided orally within 24-hours of the Permittees becoming aware of the circumstances. Information specified in **Permit Conditions I.H.12.(1).** and **(2).** shall be reported verbally within 24 hours:

(1) Information concerning the release of any hazardous waste that may endanger public water supplies.

(2) Any information of a release or discharge of hazardous waste, or of a fire or explosion at the Facility, which could threaten the environment or human health. The description of the occurrence and its cause shall include at a minimum:

- Name, address, and telephone number of owner/operator;
- Facility name, address, and telephone number;

- Date, time, and type of incident;
- Name and quantity of material(s) involved;
- The extent of injuries, if any;
- Assessment of actual or potential hazard to human health and the environment outside the Facility; and
- Estimated quantity and disposition of recovered material from the incident.

(3) A written submission shall also be provided to the Director within five (5) days of the Permittees becoming aware of the circumstances. The written submission shall contain at a minimum the following:

- Description of the noncompliance and cause;
- The periods of noncompliance, including exact dates and times, and if the noncompliance has not been corrected, the anticipated duration of the noncompliance; and
- Steps taken or planned to reduce, eliminate, and prevent reoccurrence of noncompliance.

(4) The Permittees need not comply with the 5-day written notice requirement only if the Director waives that requirement following verbal notification (**Permit Condition I.H.12.**) and the Permittees submits a written report within fifteen (15) days of the time the Permittees becomes aware of the circumstances.

I.H.13. Other Noncompliance

The Permittees shall report all other instances of noncompliance not otherwise required to be reported above, at the time monitoring reports are submitted. The reports shall contain at a minimum the information listed in **Permit Condition I.H.12.**

I.H.14. Transfer of Permits

This Permit may be transferred to a new owner or operator only if it is modified or revoked and reissued pursuant to **40 CFR 124.5**, and **40 CFR 270.40** through **43**. Before transferring ownership or operation of the Facility during the Post-closure Care Period, the Permittees shall notify the new owner or operator in writing of the requirements of **40 CFR 124**, **264**, and **270**.

I.H.15. Other Information

Whenever the Permittees become aware that he failed to submit any relevant facts in the permit application, or submitted incorrect information in a permit application or in any report to the Director, the Permittees shall promptly submit such facts or information to the Director.

I.I. PERMIT DURATION AND POST-CLOSURE CARE PERIOD

This Permit shall be in effect for ten (10) years from the date of issuance (**270.50(a)**).

The post-closure period for each hazardous waste management unit shall begin after completion of closure of the unit and continue for 30 years after that date (**264.117(a)**), **or for a reduced period if the Director approves clean closure of the unit and the reduced period is sufficient to protect human health and the environment (264.117(a)(2)(i))**. The date of final closure certification for each unit is different; therefore, the final date of post-closure care is different for each unit.

I.I.1 UNIT 5

The hazardous waste surface impoundment was closed on October 26, 1989, the post-closure care period shall extend to October 26, 2019, and the facility is required to manage this unit under a Post-closure Permit until October 26, 2019, or until the Director approves clean closure of the unit.

I.I.2 UNIT 16

UNIT 16 was operated from 1980 to 1988. The hazardous waste landfill was certified closed on August 10, 1993; therefore the post-closure care period shall extend to August 10, 2023, or until the Director approves clean closure of the unit. The facility is required to manage this unit under a Post-closure Permit until August 10, 2023, or until the Director approves clean closure of the unit.

I.J. EXTENSION OR REDUCTION OF POST-CLOSURE PERIOD

I.J.1. Reduction

The Permittees may request a reduction in the 30-year post-closure period if the following condition exist (**40 CFR 264.117(a)(2)(i)**): A shortened period is sufficient to protect human health and the environment based upon: leachate or groundwater monitoring results, characteristics of the hazardous wastes, application of advanced technology, or alternate disposal, treatment, or reuse techniques indicate that the facility is secure.

I.J.2. Extension

The Director may extend the post-closure period applicable to the hazardous waste management unit or facility if the extended period is necessary to protect human health and the environment (e.g., leachate or groundwater monitoring results indicate a potential for migration of constituents at levels which may be harmful to human health and the environment). (**40 CFR 264.117(a)(2)(ii)**).

I.K. COMPLIANCE PERIOD

The Compliance Period is the period of time that the facility is required to remain in compliance with the **Groundwater Protection Standards** (**GPS, Appendix G** of **Permit Attachment 2**, and **Appendix G** of **Permit Attachment 3** for Unit 5 and Unit 16, respectively) in the uppermost aquifer beneath the unit at the point of compliance (**40 CFR 264.92** and **264.96**). The compliance period is the number of years equal to the active life of the Regulated Units including any waste management activity prior to permitting, and closure period. The compliance period begins when the owner or operator initiates a compliance monitoring program, which is the effective date of the original Permit issued. The details for each unit are following:

I.K.1 UNIT 5

The closed surface impoundment (unlined from 1970 to 1981; lined from 1981 to 1989) operated as the collection impoundment downstream from an acid tank farm from 1970 until final closure of the unsaturated soils in 1989. The compliance period during which the GPS (**Appendix G of Permit Attachment 2**) applies is nineteen (19) years. The original permit for unit 5 was issued on September 28, 2001. The compliance period, therefor, continues until October 28, 2020, or until the Director approves clean closure of the unit.

If at the end of the specified compliance period, the facility is engaged in a corrective action program, the compliance period shall be extended until the Permittees can demonstrate that the GPSs have not been exceeded at the point of compliance for a period of three (3) consecutive years (**40 CFR 264.96(c)**).

I.K.2 UNIT 16

The closed hazardous waste landfill consisted of a trench without a liner or leachate collection system. UNIT 16 was operated from 1980 to 1988 and the unit was certified closed on August 10, 1993. The compliance period during which the GPS (**Appendix G of Permit Attachment 3**) applies is (13) years from the effective date of this permit and continues until 2015, or until the Director approves clean closure of the unit.

If at the end of the specified compliance period, the facility is engaged in a corrective action program, the compliance period shall be extended until the Permittees can demonstrate that the GPSs have not been exceeded at the point of compliance for a period of three (3) consecutive years (**40 CFR 264.96(c)**).

I.L. REVIEW AND APPROVAL OF SUBMISSIONS

In response to a Notice of Deficiency concerning a submission, the Permittees shall modify the submission to address the specified deficiencies within the time period established by the Director taking into account the tasks to be performed, and submit the revisions to the Department for approval.

If the revised submission is not approved, the Director will notify the Permittees of the deficiencies in writing and specify a schedule for the Permittees to correct the deficiencies and resubmit the submission to the Department. The Permittees shall correct the deficiencies as directed by the Director and forward the revised submission to the Department within the time period specified.

In the event the Permittees disagree with the Director's disapproval of the revised submission, the Permittees shall notify the Department in writing of its objections, and the basis therefor, within fourteen (14) days of receipt of the Department's disapproval. Such notice shall set forth the specific matters in dispute, the position the Permittees assert should be adopted as consistent with the requirements of the Permit, the basis for the Permittees' position and any matters considered necessary for the Director's determination. The Department and the Permittees shall have an additional fourteen (14) days from receipt of the notification to meet or confer to resolve any disagreement. In the event agreement is reached, the Permittees shall submit the revised submission and implement the same in accordance with such agreement. If agreement is not reached within the 14-day period, the Department will notify the Permittees in writing of its decision on the dispute.

MODULE II.

GENERAL FACILITY CONDITIONS

The **Permit Sections II.A**, and **II.D** through **II.H** in this module apply to both units, Unit 5 and Unit 16.

II.A. DESIGN AND OPERATION OF FACILITY

The Permittees shall maintain and operate the facility, the location of which is shown by the location map, topographic map, and facility map (**Appendix A** of **Permit Attachment 1**), to minimize the possibility of fire, explosion, or any unplanned sudden or non-sudden release of hazardous waste constituents to the air, soil, or surface water which could threaten human health or the environment.

II.B. FACILITY DESCRIPTION AND SITE IDENTIFICATION

The facility, Radford Army Ammunition Plant, is located in the mountains of southwestern Virginia within Pulaski and Montgomery Counties. The site location map is presented in **Appendix A of Permit Attachment 1**. The installation consists of two noncontiguous areas - the Radford Unit (or Main Section) and the New River Ammunition Storage Area Unit. The Main Section is located approximately 4 miles northeast of the city of Radford, approximately 10 miles west of Blacksburg, and 47 miles southwest of Roanoke, Virginia. The New River Unit is located approximately 6 miles west of the Main Section, near the town of Dublin, Virginia. The New River divides the Radford Army Ammunition Plant into two areas (see **Appendix A of Permit Attachment 1**). The southern area, which comprises approximately two-thirds of Radford Army Ammunition Plant, is called the "Main Plant Area." The remaining northern one-third section is called the "Horseshoe Area," and is located within a meander of the New River.

Forty three (43) Solid Waste Management Units (SWMUs) (**Appendix A.4 of Permit Attachment 1**) and six (6) HWMUs (see **Appendix L** of **Permit Attachment 1**) are located in both the Main Plant Area and the Horseshoe Area. This permit includes two (2) Hazardous Wastes Management Units: Unit 5 and Unit 16.

The Radford Army Ammunition Plant is a government-owned, contractor-operated (GOCO) military industrial installation supplying solvent and solventless propellant grains and trinitrotoluene (TNT) explosives. From its inception as a GOCO installation in 1940 until 1995, the Radford Army Ammunition Plant was operated by Hercules Incorporated. On March 15, 1995 Alliant Techsystems, Incorporated acquired Hercules Incorporated and took over operation of the Radford Army Ammunition Plant. BAE Systems, Ordnance Systems Inc. became the operating contractor on July 1, 2012.

Construction of the Radford Army Ammunition Plant began in 1940. Initially, the Radford Army Ammunition Plant consisted of two distinct areas - a smokeless-powder plant (Radford Ordnance Works [ROW]) and a bag-manufacturing and loading plant for artillery, cannon, and mortar projectiles (New River Ordnance Works [NROW]). These two production facilities were operated separately from 1940 to 1945. Late in 1945, ROW was designated as the Radford Arsenal, and NROW was designated as a subpost. By January 1950, NROW was made an integral part of the Radford Arsenal and no longer considered a subpost. The arsenal was renamed Radford Ordnance Plant in 1961 and was finally redesignated as the Radford Army Ammunition Plant in August 1963.

Expansion of both ROW and NROW continued throughout World War II. Late in 1945, the Radford Unit was placed on standby status. The following year, the nitric acid area of the plant was reactivated to produce ammonium nitrate fertilizer, an activity that continued until 1949 under contract with Hercules Powder Company (later Hercules Incorporated). In September 1945, the NROW was declared surplus; but in April 1946, the magazine areas were changed from surplus to standby status. Between December 1946 and January 1948, large parcels of the NROW plant manufacturing area were sold. These parcels were excess land holdings that had never been used for production purposes. Between 1952 and 1958, the Goodyear Aircraft Corporation was contracted to manufacture component parts used in missile production at the Radford Army Ammunition Plant. In 1958, Hercules took over the Goodyear operations at the Plant. In mid-1968, the continuous TNT plant was put into production and remained in operation until destroyed by an explosion in May 1974. The TNT plant was restarted in 1983 and operated until 1986. In December 1988, a facility cleanup was conducted and the TNT plant was prepared for long-term standby status. Between 1990 and 1992, two nitroglycerin lines were modernized and went back into production as needed.

The general responsibilities assigned to the Radford Army Ammunition Plant include:

- Manufacturing of explosives and propellants;
- Handling and storage of strategic and critical materials as directed for other government agencies;
- Operation and maintenance, as directed, of active facilities in support of current operations. Maintenance and/or lay-away in accordance with Ammunition Procurement and Supply Agency instructions, of standby facilities, including any machinery and packaged lines received from industry, in such conditions as will permit rehabilitation and resumption of production within the time limitations prescribed;
- Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service Stock and industrial stock as required or directed;
- Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials;

- Mobilization planning, including review and revision of plant as required;
- Custodial maintenance and administrative functions of subinstallations; and
- Support services for tenants.

These responsibilities are met through the efforts of the operating contractor, BAE Systems Ordnance Systems Inc.. The Administrative Contracting Officer (ACO) and his staff provide technical assistance and administer the contracts with the civilian operating contractors. Radford Army Ammunition Plant also provides logistics support for tenant activities.

Production at Radford Army Ammunition Plant is accomplished at the primary and secondary manufacturing areas. The primary manufacturing processes include the production of single-base and multi-base solvent propellants, cast and solventless propellants, and TNT. From 1941 to present the principle products at Radford AAP have been single or multi base solvent and solventless propellants. TNT has only been in operation at Radford AAP from 1968-1974 and from 1983-1986. The secondary (intermediate) manufacturing processes include the production of oleum (concentrated sulfuric acid), nitric acid, nitroglycerine (NG), and nitrocellulose (NC). Oleum operations ceased in the mid to late 1980's and is no longer manufactured at Radford AAP. In 1999 a Medium Caliber Ammunition Load Assemble and Pack operation was started.

Production at Radford Army Ammunition Plant is accomplished at the primary and secondary manufacturing areas. The primary manufacturing processes include the production of single-base and multi-base solvent propellants, cast and solventless propellants, and TNT. The secondary manufacturing processes include the production of oleum, sulfuric and nitric acids, nitroglycerine, and nitrocellulose.

II.B.1 UNIT 5

Unit 5 is a closed lined neutralization pond. It is located on a river terrace which gently slopes to the north towards the New River. This pond was operated as an unlined pond prior to being retrofitted with a liner in 1981. Leakage from the unit may have occurred prior to the installation of the liner. Numerous karst features, predominantly sinkholes, are near this unit.

II.B.2 UNIT 16

Unit 16 is located within the Horseshoe Area of the New River and is a hazardous waste trench located within a solid waste landfill. Several sources, the Soil Conservation Services and consultant reports, indicated that the unit is located within a karst dominated area. The unit is underlain by clay, silty sands, gravels, and limestone. The clay and silt deposits can be up to 38 feet thick. The overburden materials are terrace deposits. The bedrock is the Elbrook Formation which is encountered at a depth of 50 to 60 feet on the west end and at 70 feet on the east end. The formation is highly fractured and fragmented with breccia, vugs, and solution channels.

II.C. GENERAL WASTE ANALYSIS

The general chemical and physical analysis of the wastes handed in the facility for each unit are addressed as in the following.

II.C.1 UNIT 5

During its operation, the lined neutralization pond received stormwater runoff, spilled liquids, and washdown waters from an acid tank farm. The effluent from UNIT 5 was discharged to an equalization basin (HWMU 4). The primary function of UNIT 5 was to hold acidic waste waters prior to discharge to an equalization basin. The wastes deposited in UNIT 5 were characteristically hazardous as corrosive (D002). The waste waters in UNIT 5 were both nitric (NO_3) and sulfuric (SO_4) in composition. The pH of the surface impoundment was 1.5 and the dominant components of the hazardous wastes sent to the unit were the noted mixed acids. Several heavy metals were detected in low concentrations. A description of all wastes and waste constituents that were ever known to have been discharged to the closed surface impoundment is provided in **Appendix C of Permit Attachment 2**. This description is based upon information provided by the Facility.

II.C.2 UNIT 16

UNIT 16 is a closed hazardous waste landfill, which is closed in accordance with the regulations promulgated under the authority of the Resource Conservation and Recovery Act (RCRA) of 1976. Hazardous wastes and other waste known to have been disposed of within HWMU-16 included 3898 tons of ash from the burning of waste explosives and explosives-contaminated material (EPA Hazardous Waste Code D003, D004, D007 and D008; arsenic, cadmium, chromium and lead), 545 tons of wastewater treatment sludges (EPA Hazardous Waste Code K044 and K045, with the characteristic of ignitability, corrosivity or reactivity), 6 tons of asbestos, and various laboratory chemicals. Additionally, the following wastes were disposed of in UNIT 16 in unknown quantities: ash from waste propellant incinerator (EPA Hazardous Waste Code D003), residue from waste propellant burning (EPA Hazardous Waste Code D003), residue from explosive contaminated waste burning (EPA Hazardous Waste Code D003), Sulfur Acid Regeneration (SAR) area fume burner ash (EPA Hazardous Waste Code D006 and D007), sludges from Bioplant Building 470 (EPA Hazardous Waste Code K044), and NG 2 Pretreatment Building 9410 (EPA Hazardous Waste Code K044).

From the beginning of disposal activities at Unit 16, reactive wastes were incinerated or open burned prior to disposal in the unit. However, several heavy metals were detected during EP toxicity analyses conducted on ash residues disposed in the Unit. Furthermore, several of the laboratory chemicals disposed of within the Unit are listed. A complete listing of the wastes contained in the Unit is presented in **Appendix C of Permit Attachment 3.**

The groundwater has been monitored since 1981 as part of the requirements of RCRA interim status. The Unit was certified as closed in 1993 with all waste materials remaining in place and a final cover system has been provided. No waste has been managed in Unit 16 since it was closed.

The primary contaminants of concern at Unit 16 are lead, the explosive-related compounds (2,4,6-TNT; 2,4-DNT and 2,6-DNT), several purgeable organic compounds (acetone, ethyl ether, and toluene), and a few of the base-neutral extractable organic compounds (specifically di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, di-n-octyl phthalate, and resorcinol).

A description of all hazardous wastes and waste constituents, which were ever known to have been discharged to and which were suspected to have been placed in the hazardous waste landfill, are provided in the List of Wastes (**Appendix C of Permit Attachment 3**) and the Compliance (Quarterly) Groundwater Monitoring List (**Appendix E of Permit Attachment 3**). These lists are based upon information provided by the facility. All **Appendix IX to 40 CFR 264** Annual Groundwater Sampling constituents (**Appendix I of Permit Attachment 1**), that have been detected in groundwater and are reasonably expected to have originated from the unit, have been included on the list.

II.D. SECURITY

The Permittees shall comply with the security provisions of **40 CFR Section 264.14**. The security measures shall follow the requirements described in **Appendices C and E of Permit Attachment 1**.

II.E. GENERAL INSPECTION REQUIREMENTS

The Permittees shall follow the inspection plan set out in **Appendix F of Permit Attachment 1**. The Permittees shall remedy any deterioration or malfunction discovered by an inspection (**40 CFR Section 264.15**). Inspection records shall be kept as required by **40 CFR Section 264.15(d)**.

II.F. PERSONNEL TRAINING

The Permittees shall conduct required personnel training (**40 CFR Section 264.16**). This training program shall follow **Appendix G of Permit Attachment 1**. The Permittees shall maintain training documents and records (**40 CFR Section 264.16(e)**).

II.G. RECORDKEEPING AND REPORTING

II.G.1. Operating Record.

Pursuant to **40 CFR Section 264.73**, the Permittees shall maintain a written operating record at the Facility. The record can be a compilation of various documents and shall include, but not be limited to, the information listed below.

(1) The following records shall be maintained until post-closure is complete and certified:

(a) Records of spills and releases required by existing environmental laws, including, but not limited to Section 103 of the Comprehensive Environmental Response, Compensation and Liability Act;

(b) Written reports and records of verbal notification to the Director to address releases, fires, and explosions;

(c) All reports of noncompliance pursuant to **Permit Condition I.H.11.**;

(d) All submittals prepared pursuant to **Permit Condition I.H.12.**;

(e) Records of all monitoring information pursuant to **Permit Section I.E.**; and

(f) Training records of current Facility personnel.

(2) The following records shall be maintained for a minimum of 3 years. This time period may be extended by the Department in the event of enforcement action or notification by the Department that an investigation is ongoing.

(a) Generator Biennial Reports submitted in compliance with 40 CFR Section 262.41;

(b) Facility Biennial Reports submitted in compliance with **40 CFR Section 264.75**;

(c) Training records of former Facility personnel; and

(d) Records of all inspections, pursuant to **40 CFR Section 264.15**, which shall include at a minimum:

- The date and time of the inspection;
- The name of the person performing the inspection;
- A notation of the observations made; and
- The date and nature of any repairs or remedial actions.

(3) Current copies of the following documents as amended, revised, and modified shall be maintained at the Facility until post-closure and corrective

action are complete and certified:

(a) Training Plan; and

(b) All closure, post-closure, interim measures, and final corrective action cost estimates; financial assurance documents prepared pursuant to this Permit; and the company names and addresses of Facility insurers.

II.G.2. Required Reports.
The Permittees shall comply with all applicable reporting requirements as described in **Permit Sections I.E. and F.**

II.H. COST ESTIMATE AND FINANCIAL ASSURANCE FOR FACILITY POST-CLOSURE

Pursuant to **Subpart H to 40 CFR 264** – Financial Requirement. The federal government is exempt from the financial requirements. As the Radford AAP is a federal government installation, and all the HWMUs at the Radford AAP are exempted from the requirements of **40 CFR 264.142** through **145**.

MODULE III.

POST-CLOSURE CARE

The **Permit Sections III.B** through **III.G** in this Module apply to both units: Unit 5 and Unit 16.

Mr. Jay Stewart of BAE Systems Ordnance Systems Inc., Route 114, Radford, Virginia, 24143-0100 (540-639-7785), and Mr. James McKennaof the Department of the Army ACOP staff, Route 114 Radford, Virginia 24143-0002 are the designated persons to contact in reference to this post-closure permit during the post-closure care period.

III.A. UNIT IDENTIFICATION AND CLOSURE CONSTRUCTION

III.A.1 UNIT 5

UNIT 5 is a single hazardous waste management unit (HWMU) for the purposes of groundwater monitoring. The waste is remained in place at closure. Therefore, the Permittees are required to conduct post-closure care for the HWMU in accordance with the terms and conditions of this permit. The basic closure construction includes a cap and a liner.

The closed Unit 5 has been capped with a composite liner consisting of (from ground surface to base of cap):

- Vegetative cover;
- Two feet of topsoil;
- One foot of drainage layer (10^{-3} cm/sec permeability);
- A 30 mil PVC membrane liner; and
- Two feet of clay (10^{-7} cm/sec permeability).

Details of the cap construction and effectiveness are presented in the closure plan for the Unit (**Appendix C** to **Permit Attachment 1**).

UNIT 5 was put into operation as an unlined surface impoundment in 1970 and was retrofitted with a liner in 1981. The Unit's dimensions were approximately 150 feet by 100 feet at the top of the berm. The berm rose 10 feet above the base of the impoundment. The impoundment was taken out of operation in 1986.

III.A.2 UNIT 16

The hazardous waste landfill closure details and specifications are included in **Appendix C to Permit Attachment 1**. UNIT 16 consisted of a trench measuring approximately 60 feet width, 400 length and 10 to 14 depth feet. The trench was constructed without a liner or leachate collection system. The hazardous waste landfill unit trench was first used in 1980. Waste disposal within the Unit began in 1980. The trench had an estimated capacity of 6,000 cubic yards, and was filled to approximately 80% of its capacity.

The closure construction included leachate drain installation and cover system installation. The final cover system consists of one foot of topsoil with grass cover; one foot of cover soil; one foot of drainage sand layer, a 30-mil PVC membrane cap; and a two-foot thick clay cap.

III.B. POST-CLOSURE PROCEDURES AND USE OF PROPERTY

III.B.1. Post-closure Care

The Permittees shall conduct post-closure care for the hazardous waste management units listed in **Permit Sections III.A.1** (Unit 5) and **III.A.2** (Unit 16), for a period of thirty (30) years after final closure certification was accepted by Department. The specific date for each unit is listed **Permit Section I.I**. The 30-year post-closure care period may be shortened upon petition and demonstration by the facility, if the Director determines that the facility is secure. Conversely, the post-closure care period may be extended if the Director finds this necessary to protect human health and the environment in accordance with **40 CFR 264.117(a)(2)**.

III.B.2. Groundwater System Maintenance

The Permittees shall maintain and monitor the groundwater system and comply with all other applicable requirements of **40 CFR 264.90** during the post-closure care period in accordance with **40 CFR 264.117(a)**.

III.B.3. Post-closure Use

The Permittees shall not allow any post-closure use in **Permit Sections III.A.1** (Unit 5) and **III.A.2** (Unit 16) that would disturb the integrity or the function of the facility's monitoring systems and cover during the post-closure care period in accordance with 40 CFR 264.117(c).

III.B.4. Post-closure Plan

The Permittees shall implement the Post-closure Plan in accordance with **Appendix C to Permit Attachment 1**. All post-closure care activities must be conducted in accordance with the provisions of the Post-closure Plan, and **40 CFR 264.117(d)** and **40 CFR 264.118(b)**.

III.C. INSPECTIONS

The Permittees shall inspect the components, structures, and equipment at the site in accordance with the Inspection Requirements of **Appendix F of Permit Attachment 1** and **40 CFR 264.117(a)(1)(ii)**.

III.D. SECURITY

The Permittees shall maintain security at the facility during the post-closure care period, in accordance with **Appendix E of Permit Attachment 1**, and **40 CFR 264.117(b)**.

III.E. NOTICES AND CERTIFICATION

III.E.1. Notices

If the Permittees or any subsequent owner or operator of the land upon which any of or all four units were located, wish to remove hazardous wastes and hazardous waste residues, or contaminated soils, or contaminated groundwater, then they shall request modification to this Post-closure Permit in accordance with the applicable requirements in **40 CFR Section 264.119(c)** and **40 CFR 270.42**. The Permittees or any subsequent owner or operator of the land shall demonstrate that the removal of hazardous wastes will satisfy the criteria of **40 CFR 264.117(c)**.

III.E.2. Certification

No later than sixty (60) days after completion of the established post-closure care period, the Permittees shall submit, by registered mail to the Director for approval, a certification that the post-closure care for the hazardous waste disposal unit was performed in accordance with the specifications in the approved Post-closure Plan. The certification must be signed by the Permittees and an independent, registered, Virginia-certified professional engineer. Documentation supporting the independent, registered professional engineer's license and certification must be furnished upon request.

III.F. FINANCIAL ASSURANCE

Financial assurance is not required for the federal facility.

III.G. POST-CLOSURE PERMIT MODIFICATIONS

The Permittees must request a permit modification to authorize a change in the approved Post-closure Plan. This request must be in accordance with applicable requirements of **40 CFR Section 264.119(c)** and **40 CFR 270.42** and must include a copy of the proposed amended Post-closure Plan for approval by the Director. The Permittees shall request a permit modification whenever changes in operating plans or facility design affect the approved Post-closure Plan, or other events occur that effect the approved Post-closure Plan.

MODULE IV.

GROUNDWATER DETECTION MONITORING

IV.A. HIGHLIGHTS

None of the two units (HWMU 5 or 16) are now in detection monitoring.

IV.A.1 UNIT 5

At the time of the GWQAP report (August 1999), eleven inorganic constituents, three volatile organic constituents, and two explosive/propellant constituents had been historically detected in the groundwater monitoring network at UNIT 5, at statistically significant concentrations above calculated background concentrations.

In summary, from the first quarter of 1996 to the first quarter of 1999, the concentrations of antimony, beryllium, 2-6 dinitrotoluene, lead, thallium, trichloroethene and bis(2-ethylhexyl)phthalate are historical maximums that were recorded prior to the establishment of groundwater protection standards in the permit, for the monitored constituents proposed by the facility in point of compliance wells at Unit 5.

IV.A.2 UNIT 16

Groundwater samples from the Unit16 area have been collected and analyzed since 1981 in compliance with the Virginia Hazardous Waste Management Regulations. Groundwater quality assessment data indicated that the groundwater in the Unit 16 area is contaminated by low levels of DNT and halomethane compounds. The nearby former TNT neutralization sludge disposal trench was identified as source of the DNT contamination. Well 16-4 is the most contaminated well and is very close to the former TNT trench. Radford AAP has submitted Annual Groundwater Monitoring Reports for Unit during the period that Unit 16 has been under interim status.

Historically, from 1992 through 1998 at least the following constituents were detected in downgradient wells: Cyanide, Xylene (Total), TOC, TOX, Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Nickel, Selenium, Silver, Thallium, Vanadium, Zinc, Bromoform, Carbon Tetrachloride, Chloromethane (methyl chloride), di-n-Butylphthalate (2-Benzenedicarboxylic acid dibutyl ester), 1,4-Dichlorobenzene, Dichlorodifluoromethane, 1,1-Dichloroethane, 1,2-Dichloroethane, 2,4-Dinitrotoluene (2,4-DNT), and 2,6-Dinitrotoluene (2,6-DNT), Ethylbenzene, Methyl ethyl ketone (MEK, 2-Butanone), 1,1,2,2-Tetrachloroethane, Trichloroethene, Toluene, *trans*-1,2-Dichloroethylene, 1,1,1-Trichloroethane, 1,1,2-Trichloroethane, Trichlorodifluoromethane,Tetryl (trinitrophenylmethylnitramine), and Vinyl chloride.

Potential hazardous constituents include a series of Polychlorodibenzofuran compounds (TCDF –Tetrachlorodibenzofuran, PECDF – Pentachlorodibenzofuran, HPCDF – Hexachlorodibenzofuran, HPCDF – Heptachlorodibenzofuran, and OCDE - Octachlorodibenzofuran).

MODULE V.

GROUNDWATER COMPLIANCE MONITORING

The **Permit Sections V.H, I and K** through **V.O** in this Module apply to both units: Unit 5 and Unit 16.

V.A. HIGHLIGHTS

Radford AAP is implementing a compliance monitoring program because a groundwater quality assessment monitoring program was established prior to the Permit issuance.

In October 1995, a Groundwater Quality Assessment Plan (GWQAP) was submitted for HWMUs 4, 5, 7, 10, and 16. A GWQAP Addendum was submitted for these HWMUs in November 1995. VDEQ met with Alliant on May 21, 1996 to negotiate a Post-closure permitting schedule for the HWMUs. It was agreed that a revised GWQAP report would be prepared for each individual HWMU rather than to consolidate the HWMUs. But, at 2001 after a negotiation between VA DEQ and the facility an agreement has been achieved to issue one consolidated Permit, which is this permit.

V.A.1. UNIT 5

Historically, the Permittees determined that hazardous waste constituents were found in groundwater at levels statistically higher than background; therefore, groundwater monitoring shall be conducted under a Compliance Monitoring program during the compliance period.

V.A.4. UNIT 16

From historic data, the Permittees determined that a plume of contamination had been released at the point of compliance for UNIT 16. At least forty three (43) hazardous constituents have been detected in the downgradient groundwater monitoring wells at UNIT 16 (see **Appendix E of Permit Attachment 3**). Data collected in previous investigations clearly indicated that groundwater was being impacted. Therefore, the groundwater is being monitored in the Compliance Monitoring Program.

V.B. HISTORICAL OVERVIEW

V.B.1. UNIT 5

In 1984, a GWQAP for HWMU's 4,5,7 and 16 was submitted. The Permittees' Phase I - Ground Water Assessment Report for SWMU's 4,5,7 was submitted in 1985. The Phase I report included hydraulic conductivity, ground water flow and rates, and chemical analyses. Also in 1985, the Permittees submitted a GWQAP report on additional ground water monitoring wells with an associated earth resistivity study for HWMU's 4,5,7, and

16. The Unit 5 was closed 1989. The Permittees submitted interim GWQAP reports and modifications to the GWQAP in 1987, 1988, 1992, 1993, and 1995 for HWMU's 4,5,7, and 16 jointly. In August, 1999, the facility submitted a last Groundwater Quality Assessment Report (GWQAR) in the Post-closure Care Permit Application Part B for Unit 5. In this GWQAR historical Isoconcentration Maps were produced to depict constituent plumes in the groundwater beneath the Unit 5 using the historical maxmum concentrations for the constituents monitored at the Unit 5 for the time periods of 1992 through 1995 and 1996 through First quarter 1999.

V.B.2. UNIT 16

A final GWQAR for the unit was submitted with the Post-closure Care Permit Application Part B together. In order to evaluate the shape and position of constituent plumes over time, historical Isoconcentration Maps were developed to illustrate the lateral extent of the combined inorganic metals, the combined volatile organic constituents, and the combined explosive/propellant constituents using the historical maximum concentrations for the constituents (see Appendix F to Permit Attachment 5) monitored at the site for the time periods of 1992 through 1995 and 1996 through 1998.

V.C. SITE HYDROGEOLOGY

V.C.1 Geologic Setting

This part applies the whole facility.

The geological and stratigraphic map is provided in **Appendix A.2 of Permit Attachment 1**.

The facility is situated in one of a series of narrow valleys typical of the Valley and Ridge physiographic province of the Appalachian Highland region of North America. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long. The valley has width of approximately eight miles at the southwest end and narrows to approximately two miles at the northeast end. Radford AAP lies along the New River in the relatively narrow northeast corner of the valley. The maximum elevation at Radford AAP is 2225 feet above mean sea level (amsl) in the southeast corner and the minimum elevation is approximately 1675 feet amsl along the New River at the northern property boundary.

The valley and Ridge physiographic province consists of folded and thrust-faulted Paleozoic sedimentary rocks ranging in age from Cambrian to Mississippian. Post-deformation weathering of these thrust-faulted and overturned Paleozoic rocks has resulted in the formation of resistant sandstone and dolomite ridges separated by valley underlain by more easily eroded shale and limestone. Well developed karst features such as sinkholes and caves are common in the Valley and Ridge.

The general geology at Radford AAP consists of limestone/dolomite bedrock covered by weathered residual deposits and/or alluvial deposits. The alluvial deposits consists of typical fluvial deposits of interbedded clay, silt, and sand/gravel deposits with cobble lenses. The thickness of the alluvial deposits ranges from a few feet to approximately 50 feet, with an average thickness of 20 feet. The residual deposits consists of clay, silt, and clasts resulting from the physical and chemical weathering of the parent bedrock. The residual deposits typically underlie the alluvium, except in locations where the residuum has been eroded to bedrock and replaced by alluvium. The thickness of the residual deposits ranges from a few feet to approximately 40 feet. Underlying the alluvium and residuum throughout most of Radford AAPis a series of dolomite, limestone, and shale atrata known as the Cambrian-aged Elbrook Formation. The Elbrook formation is the major outcropping formation as well as the predominant karstic formation below the facility. Sinkholes, solution channels, pinnacled surfaces, and springs are common to the Elbrook Formation.

V.C.2 Karst Trace Analysis

This part applies the whole facility.

A fracture trace map is provided in **Appendix A.3 of Permit Attachment 1**.

(1) Fracture Trace Analysis

A total of 66 fracture traces were identified within and around Radford AAP in a photogeologic study conducted by the USEPA's Environmental Photographic interpretation center (EPIC) in 1992. Fracture traces are linear features identified in aerial photographs that represent the surface expression of primary joint sets, major fractures, and/or zones of fracturing in the subsurface. These features may be expressed as soil-tonal variations and vegetational and topographical alignments, and are significant in consideration of groundwater flow at Radford AAP. The fractures and joint sets can act as discrete conduits for groundwater flow, increasing flow rates, and in some cases, redirecting flow away from the expected flow direction. In Karst terrains, such features are environmentally significant because solutionization and resulting conduits develop along bedding plans as well as fractures and joints.

The primary traces identified at Radford AAP in the 1992 USEPA EPIC study are illustrated on the Fracture Trace Map (**Appendix A.3 of Permit Attachment 1**). The bedding plane structures, seen as ledges in the New River channel, are also illustrated on the Fracture Trace Map.

(2) Sink Hole Delineation

The locations of sinkholes at Radford AAP were also mapped during the 1992 USEPA EPIC study (Fracture Trace Map in **Appendix A.3 of Permit**

Attachment 1). In the vicinity of Radford AAP, the strike of bedding in the Elbrook Formation is roughly west/northeast, with dips to the south/southeast. As shown on the Fracture Trace Map, the orientation of bedding can be seen in the nearly east-west alignment of sinkholes at Radford AAP and surrounding areas. Most of the sinkholes in the area are oval shaped and elongated with respect to the strike of bedding planes. In some instances, the sinkholes appear to align with respect to the fracture traces. The sinkholes most likely represent bedrock units with a greater carbonate content and lower shale content within the underlying Elbrook formation (USEPA, 1992).

(3) Dry Trace Results
In September 1993 through December 1993, engineering-Science, Inc. of Fairfax, VA conducted a dye-trace test to identify hydrologic connections between areas of groundwater recharge (upland sinkholes) in the south-central portion of Main Plant and their respective discharge areas around the facility. The south-central portion of the Main Plant area is characterized by numerous sinkholes and a deep water table. The karst development within the underlying folded limestone and dolomite of the Elbrook Formation likely has a significant influence on groundwater flow through the bedrock in this area.

V.C.3 Occurrence of Groundwater

The general hydrogeological setting at Radford AAP is characterized by porous alluvial sediments overlying weathered and unweathered dolomite and limestone. In areas where the porous allluvial sediments are the uppermost water-bearing zone, groundwater flow is generally from topographically high areas to topographically low areas. In some areas of Radford AAP, the uppermost water-bearing zone is within the limestone and dolomite bedrock. The karst features within the bedrock aquifer can provide conduits for rapid transport of groundwater to the New River, which is the discharge area for regional groundwater flow.

Seasonal variations in precipitation can affect the direction of groundwater flow within the bedrock aquifer at Radford AAP. During wet seasons (high flow conditions), groundwater flow may occur in higher elevation conduits that are not normally saturated during dry seasons (low flow conditions). As a result, flow may short-circuit the predominant flow paths and be redirected, discharging in unexpected areas.

In addition to seasonal variations, groundwater levels within the bedrock aquifer may fluctuate dramatically during heavy precipitation events. Groundwater levels in the karst bedrock aquifer generally respond to heavy precipitation within approximately 14 hours, and may rise several feet in a short time (Engineering-Science, 1994). This condition exists throughout Radford AAP, especially in areas where surface water infiltrates through these conduits, stormwater infiltrating in the uplands of the facility may discharge to the New River in a matter of a few days following a storm event. The turbulent flow created by these conditions aerates the infiltrating water. The increased O_2 content can significantly affect the chemistry of the groundwater, increasing the concentration of many commonly occurring inorganic analytes. It is this direct connection between surface water and groundwater and the rapid movement of groundwater through the aquifer that is vital to interpreting the migration of both naturally occurring and released constituents in the groundwater at Radford AAP.

V.C.1. UNIT 5

V.C.1.a Geology/Structure

Geological Cross Sections are presented in **Appendix A.2 of Permit Attachment 2**. Bedrock below the unit is generally encountered at a depth ranging from 28 to over 56 feet below ground level, with alluvial sediments and weathered bedrock residuum overlying the bedrock. It is characterized by "floaters", depressions and pinnacles resulting from differential physical and chemical weathering influenced primarily by the structural, depositional, and mineralogical nature of the uppermost lithologic unit (i.e, predominantly brecciated, shaley, or crystalline carbonate). The shaley units of the Elbrook Formation tend to be more resistant, resulting in pinnacles or bedrock highs. In general, the bedrock below the southern portion of the unit slopes downward to the north-northeast, while the bedrock to the north of the unit slopes downward to the south-southwest. This appears to indicate the development of a sinkhole in the vicinity of monitoring well cluster 5WC21, 5WC22, and 5WC23. The area around Unit 5 is characterized by the development of sinkholes without any apparent alignment or preferred orientation. The fracture lineations identified during the fracture trace analysis, however, appear to be oriented radially, trending northeast-southwest to northwest-southeast in the area of Unit 5. It is probable that there are well developed karst conduits which convey aerated surface water during precipitation events from the upland sinkholes through these solution-enhanced fractures and joints towards the New River at relatively rapid velocities.

V.C.1.b Groundwater Movement

Groundwater elevation (potentiometric surface) and flow direction maps are provided in **Appendix A.3 of Permit Attachment 2.** GW is encountered at depths ranging from 9 feet to 18 feet bgl with the water table generally located at or just above alluvium/weathered residuum interface. GW level fluctuation in this zone do not appear to exceed 2 to 5 feet annually over most of the site; however, GW levels fluctuated by as much as 8 feet in the farthest downgradient locations (wells 5W10A and 5W11A) in 1994. These farthest downgradient wells are the only monitoring wells that appear to be screened across the bedrock/weathered residuum interface. Groundwater movement beneath the unit is generally to the north-northeast towards the New river. The groundwater contours and the topography in this unit suggest that the unit is located on a river terrace that contains several sinkholes and drains north toward the New River.

V.C.2. UNIT 16

V.C.2.a Geology/Structure

Geological Cross Sections are presented in **Appendix A.2 of Attachment 3.** Bedrock below the unit is generally encountered at a depth ranging from 30 to 70 feet below ground level (bgl), although the soil/bedrock interface is gradational. It is characterized by "floaters", depressions and pinnacles resulting from differential physical and chemical weathering influenced primarily by the depositional and mineralogical nature of the uppermost lithologic unit (i.e. predominantly shaley, or crystalline carbonate). The shaley units of the Elbrook Formation tend to be more resistant, resulting in pinnacles or bedrock highs. In general, the bedrock below the unit slopes to the east and south towards the New River. The area around Unit 16 is characterized by the development of sinkholes without any apparent alignment or preferred orientation. The fracture lineations identified during the fracture trace analysis, however, appear to be oriented radially, trending east-west to north-south from the crest of the horseshoe towards the New River. It is probable that there are well developed karst conduits which convey aerated surface water during precipitation events from the upland sinkholes through these solution-enhanced fractures and joints towards the New River at relatively rapid velocities.

V.C.2.b Groundwater Movement

Groundwater elevation (potentiometric surface) and flow direction maps are provided in **Appendix A.3 of Permit Attachment 3**. GW is encountered at roughly 40 feet bgl with the water table generally located at or just above the soil bedrock interface. Groundwater fluctuations in this zone do not appear to exceed 2 to 4 feet annually, although individual wells tapping karst conduits could show dramatic fluctuations following storm events. Groundwater movement beneath the unit is generally to the east-northeast towards a spring located roughly 500 feet northeast of Unit 16. The groundwater contours and the topography in this unit suggest that the unit is located on top of a structural swale which directs water towards the spring.

V.D. COMPLIANCE MONITORING SYSTEM AND SAMPLING SCHEDULE

V.D.1. UNIT 5

V.D.1.a. Groundwater Monitoring System

The Compliance Monitoring Program requires monitoring at the background well (s), Point of Compliance Wells and at all wells designated as Plume Monitoring Wells semiannually in single samples. Static groundwater elevations (as made applicable by **Permit Condition V.H.**) will be measured at all wells specified in **V.D.1.a.(1), (2), and (3)** during each sampling event. The groundwater monitoring system follows:

(1) The groundwater beneath the closed WMA shall be monitored with one upgradient groundwater monitoring well and five (5) downgradient point of compliance wells located as specified on the map presented in **Appendix A.1 of Permit Attachment 2**. Monitoring well 5W8B is the background well for the WMA and monitoring wells 5W5B, 5W7B, 5WC21, 5WC22, and 5WC23 are the point of compliance wells.

(2) In addition to the wells specified in **Permit Condition V.D.1.a.(1).**, well 5W12A will serve as plume monitoring wells downgradient of the unit to determine whether continued migration of contaminants has occurred.

(3) Well(s) S5W5, S5W7, 5W9A, 5W10A, 5W11A, 5WCA, S5W6, S5W8, 5WC11, and 5WC12 will be used as piezometers to measure static groundwater elevations during each sampling event.

V.D.1.b. Sampling Schedule

The upgradient well, the point of compliance wells, and plume monitoring wells will be sampled in accordance with the Compliance Monitoring Sampling and Analysis Plan (**Appendix H of Permit Attachment 1**) and the following schedule:

(1) The upgradient well and downgradient point of compliance wells specified in **Permit Conditions V.D.1.a.(1)** will be sampled at least semi-annually for the constituents listed in **Appendix E of Permit Attachment 2**. The Permittees must collect, at least, a single sample for each specified constituent at each well and analyses must be obtained using the EPA SW-846 Methods specified in **Appendix E of Permit Attachment 2**.

(2) The Plume Monitoring Wells specified in **Permit Condition V.D.1.a.(2)** shall be sampled at least semi-annually for all constituents listed in **Appendix E of Permit Attachment 2**. Single samples for each constituent shall be collected and analyses shall be obtained using the EPA SW-846 Methods specified in **Appendix E of Permit Attachment 2**.

(3) Downgradient Point of Compliance Wells listed in **Permit Condition V.D.1.a.(1)**. will be sampled annually for all constituents in **Appendix IX to 40 CFR Part 264** as listed in **Appendix I of Permit Attachment 1** and analyses shall be obtained using the EPA SW-846 Methods specified in **Appendix I of Permit Attachment 1**.

V.D.1.c. Additional Monitoring Wells

If additional constituents on the Compliance Monitoring list are detected at statistically significant levels above background in the Plume Monitoring Wells specified in **Permit Condition V.D.1.a.(2)** and if there is evidence that changes in the nature or extent of groundwater contamination have occurred as required by **40 CFR Part 264.99(j)**, the Permittees shall install groundwater monitoring wells to further define the vertical and horizontal extent of contamination in accordance with **40 CFR Section 264.90**.

(1) The Permittees shall notify the Director within seven (7) days of determining that a constituent was detected at statistically significant levels above background in any downgradient plume monitoring well.

(2) If the Permittees choose to attempt a verification sampling event as defined by **Permit Conditions V.J.1.e(1) and V.J.1.h.**, this intent and a brief description of proposed resampling activities shall be included in the notification required by **Permit Condition V.D.1.c.(1).**

(3) If the results of the resampling indicate that the statistical increase was valid or no resampling is conducted, the Permittees shall submit to the Director a plan to sample existing wells and/or install additional monitoring wells to define the vertical and horizontal extent of the constituent in the groundwater downgradient of the unit. This plan shall be submitted within thirty (30) days of the notification required by **Permit Condition V.D.1.c.(1).**

(4) Appropriate modifications to the Compliance Monitoring Program shall be proposed following the installation of any additional wells, as required to meet the performance standards of the monitoring program.

(5) The Permittees may choose to demonstrate that the statistical increase was a result of a source or sources other than the unit. Notification that this demonstration will be attempted should be forwarded to the Director along with the notification that a statistically significant increase has been detected. Additional plume delineation will not be required if the Permittees demonstrate to the satisfaction of the Director that a source or sources other than the unit is the source of increased groundwater contamination.

V.D.2 UNIT 16

V.D.2.a. Groundwater Monitoring System

The Compliance Monitoring Program requires monitoring at the background well (s), Point of Compliance Wells and at all wells designated as Plume Monitoring Wells semiannually in single samples. Static groundwater elevations (as made applicable by **Permit Condition V.H**) will be measured at all wells specified in **V.D.2.a.(1), (2), and (3)** during each sampling event. The groundwater compliance monitoring system follows:

(1) The groundwater beneath the HWMA shall be monitored with one (1) upgradient groundwater monitoring well and four (4) downgradient point of compliance wells located as specified on the map presented in **Appendix A.1 of Permit Attachment 3** (Well Location Map). Monitoring well 16C1 is the background (upgradient groundwater monitoring) well for the UNIT 16 and the downgradient groundwater monitoring wells 16MW8, 16MW9, 16WC1A, and 16WC1B are the point of compliance wells.

(2) In addition to the wells specified in **Permit Condition V.D.2.a.(1)**., four (4) wells, 16-2, 16-3, 16-5 and 16WC2B, will serve as plume monitoring wells downgradient of the unit. The Spring (16SPRING) will serve as an additional sampling point. These five monitoring points shall be used to determine whether continued migration of contaminants is occurring.

(3) Four wells, 16-1, 16WC2A, 16C3, and 16CDH3, will be used as piezometers to measure static groundwater elevations during each sampling event.

V.D.2.b. Sampling Schedule

The upgradient well, the point of compliance wells, and plume monitoring wells will be sampled in accordance with the Compliance Monitoring Sampling and Analysis Plan (**Appendix H of Permit Attachment 1**) and the following schedule:

(1) The upgradient well and downgradient point of compliance wells specified in **Permit Conditions V.D.2.a.(1)** will be sampled at least semi-annually for the constituents listed in **Appendix E of Permit Attachment 3**. The Permittees must collect, at least, a single sample for each specified constituent at each well and analyses must be obtained using the EPA SW-846 Methods specified in **Appendix E of Permit Attachment 3.**

(2) The Plume Monitoring Wells specified in Permit Condition V.D.4.a.(2). shall be sampled at least semi-annually for all constituents listed in **Appendix E of Permit Attachment 3**. Single samples for each constituent shall be collected and analyses shall be obtained using the EPA SW-846 Methods specified in **Appendix E of Permit Attachment 3.**

(3) Downgradient Point of Compliance Wells listed in **Permit Condition V.D.2.a.(1)**. will be sampled annually for all constituents in **Appendix IX to 40 CFR Part 264** as listed in **Appendix I of Permit Attachment 1** and analyses shall be obtained using the EPA SW-846 Methods specified in **Appendix I of Permit Attachment 1.**

V.D.2.c. Additional Monitoring Wells

If additional constituents on the Compliance Monitoring list are detected at statistically significant levels above background in the Plume Monitoring Wells specified in **Permit Condition V.D.2.a.(2).** and if there is evidence that changes in the nature or extent of groundwater contamination have occurred as required by **40 CFR Part 264.99(j)**, the Permittees shall install groundwater monitoring wells to further define the vertical and horizontal extent of contamination in accordance with **40 CFR Section 264.90.**

(1) The Permittees shall notify the Director within seven (7) days of determining that a constituent was detected at statistically significant levels above background in any downgradient plume monitoring well.

(2) If the Permittees choose to attempt a verification sampling event as defined by **Permit Conditions V.J.2.e(1) and V.J.2.h.**, this intent and a brief description of proposed resampling activities shall be included in the notification required by **Permit Condition V.D.2.c.(1).**

(3) If the results of the resampling indicate that the statistical increase was valid or no resampling is conducted, the Permittees shall submit to the Director a plan to sample existing wells and/or install additional monitoring wells to define the vertical and horizontal extent of the constituent in the groundwater downgradient of the unit. This plan shall be submitted within thirty (30) days of the notification required by **Permit Condition V.D.2.c.(1).**

(4) Appropriate modifications to the Compliance Monitoring Program shall be proposed following the installation of any additional wells, as required to meet the performance standards of the monitoring program.

(5) The Permittees may choose to demonstrate that the statistical increase was a result of a source or sources other than the unit. Notification that this demonstration will be attempted should be forwarded to the Director along with the notification that a statistically significant increase has been detected. Additional plume delineation will not be required if the Permittees demonstrate to the satisfaction of the Director that a source or sources other than the unit is the source of increased groundwater contamination.

V.E. WELL CONSTRUCTION AND MAINTENANCE

V.E.1 UNIT 5

V.E.1.a. Well Construction

(1) The locations of the monitoring wells listed in **Permit Condition V.D.1.a** are specified on the map presented in **Appendix A.1 of Permit Attachment 2.**

(2) Boring logs, design and construction details for monitoring wells listed in **Permit Condition V.D.1.a** are included as **Appendix H to Permit Attachment 2.**

V.E.1.b. Maintenance

All monitoring wells in the Compliance Monitoring Program, as listed in **Permit Condition V.D.1.a.**, shall be maintained and inspected at least semiannually to ensure proper operation. Any required repairs shall be made by the Permittees as soon as possible and before the next sampling event. If any of these wells are damaged beyond reasonable efforts for repair, the Permittees may petition the Director for approval to abandon the affected. Appropriate permit modification applications shall be submitted.

V.E.1.c. Standard

All monitoring wells required by this Permit shall be maintained in conformance with the following:

(1) The monitoring system must yield samples in upgradient well(s) that represent the quality of the background groundwater unaffected by leakage from the Regulated Units, and in downgradient wells yield samples that represent the quality of groundwater passing the compliance point.

(2) The number and location of wells must be sufficient to identify and define all logical release pathways from the unit(s) to the uppermost aquifer based on site specific hydrogeologic characterization.

V.E.1.d. Installation and Abandonment

The Director must approve the addition or removal of all monitoring wells prior to installation or abandonment through a permit amendment.

(1) All wells deleted from the monitoring program shall be plugged and abandoned in accordance with **Appendix K to Permit Attachment 1**. Well plugging methods and abandonment certification shall be submitted to the Director within thirty (30) days from the date the wells are removed from the monitoring program.

(2) All wells added to the existing monitoring system described in **Permit Condition V.E.1.a**. must be constructed in accordance with the requirements of EPA's 1986 RCRA Groundwater Monitoring Technical Enforcement Guidance Document (TEGD) and/or as approved by the Department (**Appendix H.5 to Permit Attachment 1**).

V.E.2 UNIT 16

V.E.2.a. Well Construction

(1) Monitoring well design and construction details for monitoring wells 16C1, 16MW8, 16MW9, 16WC1A, 16WC1B, 16-1, 16-2, 16-3, 16-5, 16WC2B, 16WC2A, 16C3, and 16CDH3 are included as **Appendix H of Permit Attachment 3.**

(2) Boring logs for monitoring wells 16C1, 16MW8, 16MW9, 16WC1A, 16WC1B, 16-1, 16-2, 16-3, 16-5, 16WC2B, 16WC2A, 16C3, and 16CDH3 are included as **Appendix H of Permit Attachment 3.**

V.E.2.b. Maintenance

All monitoring wells in the Compliance Monitoring Program, as listed in **Permit Condition V.D.2.a.**, shall be maintained and inspected at least semiannually to ensure proper operation. Monitoring well design and construction details for monitoring wells 16C1, 16MW8, 16MW9, 16WC1A, 16WC1B, 16-1, 16-2, 16-3, 16-5, 16WC2B, The Permittees shall maintain groundwater monitoring wells 16C1, 16MW8, 16MW9, 16WC1A, 16WC1B, 16-1, 16-2, 16-3, 16-5, 16WC2B, 16WC2A, 16C3, and 16CDH3 at the locations specified on the map presented in **Appendix A of Permit Attachment 3.**

(1) All monitoring wells in the Compliance Monitoring Program, as listed in **Permit Conditions V.D.2.a. through V.D.2.c.**, shall be maintained and inspected at least quarterly to ensure proper operation. Any required repairs shall be made by the Permittees as soon as possible and before the next sampling event

(2) The Permittees shall inspect the monitoring wells 16C1, 16MW8, 16MW9, 16WC1A, 16WC1B, 16-1, 16-2, 16-3, 16-5, 16WC2B, 16WC2A, 16C3, and 16CDH3 at least annually to ensure that they are not damaged. If any of these wells are damaged beyond reasonable efforts for repair, the Permittees may petition the Director for approval to abandon the affected. Appropriate permit modification applications shall be submitted.

V.E.2.c. Standard

All monitoring wells required by this Permit shall be maintained in conformance with the following:

(1) The monitoring system must yield samples in upgradient well(s) that represent the quality of the background groundwater unaffected by leakage from the Regulated Units, and in downgradient wells yield samples that represent the quality of groundwater passing the compliance point.

(2) The number and location of wells must be sufficient to identify and define all

logical release pathways from the unit(s) to the uppermost aquifer based on site specific hydrogeologic characterization.

V.E.2.d Installation and Abandonment
The Director must approve the addition or removal of all monitoring wells prior to installation or abandonment through a permit amendment.

(1) All wells deleted from the monitoring program shall be plugged and abandoned in accordance with **Appendix K to Permit Attachment 1.** Well plugging methods and abandonment certification shall be submitted to the Director within thirty (30) days from the date the wells are removed from the monitoring program.

(2) All wells added to the existing monitoring system described in **Permit Condition V.E.1.** must be constructed in accordance with the requirements of EPA's 1986 *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (TEGD) and/or as approved by the Department (**Appendix H.5 of Permit Attachment 1**).

V.F. GROUNDWATER PROTECTION STANDARD

V.F.1. UNIT 5

V.F.1.a. Groundwater Protection Standard
The Permittees shall monitor the groundwater to determine whether regulated units are in compliance with the groundwater protection standard under **40 CFR Part 246.92**. The groundwater protection standard is based upon upgradient concentrations from the facility's background groundwater monitoring (**Appendix F to Permit Attachment 2**), EPA Safe Drinking Water Act Maximum Contaminant Levels (SDWA MCLs), or an Alternate Concentration Limit (ACL) approved by the Director (Health-based Risk Assessment Levels generated by the REAMS model or an equivalent method). The hazardous constituents, and their concentration limits listed in **Appendix G of Permit Attachment 2** comprise the groundwater protection standard.

The concentration limits (groundwater protection standards) for the monitored constituents are given in the **Appendix G of Permit Attachment 2**,

V.F.1.b. Background Concentration for Additional Constituents
The Permittees shall monitor all wells as described in **Permit Condition V.D.1.a.(1) and (2)** for all parameters and constituents specified in **Appendix E of Permit Attachment 2** and **Appendix I of Permit Attachment 1** as appropriate. For any additional hazardous constituents detected during the annual analysis of all monitoring wells at the point of compliance, as specified above in **Permit Section V.D.1**, for all constituents contained in **Appendix IX to 40 CFR**

264 (see **Appendix I of Permit Attachment 1**) for which no accurate background values have been established at the time the Permit was issued, the Permittees shall establish accurate background values in accordance with **40 CFR 264.97(g)**, and as specified below:

(1) Background groundwater quality for a monitoring parameter or constituent shall be based on data from quarterly sampling of a properly installed well(s) upgradient from the waste management area for one (1) year.

(2) The Permittees shall take a sequence of at least four (4) samples from each upgradient well, to determine background groundwater quality for each parameter and/or constituent each time the system is sampled.

V.F.1.c. Effective Duration

The Compliance Period, during which The Groundwater Protection Standard applies, is equal to the period of time from the beginning of the waste management area's active life until the end of the closure period and begins when the Permittees initiate a Compliance Monitoring Program meeting the requirements of **40 CFR 264.99**.

The Permittees operated the surface impoundment known as Unit 5 from 1970 until final closure of unsaturated soils in 1989. Therefore, the compliance period, as specified in **40 CFR 264.96**, is 19 years. The original Permit was issued on September 28, 2001. The Compliance Period, therefore, shall begin on the effective date of the original Permit and shall continue until the nineteenth anniversary of that effective date in 2020, or until the Director approves clean closure of the unit. If the Permittees are required to conduct corrective action at the end of the specified compliance period, then the compliance period shall be extended until the Permittees demonstrate that the **Groundwater Protection Standard** has not been exceeded for three (3) consecutive years.

V.F.2. UNIT 16

V.F.2.a. Groundwater Protection Standard

The Permittees shall monitor the groundwater to determine whether regulated units are in compliance with the groundwater protection standard under **40 CFR Part 246.92**. The groundwater protection standard is based upon upgradient concentrations from the facility's background groundwater monitoring (**Appendix F of Permit Attachment 3**), EPA Safe Drinking Water Act Maximum Contaminant Levels (SDWA MCLs), or an Alternate Concentration Limit (ACL) approved by the Director (Health-based Risk Assessment Levels generated by the REAMS model or an equivalent method). The hazardous constituents, and their concentration limits listed in **Appendix G of Permit Attachment 3** comprise the groundwater protection standard.

V.F.2.b. Background Concentration for Additional Constituents

The Permittees shall monitor all wells as described in **Permit Condition V.D.2.a.(1) and (2)** for all parameters and constituents specified in **Appendix E of Permit Attachment 3** and **Appendix I of Permit Attachment 1** as appropriate. For any additional hazardous constituents detected during the annual analysis of all monitoring wells at the point of compliance, as specified above in **Permit Section V.D.2**, for all constituents contained in **Appendix IX to 40 CFR 264** (see **Appendix I of Permit Attachment 1**) for which no accurate background values have been established at the time the Permit was issued, the Permittees shall establish accurate background values in accordance with **40 CFR 264.97(g)**, and as specified below:

(1) Background groundwater quality for a monitoring parameter or constituent shall be based on data from quarterly sampling of a properly installed well(s) upgradient from the waste management area for one (1) year.

(2) The Permittees shall take a sequence of at least four (4) samples from each upgradient well, to determine background groundwater quality for each parameter and/or constituent each time the system is sampled.

V.F.2.c. Effective Duration

The Compliance Period, during which the Groundwater Protection Standard applies, is equal to the period of time from the beginning of the waste management area's active life until the end of the closure period and begins when the Permittees initiate a Compliance Monitoring Program meeting the requirements of **40 CFR 264.99**.

The Permittees operated the hazardous waste landfill known as Unit 16 from 1980 until 1988. The Permittees certified closure on August 10, 1993. Therefore, the compliance period, as specified in **40 CFR 264.96**, is 13 years. The Compliance Period shall begin on the effective date of this Permit and shall continue until October 30, 2015, or until the Director approves clean closure of the unit. If the Permittees are required to conduct corrective action at the end of the specified compliance period, then the compliance period shall be extended until the Permittees demonstrate that the **Groundwater Protection Standard** has not been exceeded for three (3) consecutive years.

V.G. SAMPLING AND ANALYSIS PROCEDURES

The Permittees shall use the following techniques and procedures when obtaining and analyzing samples from the groundwater monitoring wells described in **Permit Conditions V.D.1., and V.D.2.**:

V.G.1. UNIT 5

V.G.1.a. Samples shall be collected using the techniques described in **Appendix H of**

Permit Attachment 1.

V.G.1.b. Samples shall be preserved, packed, and shipped off-site for using the techniques described in **Appendix H of Permit Attachment 1.**

V.G.1.c. Samples shall be analyzed in accordance with the procedures specified in **Appendix I of Permit Attachment 1 and Appendix E of Permit Attachment 2.**

V.G.1.d. Samples shall be tracked and controlled following the chain-of-custody techniques in **Appendix H of Permit Attachment 1.**

V.G.1.e. The Permittees must determine the concentration of constituents and parameters listed in **Appendix E of Permit Attachment 2** in the groundwater at the compliance point at least semiannually during the compliance period specified in **Permit Condition V.F.1.c.**

V.G.1.f. The Permittees must analyze samples from all monitoring wells listed in Permit Condition V.D.1.a.(1) at the compliance point, for all constituents contained in **Appendix IX to 40 CFR Part 264 (Appendix I of Permit Attachment 1)** at least annually during the compliance period.

V.G.2. UNIT 16

V.G.2.a. Samples shall be collected using the techniques described in **Appendix H of Permit Attachment 1.**

V.G.2.b. Samples shall be preserved, packed, and shipped off-site for analysis using the techniques described in **Appendix H of Permit Attachment 1.**

V.G.2.c. Samples shall be analyzed in accordance with the procedures specified in **Appendix I of Permit Attachment 1 and Appendix E of Permit Attachment 3.**

V.G.2.d. Samples shall be tracked and controlled following the chain-of-custody techniques in **Appendix H of Permit Attachment 1.**

V.G.2.e. The Permittees must determine the concentration of constituents and parameters listed in **Appendix E of Permit Attachment 3** in the groundwater at the compliance point at least semiannually during the compliance period specified in **Permit Condition V.F.2.c.**

V.G.2.f. The Permittees must analyze samples from all monitoring wells listed in Permit Condition V.D.4.a.(1) at the compliance point, for all constituents contained in **Appendix IX to 40 CFR Part 264 (Appendix I of Permit Attachment 1)** at least annually during the compliance period.

V.H. ELEVATION OF THE GROUNDWATER SURFACE

V.H.1. Groundwater Surface Elevation

The Permittees shall determine the groundwater surface elevation (and depth to bottom of wells not equipped with dedicated pumps) at each monitoring well specified in **Permit Conditions V.D.1.a., and 2.a.**, for Unit 5 and Unit 16, respectively, each time groundwater is sampled in accordance with procedures contained in **Appendix H of Permit Attachment 1.**

(1) Static groundwater elevations (and total depths--for wells that do not contain dedicated pumps) will be measured at all wells specified in **Permit Conditions V.E.1., and 2.** for Unit 5 and Unit 16, respectively during each sampling event.

(2) The first quarterly monitoring event as described in **Permit Module V** shall be completed no later that 90 days from the date of Permit issuance.

(3) If, during the course of purging and sampling, the data from turbidity measurements and field parameters indicate that silt has accumulated in any well, the pump (if dedicated) shall be pulled and the total well depth and sediment thickness shall be calculated. Corrective measures shall be taken prior to the next sampling event, if necessary.

V.H.2. Additional/Replacement Wells

The Permittees shall report the surveyed elevation of any additional or replacement monitoring well(s) when installed with as-built drawings. The total depth of wells and the elevation of the following shall be recorded: top of the casing, ground surface and/or apron elevation, and the protective casing.

V.I. STATISTICAL PROCEDURES

V.I.1. Statistical Evaluation

When evaluating the monitoring results in accordance with **Permit Sections V.J.1, and 2** for Unit 5 and Unit 16, respectively, the Permittees shall determine whether there is statistically significant evidence of increased contamination for any hazardous constituent or parameters specified in the **Groundwater Protection Standard (Appendix G of Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively) using the statistical procedures specified in **Appendix J of Permit Attachment 1** in accordance with **40 CFR 264.97(h), 264.97(i), 264.99(d), and 264.99(h)** or using an alternative method approved by the Director.

V.I.2. Simple Empirical Comparison

The Permittees may elect to perform a simple empirical comparison of Point of Compliance data to the **Groundwater Protection Standard** (**Appendix G of Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively) or Compliance Well data to the established background concentration in **Appendix F to Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively, instead of the statistical procedures specified in **Appendix J of Permit Attachment 1.**

V.I.3. Statistical Procedures

The Permittees shall conduct all statistical procedures as specified in **Appendix J of Permit Attachment 1.**

V.I.4. Schedule for Statistical Evaluation

The Permittees shall perform the statistical evaluation required by **Permit Conditions V.I.1, 2, and 3** above within 30 days from when the results of the analyses are available from the laboratory performing the analyses, but not later than the following schedule in accordance with **40 CFR 264.99(d)(2).**

Samples Collected During The Months of:	***Statistical Results Due by:***
April – June	*August 15*
October – December	*March 1*

The results of the evaluation shall be reported to the Director.

V.J. MONITORING PROGRAM AND DATA EVALUATION

The Permittees shall conduct groundwater quality evaluation as follows:

V.J.1. UNIT 5

V.J.1.a. Sampling and Analysis

The Permittees shall collect, preserve, and analyze groundwater samples taken from all monitoring wells specified in this **Permit**, at least semiannually , pursuant to **Permit Section V.G.1.**

V.J.1.b. Analytical Constituents

The Permittees shall determine the concentration of compliance monitoring constituents and/or parameters, as listed in the Compliance Monitoring Constituent List (**Appendix E of Permit Attachment 2**), in the groundwater at each monitoring well specified in **Permit Section V.D.1.a.(1) and (2)** at least semiannually in accordance with **40 CFR 264.99(a).**

The Permittees shall determine the concentration of hazardous constituents and/or parameters, as specified in the Groundwater Protection Standard (**Permit Section V.F.1,** also **Appendix G of Permit Attachment 2**), in the groundwater at each monitoring well specified in **Permit Section V.D.1.a.(1)** at least semiannually in accordance with **40 CFR 264.99(a).**

V.J.1.c. Analysis Data Presentation

The Permittees shall present the groundwater quality at each monitoring well in a form appropriate for the determination of statistically significant increases in accordance with **40 CFR 264.97(h).**

The Permittees' report shall include at least the following information: the constituents analyzed; the SW-846 test methods; method detection limits, level of quantitation; estimated quantitation limits; the internal laboratory quality assurance/quality control (QA/QC); matrix spike duplicates; percent recovery; duplicate analyses; dilution factors; any lab specific limit of detection and/or limit of quantitation; and, the results of any screening analyses.

V.J.1.d. Groundwater Flow Direction and Rate

The Permittees shall determine the groundwater flow rate and direction in the uppermost aquifer at least annually to determine compliance with **40 CFR 264.99(e)**. The Permittees shall also measure the groundwater surface elevations each time groundwater is sampled in accordance with the requirements of 40 CFR 264.97(f).

V.J.1.e. Appendix IX to 40 CFR Part 264

The Permittees shall analyze samples from all wells listed in Permit Condition V.D.1.a.(1) at the compliance point, for all constituents contained in **Appendix IX to 40 CFR Part 264 (Appendix I of Permit Attachment 1)** at least annually to determine whether additional **Appendix IX to 40 CFR Part 264** constituents, which are not listed in **Appendix E of Permit Attachment 2**, are present in the uppermost aquifer.

(1) If the Permittees find additional constituents present (i.e. not listed in **Appendix E of Permit Attachment 2**), the Permittees shall notify the Director within seven (7) days of the data being available from the laboratory. The Permittees may resample within (60) days from the date of the data validation and repeat the analysis for the detected **Appendix IX to 40 CFR Part 264** constituent. If confirmation sampling is intended, the Permittees shall include the proposed sampling date with the notification.

(2) If the second analysis confirms the presence of the additional constituents,

the Permittees shall report the concentration of these constituents to the Director in writing within seven (7) days after the completion of the second analysis and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 2**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 2**).

(3) If the Permittees choose not to resample, then the Permittees shall report the concentrations of these additional constituents to the Director within seven (7) days after completion of the initial analysis and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 2**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 2**).

(4) If the constituent has been previously detected in the monitoring well, then the Permittees may choose not to resample. The Permittees shall report the concentration within seven (7) days after the completion of the analyses and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 2**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 2**).

(5) The Permittees may attempt to demonstrate that the newly detected additional Appendix IX constituent was from a source or sources other than the Regulated Unit. The Director shall be notified of the intent to make the demonstration either with the original notification that a new constituent was detected or with the results of the resampling.

- This demonstration shall prove to the satisfaction of the Director that an alternate source caused the detection.
- The demonstration shall commence within a reasonable time following the notification in **Permit Condition V.J.1.e.(2) or (3)** above, and the results shall be submitted for review no later than 90 days from the original notification.
- The Permittees must continue to monitor in accordance with the Compliance Monitoring Program established under **40 CFR Section 264.99**.

V.J.1.f Background Values for Newly Detected Constituents

If the second analysis (**Permit Condition V.J.1.e.(2)**) confirms the presence of constituents not included in the Compliance Monitoring program, the Permittees choose not to resample (**Permit Condition V.J.1.e.(3).**), or the Permittees are unable to prove to the satisfaction of the Director that a source other than the Regulated Unit is responsible, the Permittees shall establish the background values for each additional **Appendix IX to 40 CFR Part 264** constituent listed in **Appendix I of Permit Attachment 1** found in the groundwater in accordance with the following procedures:

(1) Background groundwater quality for a newly listed monitoring parameter or constituent shall be based on data (single samples) from at least quarterly sampling of an upgradient monitoring well for each unit, as specified by **Permit Condition V.D.1.a.(1).**, for one (1) year.

(2) Background groundwater quality for each newly listed parameter and/or constituent for each compliance point and plume monitoring wells, as listed in **Permit Conditions V.D.1.a.(1) and a.(2)**, respectively, shall be based on data (single samples) from at least quarterly sampling for one (1) year.

V.J.1.g. GPS (Appendix G of Permit Attachment 2) for Newly Detected Constituents
For each additional **Appendix VIII to 40 CFR Part 261** hazardous constituent confirmed in accordance with **Permit Condition V.J.1.e.(2)** or directly added to the monitoring list (**Appendix E of Permit Attachment 2**) without resampling in accordance with **Permit Condition V.J.1.e.(3)**, the Director shall establish a Groundwater Protection Standard and amend **Appendix G of Permit Attachment 2**. The background value determined through **Permit Condition V.J.1.f** will be utilized as the groundwater protection standard under **40 CFR Part 264.92.** The Permittees may request and the Director may establish an Alternate Concentration Limit (ACL) in accordance with **40 CFR Part 264.94(b).**

V.J.1.h. Comparison to Background Concentrations
During the compliance period, for each hazardous constituent identified in **Permit Condition V.J.1.e**, the Permittees shall determine whether there is statistically significant evidence of increased contamination each time when the concentration of hazardous constituents is monitored in groundwater at the compliance point; pursuant to **Permit Section V.I.1** and using the statistical procedures in **Appendix J of Permit Attachment 1** or an alternate method approved by the Director prior to use. To make that determination, the Permittees shall compare the groundwater quality at each monitoring well specified in **Permit Section V.D.1** to the background concentrations for that constituent, in accordance with the procedures specified in **Permit Section V.I.1**. These determinations shall be made at least semiannually and the results reported to the Director.

(1) If the appropriate statistical test (specified in **Appendix J of Permit Attachment 1** and/or approved by the Director) indicates that the difference between the established background (or upgradient concentration) and the downgradient well concentration is significant, the Permittees shall notify the

Director in writing within seven (7) days of determining that a constituent was detected at statistically significant levels in any downgradient well. The notice should indicate whether the Permittees resample to confirm the exceedance.

(2) The Permittees may repeat the same procedure with an independent sample from the monitoring well within 30 days of determination that the difference was statistically significant. If the Permittees choose to attempt a resampling demonstration as defined by **Permit Condition V.J.1.e.(1).**, this intent and a brief description of proposed confirmation sampling activities shall be include in the notification required above.

V.J.1.i. Comparison to Groundwater Protection Standards

For each hazardous constituent identified in **Permit Condition V.J.1.e** and listed in **Appendix G of Permit Attachment 2.**, the Permittees shall determine whether there is statistically significant evidence of increased contamination each time when the concentration of hazardous constituents is monitored in groundwater at the compliance point. In determining whether such an increase of contamination has occurred, at least semiannually the Permittees shall compare the groundwater concentration at each monitoring well specified in **Permit Section V.D.1.a (1)**, to the Groundwater Protection Standard for that constituent, in accordance with the procedures specified in **Appendix J of Permit Attachment 1** if appropriate.

(1) Methods of Comparison

(a) If a single independent sample was collected at the monitoring well, the Permittees shall conduct a simple empirical comparison of the measured value to the **GPS (Appendix G of Permit Attachment 2)**.

(b) If multiple independent samples were collected from each monitoring well, a statistical comparison, as approved by the Director, to the GPS shall be conducted. Guidelines for method selection are contained in **Appendix J of Permit Attachment 1**.

(2) Notification

For constituents that have not statistically exceeded the **Groundwater Protection Standard** during previous sampling events, the Permittees shall submit written notification to the Director within 7 days of determining that the **GPS (Appendix G of Permit Attachment 2)** has been exceeded for the additional constituent. The notification shall include the following:

(a) concentration of constituent exceeding the GPS (**Appendix G of Permit Attachment 2**);

(b) identification of the monitoring well where the GPS (**Appendix G of**

Permit Attachment 2) was exceeded; and

(c) a map showing the extent of the groundwater contaminant plume with concentrations mapped.

(3) *Other Source Demonstration*
The Permittees may make a demonstration that the groundwater protection standard as indicated in **Appendix G of Permit Attachment 2** was exceeded due to sources other than the unit; errors in sampling, analysis, and evaluation; or natural variation in the groundwater. The demonstration shall be conducted as follows:

(a) The Permittees shall include in the notification to the Director in **Permit Condition V.J.1.i(2)**., that the demonstration will be attempted.

(b) Resampling must be conducted as described in V.J.1.e.(1).

(c) Four (4) independent samples shall be collected from the well for each constituent the Permittees included in the demonstration. A statistical evaluation of the data shall be conducted using a statistical method approved by the Director.

(d) The Permittees must submit a report to the Director within 90 days of the notification that demonstrates a source other than the unit caused the groundwater protection standard to be exceeded or that the apparent non-compliance was a result of an error in sampling, analysis, or evaluation. The Permittees must also submit to the Director within 90 days of the notification in **Permit Condition V.J.1.i(2)** an application for a permit modification to make any appropriate changes in the Compliance Monitoring Program.

(e) If the Director approves the results of the demonstration, the constituent shall remain on the Annual 40 CFR 264 Appendix IX Constituent list (**Appendix I of Permit Attachment 1**) and Compliance Monitoring List (**Appendix E of Permit Attachment 2**) and samples shall continue to be collected and analyzed as specified.

(4) *Specification*
The Permittees shall specify all **Groundwater Protection Standard** exceedances from the reported sampling event in the Semiannual Monitoring Report.

V.J.2. UNIT 16

V.J.2.a. Sampling and Analysis

The Permittees shall collect, preserve, and analyze groundwater samples taken from all monitoring wells specified in this **Permit**, at least semiannually, pursuant to **Permit Section V.G.2.**

V.J.2.b. Analytical Constituents

The Permittees shall determine the concentration of compliance monitoring constituents and/or parameters, as listed in the Compliance Monitoring Constituent List (**Appendix E of Permit Attachment 3**), in the groundwater at each monitoring well specified in **Permit Section V.D.2.a.(1) and (2)** at least semiannually in accordance with **40 CFR 264.99(a)**.

The Permittees shall compare the results of the analysis from Appendix E of Permit Attachment 5 with the concentration of hazardous constituents and/or parameters, as specified in the Groundwater Protection Standard (**Permit Section V.F.2,** also **Appendix G of Permit Attachment 3**), in the groundwater at each monitoring well specified in **Permit Section V.D.2.a.(1)** at least semiannually in accordance with **40 CFR 264.99(a)**.

V.J.2.c. Analysis Data Presentation

The Permittees shall present the groundwater quality at each monitoring well in a form appropriate for the determination of statistically significant increases in accordance with **40 CFR 264.97(h)**.

The Permittees' report shall include at least the following information: the constituents analyzed; the SW-846 test methods; method detection limits; level of quantitation; estimated quantitation limits; the internal laboratory quality assurance/quality control (QA/QC); matrix spike duplicates; percent recovery; duplicate analyses; dilution factors; any lab specific limit of detection and/or limit of quantitation; and, the results of any screening analyses.

V.J.2.d. Groundwater Flow Direction and Rate

The Permittees shall determine the groundwater flow rate and direction in the uppermost aquifer at least annually to determine compliance with **40 CFR 264.99(e)**. The Permittees shall also measure the groundwater surface elevations each time groundwater is sampled in accordance with the requirements of 40 CFR 264.97(f).

V.J.2.e. Appendix IX to 40 CFR Part 264

The Permittees shall analyze samples from all wells listed in Permit Condition V.D.4.a.(1) at the compliance point, for all constituents contained in **Appendix**

IX to 40 CFR Part 264 (Appendix I of Permit Attachment 1) at least annually to determine whether additional **Appendix IX to 40 CFR Part 264** constituents, which are not listed in **Appendix E of Permit Attachment 3**, are present in the uppermost aquifer.

(1) If the Permittees find additional constituents present (i.e. not listed in **Appendix E of Permit Attachment 3**), the Permittees shall notify the Director within seven (7) days of the data being available from the laboratory. The Permittees may resample within (60) days from date of the original sampling and repeat the analysis for the detected **Appendix IX to 40 CFR Part 264** constituent. If confirmation sampling is intended, the Permittees shall include the proposed sampling date with the notification.

(2) If the second analysis confirms the presence of the additional constituents, the Permittees shall report the concentration of these constituents to the Director in writing within seven (7) days after the completion of the second analysis and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 3**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 3**).

(3) If the Permittees choose not to resample, then the Permittees shall report the concentrations of these additional constituents to the Director within seven (7) days after completion of the initial analysis and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 3**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 3**).

(4) If the constituent has been previously detected in the monitoring well, then the Permittees may choose not to resample. The Permittees shall report the concentration within seven (7) days after the completion of the analyses and add them to the Compliance Monitoring list (**Appendix E of Permit Attachment 3**). If the constituent is hazardous (listed in **Appendix VIII to 40 CFR Part 261**), the Permittees shall add it to the Groundwater Protection Standard list (**Appendix G of Permit Attachment 3**).

(5) The Permittees may attempt to demonstrate that the newly detected additional **Appendix IX** constituent was from a source or sources other than the Regulated Unit. The Director shall be notified of the intent to make the demonstration either with the original notification that a new constituent was detected or with the results of the resampling.

- This demonstration shall prove to the satisfaction of the Director that an alternate source caused the detection.

- The demonstration shall commence within a reasonable time following the notification in **Permit Condition V.J.2.e.(2) or (3)** above, and the results shall be submitted for review no later than 90 days from the original notification.
- The Permittees must continue to monitor in accordance with the Compliance Monitoring Program established under **40 CFR Section 264.99**.

V.J.2.f **Background Values for Newly Detected Constituents**

If the second analysis (**Permit Condition V.J.2.e.(2).**) confirms the presence of constituents not included in the Compliance Monitoring program, the Permittees choose not to resample (**Permit Condition V.J.2.e.(3).**), or the Permittees are unable to prove to the satisfaction of the Director that a source other than the Regulated Unit is responsible, the Permittees shall establish the background values for each additional **Appendix IX to 40 CFR Part 264** constituent listed in **Appendix I of Permit Attachment 1** found in the groundwater in accordance with the following procedures:

(1) Background groundwater quality for a newly listed monitoring parameter or constituent shall be based on data (single samples) from at least quarterly sampling of an upgradient monitoring well for each unit, as specified by **Permit Condition V.D.2.a.(1).**, for one (1) year.

(2) Background groundwater quality for each newly listed parameter and/or constituent for each compliance point and plume monitoring wells, as listed in **Permit Conditions V.D.2.a.(1) and (2)**, respectively, shall be based on data (single samples) from at least quarterly sampling for one (1) year.

V.J.2.g. **GPS (Appendix G of Permit Attachment 3) for Newly Detected Constituents**

For each additional **Appendix VIII to 40 CFR Part 261** hazardous constituent confirmed in accordance with **Permit Condition V.J.2.e.(2)** or directly added to the monitoring list (**Appendix E of Permit Attachment 3**) without resampling in accordance with **Permit Condition V.J.2.e.(3)**, the Director shall establish a Groundwater Protection Standard and amend **Appendix G of Permit Attachment 3**. The background value determined through **Permit Condition V.J.2.f** will be utilized as the groundwater protection standard. The Permittees may request and the Director may establish an Alternate Concentration Limit (ACL) in accordance with **40 CFR Part 264.94(b)**.

V.J.2.h. **Comparison to Background Concentrations**

During the compliance period, for each hazardous constituent identified in **Permit Condition V.J.2.e**, the Permittees shall determine whether there is statistically significant evidence of increased contamination each time when the concentration of hazardous constituents is monitored in groundwater at the compliance point; pursuant to **Permit Section V.I.4** and using the statistical procedures in

Appendix J of Permit Attachment 1 or an alternate method approved by the Director prior to use. To make that determination, the Permittees shall compare the groundwater quality at each monitoring well specified in **Permit Section V.D.2.a.(1)** to the background concentrations for that constituent, in accordance with the procedures specified in **Permit Section V.I.4** These determinations shall be made at least semiannually and the results reported to the Director

(1) If the appropriate statistical test (specified in **Appendix J of Permit Attachment 1** and/or approved by the Director) indicates that the difference between the established background (or upgradient concentration) and the downgradient well concentration is significant, the Permittees shall notify the Director in writing within seven (7) days of determining that a constituent was detected at statistically significant levels in any downgradient well The notice should indicate whether the Permittees resample to confirm the exceedance.

(2) The Permittees may repeat the same procedure with an independent sample from the monitoring well within 30 days of determination that the difference was statistically significant If the Permittees choose to attempt a resampling demonstration as defined by **Permit Condition V.J.2.e.(1).**, this intent and a brief description of proposed confirmation sampling activities shall be include in the notification required above.

V.J.2.i. Comparison to Groundwater Protection Standards

For each hazardous constituent identified in **Permit Condition V.J.4.e** and listed in **Appendix G of Permit Attachment 3.**, the Permittees shall determine whether there is statistically significant evidence of increased contamination each time when the concentration of hazardous constituents is monitored in groundwater at the compliance point In determining whether such an increase of contamination has occurred, at least semiannually the Permittees shall compare the groundwater concentration at each monitoring well specified in **Permit Section V.D.2.a.(1)** to the Groundwater Protection Standard for that constituent, in accordance with the procedures specified in **Appendix J of Permit Attachment 1** if appropriate.

(1) Methods of Comparison

(a) If a single independent sample was collected at the monitoring well, the Permittees shall conduct a simple empirical comparison of the measured value to the GPS (**Appendix G of Permit Attachment 3**).

(b) If multiple independent samples were collected from each monitoring well, a statistical comparison, as approved by the Director, to the GPS (**Appendix G of Permit Attachment 3**) shall be conducted. Guidelines for method selection are contained in **Appendix J of Permit Attachment 1**.

(2) *Notification*
For constituents that have not statistically exceeded the **Groundwater Protection Standard** during previous sampling events, the Permittees shall submit written notification to the Director within 7 days of determining that the **GPS (Appendix G of Permit Attachment 3)** has been exceeded for the additional constituent. The notification shall include the following:

(a) concentration of constituent exceeding the GPS (**Appendix G of Permit Attachment 3**);

(b) identification of the monitoring well where the GPS (**Appendix G of Permit Attachment 3**) was exceeded; and

(c) a map showing the extent of the groundwater contaminant plume with concentrations mapped.

(3). *Other Source Demonstration*
The Permittees may make a demonstration that the groundwater protection standard as indicated in **Appendix G of Permit Attachment 3** was exceeded due to sources other than the unit; errors in sampling, analysis, and evaluation; or natural variation in the groundwater. The demonstration shall be conducted as follows:

(a) The Permittees shall include in the notification to the Director in **Permit Condition V.J.2.i.(2).**, that the demonstration will be attempted.

(b) Resampling must be conducted as described in V.J.2.e.(1).

(c) Four (4) independent samples shall be collected from the well for each constituent the Permittees included in the demonstration. A statistical evaluation of the data shall be conducted using a statistical method approved by the Director.

(d) The Permittees must submit a report to the Director within 90 days of the notification that demonstrates a source other than the unit caused the groundwater protection standard to be exceeded or that the apparent non-compliance was a result of an error in sampling, analysis, or evaluation. The Permittees must also submit to the Director within 90 days of the notification in **Permit Condition V.J.2.i.(2)** an application for a permit modification to make any appropriate changes in the Compliance Monitoring Program.

(e) If the Director approves the results of the demonstration, the constituent shall remain on the Annual 40 CFR 264 Appendix IX Constituent list (**Appendix I of Permit Attachment 1**) and Compliance Monitoring List

Appendix E of Permit Attachment 3) and samples shall continue to be collected and analyzed as specified.

(4) *Specification*
The Permittees shall specify all Groundwater Protection Standard exceedances from the reported sampling event in the Semiannual Monitoring Report.

V.K. REPORTING AND RECORDKEEPING

V.K.1. Record

The Permittees shall enter all monitoring, testing, and analytical data obtained pursuant to **Permit Section V.J.1 and 2**. for Unit 5 and Unit 16, respectively in the operating record. The data packages must include all computations, calculated means, variances, t-statistic values, and t-test results or the calculations and results of statistical tests that the Director has determined to be equivalent as appropriate and shall be submitted to the Director at least annually, no later than March 1 of the calendar year, pursuant to **40 CFR 264.91(b)**. Reports containing the information shall be submitted in accordance with **Permit Condition I.E.(4)**.

V.K.2. Groundwater Elevation

The Permittees shall submit the groundwater surface elevations and potentiometric contour maps with flow paths, as specified in **Permit Section V.J.1.d and 2.d** for Unit 5 and Unit 16, respectively, to determine whether the requirements for locating the monitoring wells continue to be satisfied, at least annually, no later than March 1 of the calendar year, pursuant to **40 CFR 264.73(b)(6)**. All potentiometric contour maps shall be properly annotated with monitoring wells and groundwater surface elevations clearly marked. If the evaluation shows that the performance standards specified in **Permit Section V.E.1.c and 2.c** for Unit 5 and Unit 16, respectively are no longer satisfied, the Permittees shall, within ninety (90) days, submit a permit modification request to the Director to modify the number, location, or depth of the monitoring wells to bring the groundwater monitoring system into compliance with this requirement, pursuant to **40 CFR 264.99(j) and 40 CFR 270.42(c)**.

V.K.3. Background Values

The established background values and the computations necessary to determine background values shall be submitted to the Department whenever requested by the Director or at least annually with the annual groundwater monitoring report, no later than March 1 of the calendar year pursuant to **40 CFR 264.73(b)**.

V.L. ASSURANCE OF COMPLIANCE

The Permittees shall demonstrate to the Director that groundwater monitoring necessary to ensure compliance with the groundwater protection standard under **40 CFR Part 264.92** is being conducted during the term of the Permit by submitting all required reports, documentation, and notifications.

V.M. SPECIAL REQUIREMENT IF THE GROUNDWATER PROTECTION STANDARD IS EXCEEDED

In accordance with the requirements of this Permit and the VHMWR, if the Director or the Permittees have determined that corrective action at the point of compliance of the Waste Management Area is required, the Permit Conditions in **Permit Section V.M.** shall be applicable. The Permittees are responsible for compliance with **Permit Section V.M.** immediately upon notification by the Director that corrective action is required at the point of compliance.

V.M.1. Notice

The Permittees must notify the Director in writing within seven (7) days from the date that the analytical data is available from the laboratory that the groundwater protection standard (**Appendix G of Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively) has been exceeded at any well for any constituent contained in **Appendix E of Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively not included in previous notifications in accordance with **Permit Condition V.J.1.i and 2.i**. for Unit 5 and Unit 16, respectively. The notification must indicate specifically which concentration limits have been exceeded and be made following each semiannual sampling event if appropriate, pursuant to **40 CFR 264.99(h)(1)**.

V.M.2. Establishment for Corrective Action

The Permittees shall submit to the Director a permit modification to establish a corrective action program meeting **40 CFR Part 264.100** requirements within 180 days, or within 90 days if the Permittees have previously submitted an engineering feasibility study, pursuant to **40 CFR 264.99(h)(2)**. The application shall at a minimum include the following information:

(1) A detailed description of corrective actions that shall achieve compliance with the Groundwater Protection Standard specified in **Permit Section V.F.1 and 2** for Unit 5 and Unit 16, respectively, and

(2) A plan for a groundwater monitoring program that shall demonstrate the effectiveness of the corrective action. Such a groundwater monitoring program may be based on a compliance monitoring program developed to meet the requirements of **41 CFR 264.99**.

V.M.3. Other Source Demonstration

In accordance with **40 CFR Part 264.99(i).**, The Permittees may make a demonstration that the groundwater protection standard as indicated in **Appendix G of Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively, was exceeded due to sources other than a regulated unit or errors in sampling, analysis, evaluation, or natural variation in the groundwater.

(1) The Permittees must notify the Director in writing, within seven (7) days, that a demonstration will be made.

(2) The Permittees must submit a report to the Director within 90 days that demonstrates that a source other than a regulated unit caused the groundwater protection standard to be exceeded or that the apparent non-compliance was a result of an error in sampling, analysis, or evaluation, pursuant to **40 CFR 264.99(i)(2)**.

(3) The Permittees must submit to the Director within 90 days an application for a permit modification to make any appropriate changes in the Compliance Monitoring Program at the facility, pursuant to **40 CFR 264.99(i)(3)**; and

(4) The Permittees must continue to monitor in accordance with the Compliance Monitoring Program established under **40 CFR Part 264.99(i)(4)**.

V.N. REQUESTS FOR PERMIT MODIFICATION

This section, V.N, applies to all four units in this permit.

If the Permittees or the Director determines that groundwater corrective action is required to protect human health and the environment or if the Director determines that the corrective action ongoing at the facility is not adequate, the Permittees shall submit to the Director an application for a permit modification to establish or modify a Corrective Action Program meeting the requirements of 40 CFR Section 264.100 within 180 days of receipt of the Director's determination that corrective action is required.

If the Permittees or the Director determines the Corrective Action Program no longer satisfies the requirements of **40 CFR Part 264.100**, then, within 90 days, the Permittees must submit an application for a permit modification to make any appropriate changes to the program.

V.O. EVALUATION OF GROUNDWATER CONTAMINANT PLUME LOCATION

The results of the statistical comparisons of monitoring data from the plume monitoring wells specified in **Permit Conditions V.I.1 and 2** for Unit 5 and Unit 16, respectively shall be used to determine if the groundwater contaminant plume has migrated vertically or horizontally following the completion of the groundwater quality assessment program.

If constituents on the compliance Monitoring List **Appendix E to Permit Attachment 2 and 3** for Unit 5 and Unit 16, respectively, are detected at statistically significant levels above background in the plume monitoring well specified in **Permit Condition V.D.1.b and 2.b** for Unit 5 and Unit 16, respectively, the Permittees shall take appropriate measures to further define the extent of groundwater contamination.

V.O.1. Other Source Demonstration

The Permittees may make a demonstration that the background concentration was exceeded due to sources other than a regulated unit, errors in sampling, analysis, evaluation, or natural variation in the groundwater.

(1) The Permittees must notify the Director in writing, within seven (7) days, that a demonstration will be made.

(2) The Permittees must submit a report to the Director within 90 days that demonstrates that a source other than a regulated unit caused the background to be exceeded or that the apparent non-compliance was a result of an error in sampling, analysis, or evaluation.

(3) The Permittees must submit to the Director within 90 days a request for a modification to this Permit to make any appropriate changes in the Compliance Monitoring Program at the Facility (**Permit Condition V.N.)**

V.O.2. Additional Wells

If the demonstration in **Permit Condition V.O.1.** above is not attempted or is not accepted by the Director, the Permittees shall submit to the Director a plan to sample existing wells and/or install additional monitoring wells to define the vertical and horizontal extent of the constituent in the groundwater downgradient of the unit. This plan shall be submitted within thirty (30) days of the notification required by **Permit Condition V.O.1.(1).**

V.O.3. New Well Sampling

Unless specific approval is granted in advance by the Director, all monitoring wells installed in accordance with **Permit Condition V.O.2.**, above, shall be sampled in accordance with **Permit Condition V.D.1.b and 2.b** for Unit 5 and Unit 16, respectively, at least semiannually following installation and pending any appropriate modification to the Compliance Monitoring Program pursuant to **Permit Condition V.O.4.**. below.

V.O.4. Modification for New Well

Appropriate modifications to the Compliance Monitoring Program shall be proposed following the installation of any additional wells and/or as required to meet the performance standards of the monitoring program.

V.O.5. Statistical Evaluation

The results of the statistical evaluation shall be included in the semiannual monitoring report (**Permit Condition V.K.1.**).

MODULE VI

GROUNDWATER CORRECTIVE ACTION AND MONITORING PROGRAM FOR UNIT 5

Module VI - GW Corrective Action & Monitoring Program for Unit 5

MODULE VI
GROUNDWATER CORRECTIVE ACTION AND MONITORING PROGRAM FOR UNIT 5

VI.A. HIGHLIGHTS

The concentration of trichloroethene (TCE) in groundwater has exceeded the GPS in the POC Wells 5W5B, 5WC21, 5WC22 and 5WC23 since the issuance of the original permit for Unit 5 on September 28, 2001 During 2008, TCE concentrations were less than historic levels in wells 5WC21, 5WC22 and 5WC23. Appendix A of the Corrective Action Plan (**CAP**), **Attachment 2, Appendix I** provides the historical TCE concentrations in groundwater.

In response to exceedences of the Groundwater Protection Standards (GPSs) at point of compliance (POC) wells for Unit 5, surface impoundment (former lined neutralization pond), Radford Army Ammunition Plant (The Permittee) is implementing a Groundwater Corrective Action (CA) Monitoring Program at the regulated Unit 5. The CA will be implemented as follows:

The Permittee will implement a groundwater CA and monitoring program focused on evaluating the natural attenuation of TCE and its daughter products [1,1-Dichloroethene (1,1-DCE), cis-1,2-Dichloroethane (*c*DCE), trans-1,2-Dichloroethene (*t*DCE), and Vinyl Chloride (VC)] in the subsurface at Unit 5. Based on the characteristics of the plume that has been currently delineated, and the low concentrations of the constituents of concern (COC) currently present in the plume with decreasing TCE trends exhibited by the existing data, a monitored natural attenuation (MNA) CA program will be implemented. The MNA CA program will be conducted as specified in **Permit Module VI (Groundwater CA and Monitoring Program)** and implemented according to the schedule provided in **Permit Section VI.N.**

A groundwater monitoring program designed to evaluate the effectiveness of the CA program including compliance with the CA Specific GPSs is detailed in **Permit Attachment 2, Appendix J.** Reporting and recordkeeping requirements are presented in **Permit Section VI.J.** The schedule contained in this module **(Module VI)** shall be followed to implement the remedy for Unit 5.

VI.B. GROUNDWATER CA PROGRAM -- NATURAL ATTENUATION REMEDY

The goal of this CA measure, through performance monitoring, is to measure and track the reduction of chlorinated Volatile Organic Compounds (VOCs) to levels below the GPSs as defined in **Attachment 2, Appendix J** for the respective COCs, within a reasonable period of time Compliance will be achieved, at the POC Wells and throughout the plume in the aquifer downgradient of Unit 5 (40 CFR 264 100(b) and 264.100(e)). During natural attenuation, multiple processes such as dispersion, diffusion, dilution, sorption, volatilization, biological degradation and chemical decomposition of

COCs result in an effective reduction of contaminant concentration, toxicity, mobility, or volume to levels that are protective of human health and the ecosystem. The daughter products of TCE will be monitored and evaluated to determine the progress (effectiveness and timeliness) of the degradation process (see **Permit Attachment 2, Appendix I**).

VI.B.1. Design Conformance

The Permittee shall install one (1) monitoring well (5W12A) to replace the Plume Monitoring Wells S5W5, S5W7, 5W9A, 5W10A and 5W11A. This monitoring network will be specific to the monitoring of the Natural Attenuation Remedy The location of the new well is specified in **Permit Attachment 2, Appendix I, Figure 2**. Subsequent changes to the Remedy Design are to be addressed in accordance with **Permit Condition VI.B.5.**

VI B.2. Remedial Objectives

The MNA CA Program shall be initiated, operated and maintained in accordance with the CAP (see **Permit Attachment 2, Appendix I**) and the monitoring requirements set forth **in Permit Condition VI.C.**

The principal remedial objective is to reduce or eliminate the chlorinated VOCs of concern to levels below the GPSs as defined in **Permit Attachment 2, Appendix J**, within a reasonable period of time, defined as in Permit Condition VI.B.7.a. To accomplish this principal objective, data from the monitoring and compliance wells will be collected and evaluated following **Permit Condition VI.B.6.**

VI.B 3. Operation Specifications to Be Initiated

As a passive remedy, Natural Attenuation requires no active operation except for groundwater monitoring. The following design system shall be implemented and maintained:

a. The Permittee shall implement the CA monitoring program specified under **Permit Section VI.C** for Natural Attenuation of VOCs in groundwater at Unit-5 generally as described in the CAP (**Permit Attachment 2, Appendix I)** but subject to modifications in analytes and reporting as permitted by **Permit Condition VI.B.5.**

b. Additional monitoring wells, if needed, will be installed in accordance with **Permit Condition VI.D.3.b.**

VI.B.4. Measurement and Maintenance of Natural Attenuation Remedy

Natural Attenuation is the reduction of COC concentrations in the environment through destructive biological processes (including, but not limited to; aerobic and anaerobic biodegradation, plant and animal uptake), non-destructive physical mechanisms (advection, dispersion, diffusion, dilution, volatilization, sorption/desorption), and chemical reactions (ion exchange, complexation, decomposition, and abiotic transformation). Biodegradation of chlorinated solvents (e g., TCE) most commonly occurs via reductive dechlorination, a process that requires both electron acceptors (chlorinated aliphatic hydrocarbons) and an adequate supply of electron donors (natural organic carbon, fuel hydrocarbons, landfill leachate) in order to proceed to complete destruction. It is, therefore, a passive remedial approach reliant upon natural transport and degradation processes.

Beyond the monitoring wells, covered under **Permit Condition VI.C.1.**, there is no capital equipment requiring regular maintenance or upkeep other than as described below. The operation system for the continued maintenance of the Natural Attenuation Remedy shall, as similarly stated in **Permit Condition VI.B.3.**, above, comply with the approved CAP **(Permit Attachment 2, Appendix I)**. The following design system shall be maintained on a regular basis, as specified.

a. Groundwater monitoring well(s). In compliance with 40 CFR 264.97(a)(3), a performance well is designated as an effective well when the Department recognizes that the well is necessary for the practical and effective detection of hazardous waste constituents that have migrated beyond Unit 5.

b. In accordance with **Permit Condition VI.C.2**, the Permittee shall conduct groundwater samplings semi-annually, or annually depending on the well designation and locations The monitoring results will be reported in an annual report defined under **Permit Condition VI.J.4.**

c. If the GPS continue to be exceeded for any contaminant listed in **Appendix J to Attachment 2** at any of the POC Wells or the Plume Monitoring Well, the Permittee shall be required to continue to monitor the well(s) according to **Permit Condition VI.C.**, and all decisions and outcomes shall be reported in accordance with **Permit Condition VI.J.4.**

d. Water Quality Sampling Events—The Permittee shall conduct groundwater sampling and analysis following installation of Plume Monitoring Well 5W12A required by issuance of the Permit in accordance with the sampling and analysis procedures in **Permit Section VI.F.** In addition to the water level in the well, the following field parameters shall be measured from each well during each sampling event: pH, temperature, oxidation-reduction potential (ORP), specific conductivity and dissolved oxygen. The samples must be collected from the upgradient well, the POC wells and the plume monitoring well, and must be analyzed for all CA specific VOCs [TCE, 1,1-Dichloroethene (1,1-DCE), cis-1,2-Dichloroethene (*c*DCE), trans-1,2-Dichloroethene (*t*DCE), and Vinyl Chloride (VC)] **(Appendix J to Attachment 2)**, on a semiannual basis. In addition, groundwater samples collected during the first year of monitoring will also be analyzed for MNA indicators (ethane, ethene, methane, sulfate/sulfide, nitrate/nitrite, and total organic carbon) for the purpose of establishing a baseline concentration of these analytes. The facility's analytical laboratory shall analyze these samples in accordance with the sampling and analytical methods listed in **Permit Attachment 2, Appendix J.** Alternate analytical methods may be approved by the Department in accordance with the procedure established in **Permit Condition VI.C.2.**

e. If at any point during the CA Program any monitoring well, established in or incorporated into the Natural Attenuation Remedy, can no longer yield groundwater samples representative of the area's groundwater quality based upon low water levels the Permittee must apply for a Permit modification to deepen or replace the affected monitoring well(s).

f. Sampling points and monitoring wells in the Natural Attenuation Remedy (both temporary and permanent in status) are subject to the inspection requirements for groundwater monitoring wells as set forth in **Permit Attachment 1, Appendix F (Inspection Requirements)**.

g. Piezometers or monitoring wells designated solely for the purpose of measuring water levels (and not for water quality sampling), that are part of the Natural Attenuation Remedy, may be installed (with or without prior Department approval) or abandoned (with abandonment subject to prior Department approval). Such piezometers or water-level monitoring wells normally will not require a formal modification of the Permit under 40 CFR 270 41 or 270 42—unless an accompanying change in the text or maps of the Permit is required. Also, piezometers and water-level monitoring wells remain subject to the inspection requirements for groundwater monitoring wells as set forth in **Permit Attachment 1, Appendix F**.

VI B.5. Changes in MNA Program

If changes are required, during implementation of the Natural Attenuation Program, to either correct deficiencies or enhance resolution/performance, the Permittee shall submit a written request to the Department to change the approved design.

a. The Department shall be notified by letter of any proposed changes to the Program, at least thirty (30) days prior to the proposed date of the change. The Department shall approve the proposed changes prior to implementation. The following information shall be included in the notification:

   i. Description of the change to be made;

   ii. Justification/reason for the change;

   iii. Revaluation plan for Program performance after the change in design,

   iv. Revised maps, drawings, and schematics, if appropriate

b. Design or Program changes which are required for the continued operation of the Remedy or are required for protection of human health and the environment shall be implemented as soon as practicable following approval. In the event of an emergency, the facility must act while assuming the risk of immediate action, subject to the subsequent administrative approval of the design or Program changes. Therefore, the Permittee is encouraged to contact the Department as soon as the consequences are known. The Department shall be notified in writing of the actions taken, within 14 calendar days of the emergency event. This notification will contain a schedule for the submission of the corresponding request for the design or systems change. The Department will decide on a case by case basis whether such a design or systems change requires a permit modification (see **Permit Section VI.M**).

VI.B.6. Evaluation of MNA Program

The effectiveness of the Natural Attenuation Program shall be evaluated on an annual basis (40 CFR 264.100(g)). This evaluation shall be submitted to the Department as part of the Annual Monitoring Report (see **Permit Condition VI.J.4**). The evaluation shall contain information to demonstrate that natural attenuation is still functioning as designed. Continued decrease in concentrations will be considered progress toward the remedial objectives. The following shall be contained in the evaluation, if available:

a. Present sampling and analysis results collected for the Natural Attenuation Program in field and lab analysis (see **Permit Conditions VI.B.3 and VI.B.4**);

b. Evaluation of the changes in concentration trends over the previous twelve months, natural attenuation rate, and resulting remedial progress;

c. Review of constituent concentrations and evaluation of natural attenuation processes/progress possibly occurring. For example, potential for biodegradation occurrence, detection of daughter products, and general water quality conditions.

d. Updated compliance timeframe predictions based on revised point attenuation rates determined from concentration vs. time graphs using the principles and methods presented in Section 7.4 of **Permit Attachment 2, Appendix I**.

e. Modifications to the Remedy proposed to correct deficiencies/malfunctions or, enhance performance and;

f. Provide other recommendations regarding the CA program, as appropriate.

VI.B.7 Contingency Measures and Termination of Natural Attenuation

a. If the dissolved phase constituent concentrations in groundwater outside the containment area do not naturally attenuate within a reasonable time frame contingency, measures shall be considered and implemented as presented in **Permit Attachment 2, Appendix I** (CAP) . For the purpose of this evaluation, a reasonable timeframe is defined as the MNA-based projected remedial timeframe determined in the CAP (i.e., 12 years from the date of the evaluation in 2007, or 2019). The projected remedial timeframe was calculated based on pore-volume flushing calculations. Updated compliance timeframe predictions will be based on annually revised point attenuation rates derived from concentration v. time graphs. If the estimated remedial timeframe determined on an annual basis exceeds the projected remedial timeframe of 12 years [2019] for three consecutive years, then contingency measures as defined in **Permit Attachment 2, Appendix I (CAP)** will be implemented.

The Department shall terminate this Natural Attenuation Program subject to the Director's approval of a Permit Modification for an alternative remediation system designed to achieve the same or equivalent objectives for remediation of chlorinated VOCs in compliance with 40 CFR 264.100, if the natural attenuation is ineffective For the purpose of this evaluation, MNA would be considered to be ineffective if for three consecutive years, the estimated remedial timeframe determined from annually revised point attenuation rates is greater than 19 years [2026], which is the time for one additional pore flush, or an additional 7 years.

VI.B.8 Alternative Groundwater Remediation Methods

If the Department or the Permittee determines that MNA is ineffective as a CA program, the Permittee shall evaluate and pursue other means of groundwater remediation. The Permittee shall submit to the Department an application for a Class II permit modification to modify the CAP within 180 days of the determination that MNA is no longer effective and that a modification to the CA process is required. The alternative groundwater remediation method would be enhanced in situ anaerobic bioremediation or a similar in-situ technology which can effectively meet the remediation objectives.

VI.B.9. Termination of CA/Remedy Program

The CA/Remedy (40 CFR 264.100) for Unit-5 must continue until TCE and its daughter products' concentrations in groundwater have decreased below the GPSs specified in **Appendix J to Attachment 2** (40 CFR 264.100(f)) in the downgradient POC Wells and through the plume(s) The termination of CA must be approved by the Director. The following steps are to be taken by the Permittee in establishing that the GPSs are no longer exceeded and before the Permittee can return to the Groundwater Compliance Monitoring Program (**Permit Module V**) under 40 CFR 264.99:

a. Interpretation and Evaluation of Data Supporting Completion of 40 CFR 264.100

Termination of the use of MNA as a remedy (change from 40 CFR 264.100 to 40 CFR 264.99) shall be based on the interpretation and evaluation of the data (concentrations, parameters and indicators). In addition, 40 CFR 264.100(e) specifically requires compliance with the GPSs throughout the groundwater plume. The data from all POC Monitoring Wells associated with the release of COC from Unit 5 must be at or below the GPSs to demonstrate that the 40 CFR 264.100 objectives have been met. The procedure for completing the data evaluation is as follows:

i. This groundwater CA and monitoring program was triggered by the exceedence of the GPS for TCE. The GPS for a contaminant was developed from the background value, MCL, ACL, or RBC. The GPSs for TCE and its daughter products are listed in the **Appendix J to Attachment 2**. The exceedence of the GPS for TCE was indicated by the simple comparison of the concentrations for TCE in downgradient wells to the GPS. If GPSs have not been exceeded as determined by simple comparisons of the concentrations for TCE and its daughter products in downgradient wells to the GPSs, the Permittee can petition the Director to terminate this groundwater CA andmonitoring program. The concentrations for TCE and its daughter products in downgradient wells will be obtained through **Permit Section VI.C** (groundwater monitoring).

ii. Pursuant **Permit Condition I.K.1** the compliance period during which the GPSs applies for Unit 5 will continue until October 28, 2020. If the compliance period has not ended at the time of the Director's approval to terminate the CA program, groundwater monitoring shall then be conducted in accordance with **Permit Module V – Compliance Monitoring Program**. The Permittee shall continue CA measures during the compliance period to the extent necessary to ensure that the GPS is not exceeded, pursuant to 40 CFR 264.100(f).

iii. Any future detections at concentrations greater than the CA specific GPSs that may result from rebound effects will result in a return to the requirements of **Permit Module VI** (and 40 CFR 264 100). Thus, to avoid a premature outcome, and the resulting requirement for an immediate return to 40 CFR 264.100 groundwater monitoring and corrective measures, the Permittee must demonstrate the long-term effectiveness of the remedy prior to initiating the steps in **Permit Condition VI.B.9.**

VI.B.10. Extension of Compliance Period and CA/Remedy Program

If CA is required beyond the compliance period, as calculated in **Permit Condition I.K.1**, it shall continue until the GPS for any constituent in any well has not been exceeded for three consecutive years, pursuant to 40 CFR 264.100(f).

VI.C. GROUNDWATER CA MONITORING PROGRAM

A groundwater monitoring program must be implemented to demonstrate the effectiveness of the CA program (§264.100(d)). This program is based upon a Modification of the preexisting Groundwater Compliance Monitoring Program (**Permit Module V**), modified as necessary to meet the performance standards for a CA Program (40 CFR 264.100).

VI.C 1 Groundwater Monitoring System

a. The groundwater beneath the closed Unit 5 shall be monitored with one (1) upgradient groundwater monitoring well and five (5) downgradient POC Wells located as specified on Figure 2 of **Permit Attachment 2, Appendix I**. Monitoring well 5W8B is the upgradient well and monitoring wells 5W7B, 5W5B, 5WC21, 5WC22, 5WC23 are the POC Wells for the unit.

b. In addition to the wells specified in **Permit Condition VI.C.1.a**, one Plume Monitoring Well, 5W12A will be installed and monitored to ensure that contaminants, TCE and its daughter products are not moving downgradient away from Unit 5 and the downgradient POC wells.

VI.C.2. Sampling and Analysis Schedule

All the wells from **Permit Condition VI.C.1** will be sampled in accordance with the methods and procedures specified in the Compliance Monitoring Sampling and Analysis Plan (**Permit Attachment 1, Appendix H, Sampling and Analysis Plan, "SAP"**) and the following schedule:

a. All the wells specified in **Permit Condition VI.C.1.** will be sampled at least semi-annually for the analysis of the current CA-targeted constituents listed in **Appendix J to Attachment 2**. In addition, groundwater samples collected during the first year of monitoring will also be analyzed for MNA indicators (ethane, ethene, methane, sulfate/sulfide, nitrate/nitrite, and total organic carbon) for the purpose of establishing a baseline concentration of these analytes. Analyses shall be obtained using the EPA SW-846 Methods specified in **Permit Attachment 2, Appendix J.** Alternate/updated SW-846 methods for the contaminants listed in Appendix J may be approved by the Department, provided the request is in writing and submitted 30 days prior to the sampling event and the proposed alternate/updated methods for the contaminants listed in Appendix J must achieve the same Practical Quantification Limit (PQL) (or lower) as the specified method Also, with pre-approval, alternate/updated methods for the indicators listed in **Appendix J to Attachment 2** may be used, provided the analyte is quantified using the alternate/updated method. Proposed alternate/updated methods for the indicators listed in **Appendix J to Attachment 2** may obtain a higher PQL than the method specified.

b. The POC Wells specified in **Permit Condition VI.C.1.a** shall be sampled on at least an annual basis for the analyses of all **CA Annual Monitoring Constituents (Appendix K)** using the EPA SW-846 Methods specified in **Permit Appendix K to Attachment 2.** The **CA Annual Monitoring Constituents (Appendix K)** are based on the Compliance Monitoring List (Appendix E/G), plus those constituents historically detected.

c. Static groundwater elevations and total depths as well as the hydrogeologic and physical parameters pH, temperature, specific conductivity, DO, and ORP will be measured at all wells specified in **Permit Condition VI.C.1** during each sampling event.

VI.D WELL LOCATION, INSTALLATION AND CONSTRUCTION

VI.D.1. The Permittee shall maintain the monitoring wells located at the facility as specified below:

a. All monitoring wells listed in **Permit Condition VI.C.1** shall be maintained in accordance with the maps and boring logs in **Permit Attachment 2, Appendix I.**

b. The wells shall be inspected at least semi-annually to ensure proper operation. Any required repairs shall be made by the Permittee as soon as reasonably possible.

VI.D.2. All groundwater monitoring wells required by this Permit in the CA Program shall be maintained in conformity with the following:

a. The groundwater monitoring system must yield samples in upgradient well(s) that represent the quality of the background groundwater unaffected by leakage from any regulated unit, and in downgradient wells must yield samples that represent the quality of groundwater passing the POC.

b. The number and location of monitoring wells must be sufficient to identify and define all potential release pathways from the unit to the uppermost aquifer, based on site specific hydrogeologic characterization.

VI.D.3. The Department must approve the addition or removal of all Permanent monitoring wells that are part of the sampling network, prior to inclusion into the network or abandonment.

a. All wells removed from the monitoring program shall be plugged and abandoned in accordance with **Permit Attachment 1, Appendix K**. Well decommissioning methods and abandonment certification shall be submitted to the Department within thirty (30) days from the date the wells are removed from the monitoring program.

b. All monitoring wells added to the existing groundwater monitoring system described in **Permit Section VI.C.** must be constructed in accordance with the requirements of EPA's *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* (TEGD) and subsequent guidance, and must be approved by the Department.

VI.E. GROUNDWATER PROTECTION STANDARD

VI.E.1. The Permittee shall monitor the groundwater to ensure that the regulated unit is in compliance with the GPSs under 40 CFR 264.92, or that the groundwater is being remediated to attain the GPS.

The GPSs are established based upon background values statistically calculated from background groundwater monitoring at the Unit 5 (**Permit Attachment 2, Appendix F**), USEPA Safe Drinking Water Act Maximum Contaminant Levels (MCL), Alternate Concentration Limits (ACL) established by the Department, or USEPA Region III Risk Based Concentrations (RBCs). The GPSs of the constituents annually to be analyzed are provided in **Appendix K, Attachment 2**

The GPSs for TCE and its daughter products, together with their detection limits, background values, and applicable MCL/ACL/RBCs, are listed in **Permit Attachment 2, Appendix J**.

VI.E.2. Background concentrations established at the time of permit issuance are listed in Appendix F to **Permit Attachment 2**. For any newly detected hazardous constituents, background values shall be established in accordance with 40 CFR 264.97(g) and as specified in **Appendix J** to **Permit Attachment 1** Background groundwater quality for a constituent or monitoring parameter shall be based on at least four (4) data points collected at background monitoring well(s) during a period not exceeding one (1) year.

VI E.3 The Permittee shall use the most up-to-date USEPA MCL, the Department ACL, or EPA Region III RBC as the GPS. If USEPA implements any changes to MCLs or RBCs, the

GPS defined by that MCL or RBC will be updated to reflect the most current value established by USEPA.

Any concentration limit based on a background value or ACL may be updated if new data become available. The Department will review the ACL changes annually and decide if the changes were significant enough to warrant the Department pursuing a permit amendment. The Department will notify the Permittee of any such change and will provide an amended **Appendix K** to **Permit Attachment 2** to the Permittee. Within ninety (90) days of receiving the amended **Appendix K** to **Permit Attachment 2** to the Permittee, the Permittee shall provide notice of the modification(s) to all persons on the facility mailing list.

VI.E.4. Pursuant **Permit Condition I.K.1** the compliance period during which the GPSs apply for Unit 5 will continue until October 28, 2020. If the Permittee is conducting CA at the end of the compliance period specified, then the compliance period shall be extended automatically until the Permittee demonstrates that the COC concentrations are less than the GPS in all downgradient wells for three (3) consecutive years as defined under 40 CFR 64.100 (f)

VI.F. SAMPLING AND ANALYSIS PROCEDURES

Pursuant to 40 CFR 264.97(e), the groundwater monitoring program must include sampling and analytical methods that are appropriate for groundwater sampling and that accurately measure hazardous constituents in groundwater samples. The groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of groundwater quality below the waste management area. To make changes to the groundwater sampling and analysis procedures specified in this section, the Permittee will submit for Director approval an application for a Class 1 permit modification in accordance with 40 CFR 270.42, Appendix I. The Permittee shall use the following techniques and procedures when obtaining and analyzing samples from the groundwater monitoring wells described in **Permit Condition VI.C.1.**

VI.F.1. Samples shall be collected using the techniques and procedures described in **Permit Attachment 1, Appendix H (SAP)** and at the frequency specified in **Permit Condition VI.C.2.**

VI F.2 Samples shall be preserved, packed, and shipped or hand-delivered off-site for analysis in accordance with the procedures specified in **Permit Attachment 1, Appendix H.4.**

VI.F.3. Samples shall be tracked and controlled using the chain-of-custody procedures specified in **Permit Attachment 1, Appendix H.3.**

VI.G. ELEVATION OF THE GROUNDWATER SURFACE

The Permittee shall determine the groundwater potentiometric surface elevation (and depth to bottom of wells not equipped with dedicated pumps) at each monitoring well specified in **Permit Sections VI.C** to 0.01 foot each time groundwater is sampled in accordance with procedures contained in **Permit Attachment 1, Appendix H**.

(1) Static groundwater elevations (and total depths for wells that do not contain dedicated pumps) will be measured at all wells specified in **Permit Section VI.C.** during each sampling event.

(2) If, during the course of purging and sampling the data from field parameters and visual observation indicate that silt has accumulated in any well, the pump (if dedicated) shall be pulled and the total well depth and sediment thickness shall be calculated. Corrective measures shall be taken prior to the next sampling event, if necessary.

VI.H. MONITORING PROGRAM AND DATA EVALUATION

The Permittee shall determine groundwater quality as follows:

VI.H.1. The Permittee will determine the groundwater flow rate and direction in the uppermost aquifer at least semiannually in accordance with **Permit Condition VI.C.2.** Constituent migration rate will be calculated, if necessary to demonstrate the effectiveness of the CA and the CA monitoring program. Potentiometric maps showing groundwater elevation contours and flow direction during each sampling event shall be prepared at least annually.

VI.H.2 The Permittee shall present the analytical data obtained from the contract analytical laboratory as follows:

a. The Permittee shall determine semiannually the concentrations/values of hazardous constituents listed in **Appendix J to Attachment 2** and annually the concentrations/values of hazardous constituents listed in **Appendix K** to **Permit Attachment 2** in accordance with **Permit Sections VI.C and VI.F.** The Permittee shall independently complete the validation of the data within two (2) weeks of the data being available from the laboratory performing the analyses.

   Estimated values between the MDL and QL will be validated and qualified with the "**J**" flag to indicate the result that a constituent is present and detected at or above the MDL, but below the QL. The "**U**" flag will be used to indicate that the constituent is not detected at or above the MDL.

b. The Permittee will present the groundwater quality at each monitoring well in a form appropriate for the determination of statistically significant increases, in accordance with 40 CFR 264.97(h).

c. The Permittee's report will include at least the following information: the constituents analyzed and concentrations with qualifiers, the background values, the GPSs, the SW-846 test methods, method detection limits (MDL), quantitation limits (QL), the internal laboratory quality assurance/quality control (QA/QC), matrix spike duplicates, percent recovery, duplicate analyses, dilution factors, any lab specific detection limit and/or quantitation limit, the results of any screening analyses, and any other information needed to evaluate accuracy, precision, representativeness, comparability, and completeness of the groundwater quality data.

VI.H.3. At least semiannually, the Permittee shall determine if constituents contained in **Appendix J to Attachment 2** are present at concentrations greater than the GPS (**Permit Attachment 2, Appendix J**) in any POC well in accordance with 40 CFR 264.99(h) and **Permit Section VI.I** to evaluate the effectiveness of natural attenuation in this groundwater CA program. The Permittee shall use suitable methods to evaluate effectiveness and progress of the groundwater CA and monitoring program, for example, long-term time concentration plots of constituents of concern exceeding GPS for each well and graphic representation of groundwater impact plumes for constituents exceeding GPS, when appropriate.

VI.H.4 At least semiannually, the Permittee shall review the data and monitoring results to evaluate the concentration trends, the fate and transport for the constituents/indicators listed in **Appendix J to Attachment 2** and to evaluate the process and progress of natural attenuation.

VI.I. COMPARISON TO GROUNDWATER PROTECTION STANDARDS

At least annually, the Permittee shall analyze samples from the POC Wells specified in **Permit Condition VI.C.1.** for all constituents contained in **Appendix K** to **Permit Attachment 2 (Annual Monitoring List for CAP)** to determine whether additional hazardous constituents, which are not the targets for the current CA (e.g. TCE and its daughter products), are present in the uppermost aquifer at levels exceeding the established GPSs specified in **Appendix K** to **Permit Attachment 2.** The following procedures shall be used:

VI.I.1 Methods of Comparison

a. If a single independent sample was collected at the monitoring well, the Permittee shall conduct an empirical comparison in accordance with **Permit Attachment 1, Appendix J (Statistical Procedure).**

b. If multiple independent samples were collected from each monitoring well, a statistical comparison to the GPS which is approved by the Department shall be conducted. Guidelines for method selection are contained in **Permit Attachment 1, Appendix J.**

VI.I.2 The Permittee shall submit written notification to the Department within 7 days of the Permittee's identification of the exceedence, for constituents that have not previously exceeded the GPS (40 CFR 264.99(h)). The notification shall include the concentration of each constituent exceeding the GPS and shall identify the monitoring well(s) where the GPS was exceeded.

The Permittee may resample within 60 days from receipt of the laboratory data and repeat the analysis for the constituent exceeding the GPS. If the second analysis confirms the presence of constituents at levels exceeding an established GPS or if the Permittee does not resample, the Permittee shall then report the constituents to the Director in writing within seven (7) days and the Permittee must propose CA for that contaminant as required by **Permit Section VI.L.**

VI I.3. In accordance with 40 CFR 264 99(i), the Permittee may make a demonstration that the GPS was exceeded due to sources other than the regulated unit, was due to an error in sampling, analysis or statistical evaluation, or was due to natural variability in the groundwater. The demonstration shall be conducted as follows:

a. Within 7 days of the identification of the exceedence (see **Permit Condition VI.I.2.** above) the Permittee shall notify the Department that the Permittee will attempt an alternate source demonstration, and in 90 days from the identification of the exceedence, the Permittee shall submit a report demonstrating this alternate contamination source to the Department for its approval.

b. Any resampling, if a part of the demonstration, must be conducted within sixty (60) days of receipt of original laboratory data.

c. Throughout the alternate source demonstration the Permittee must continue to monitor in accordance with the CA Monitoring Program established under 40 CFR 264.100 and to fulfill all its Permit obligations

d. Concurrent with the submission of an alternate source demonstration, the Permittee is obligated to provide the Department with a plan for the facility's proposed CA (see procedure at 40 CFR 264(h) and **Permit Section VI.L.**) chosen from all the technologically feasible CA alternatives investigated by the facility and documented in the plan.

VI.I.4 The Permittee shall specify all GPS exceedences in the Annual Monitoring Report defined under **Permit Condition VI.J.4**, whether it is the first exceedence of that constituent or a repeated exceedence.

VI.J. <u>REPORTING AND RECORD KEEPING</u>

The Permittee shall enter all monitoring, testing, and analytical data obtained pursuant to **Permit Section VI.J.** in the operating record. The data packages must include all computations, calculated means, variances, t-statistic values, and t-test results or the calculations and results of statistical tests that the Department has determined to be equivalent as appropriate. Information concerning the maintenance of the monitoring network wells shall also be entered into the Operating Record. Reports containing the information shall be submitted in accordance with **Permit Condition I.E.3.**

VI.J.1 Groundwater Elevation/Potentiometric Contour Maps

As a component of the annual report containing all information gathered under the CA Monitoring Program, the Permittee will submit groundwater elevations and potentiometric contour maps depicting groundwater flow paths and supporting groundwater elevation data for each sampling event to determine that the existing monitoring network continues to be adequate.

VI.J.2. Maintenance and Operation of the Remedial System

a. If the evaluation determines that the existing monitoring well network no longer satisfies the requirements of 40 CFR 264.97(a), the Permittee will submit an application for a permit modification to make appropriate changes to bring the monitoring system into compliance. Actions taken for maintenance and repair of the monitoring system shall be recorded in the Facility Operating Record and included in the Annual Monitoring Report.

b The Department shall be notified in writing when the monitoring portion of the natural attenuation remedy is taken off-line or is being repaired, equipment replaced, or upgraded and the anticipated or actual duration is greater than 30 days. Periods less than 30 days shall be noted in the Operating Record and included in the Annual Monitoring Report. Note that such notification is required only for action or inaction other than the regular routine operation of the remedy set forth in this Permit Module or in the CAP in **Permit Attachment 2, Appendix I**.

VI.J.3 Annual Appendix IX of 40 CFR 264 Data (Appendix K)

The Permittee shall report the data from the specified wells (**Permit Conditions VI.C.1.a and VI.C.1.b**) for all constituents contained in (Reduced) Annual Appendix IX of 40 CFR 264 as specified in **Appendix K to Attachment 2** in the appropriate Annual Monitoring Report.

VI.J.4. Contents of an Annual Report

The annual report, submitted on March 1, of each year shall for monitoring performed in the previous calendar year meet all the requirements of an Annual Groundwater Monitoring Report and shall include an evaluation of the CA program as required by **Permit Section VI.B.6.** The following items shall be included, at a minimum:

a. The operator/owner certification signed and dated by an authorized representative of the Facility;

b. Copies of current potentiometric surface maps and static groundwater level elevations for each event during the period.

c. Evaluation of groundwater flow directions and gradients and the calculated or measured rate of migration of hazardous constituents in the groundwater for the period.

d. Data package with the certification from the contract analytical laboratory.

e. Analytical Result/Data Summary containing the following columns: well name, sampling/analytical dates, constituents analyzed, analytical methods, MDL, PQL, resulting data (concentrations) with qualifiers, and GPSs.

f Long-term time concentration plots of constituents of concern exceeding GPS for each well. When appropriate, graphic representation of groundwater impact plumes for constituents exceeding GPS;

g. An evaluation of the effectiveness of the remedial measures per 40 CFR 264.100(g) and meeting the requirements of Permit Condition VI.B.6.. The evaluation shall contain adequate information to demonstrate that the remedial measures are addressing the groundwater contamination at and downgradient of Unit 5 and progress is being made toward the remediation objectives. The evaluation shall also contain updated compliance timeframe predictions using the principles and methods presented in the Section 7.4 of **Permit Attachment 2, Appendix I.**

h. Copies of all notifications and reports required by this Permit, and 9 VAC 20-60 et seq., for the period, and

i. Copies of all statistical evaluations of the groundwater data for the period.

VI.K. ASSURANCE OF COMPLIANCE

The Permittee shall demonstrate through the implementation of the groundwater monitoring and CA measuresin this Permit, that compliance with the GPS of 40 CFR 264.92 will be achieved.

VI.L. SPECIAL REQUIREMENT IF ADDITIONAL CA AT THE REGULATED UNIT IS REQUIRED

In accordance with the requirements of this permit and the Virginia Hazardous Waste Management Regulations (VHWMR), if the Department or the Permittee has determined that additional CA at or downgradient of the POC of the Waste Management Area is required in pursuant to **Permit Condition VI.I.2., Permit Section VI.L** applies. The Permittee is responsible for compliance with **Permit Section VI.L.** immediately upon notification by the Department that additional CA is required at or downgradient of the POC (40 CFR 264.99(h)(1)).

VI.L.1. The Permittee must notify the Department in writing within seven (7) days from the date that the analytical data is available from the laboratory that the GPS has been exceeded for any constituent listed in **Permit Attachment 2, Appendix K** at any well in which the GPS has not been exceeded previously and the Department has not been previously notified, in accordance with **Permit Section VI.J.**

VI.L 2. Within 180 days from the date when the new GPS exceedence was first identified by the Permittee, the Permittee must submit a Plan to the Department for the proposed CA to address the exceedence (40 CFR 264.99(h)(2)). The Permittee is to choose this proposed CA(s) from all the technologically feasible CA alternatives evaluated, and documented in the Plan. The Plan shall address and conform to requirements set forth at 40 CFR 264.99(h)(2) and shall constitute the Permittee's application for a permit modification to initiate the additional CA .

VI L.3. To demonstrate an alternative contamination source for the GPS exceedence, other than the regulated unit, the Permittee should follow the procedures set forth at 40 CFR 264.99(i) and in **Permit Condition VI.I.3.**, above.

VI.M. REQUESTS FOR PERMIT MODIFICATION

VI M.1 If the Permittee or the Department determines in writing that the Groundwater Corrective Action ongoing at the facility is not adequate, the Permittee shall submit to the Department an application for a permit modification proposing a CA Program meeting the requirements of 40 CFR 264.100 within 180 days of receipt of the Department's determination that CA is required to be modified. Specifically, permit modification during implementation of corrective measures at the POC for the regulated Unit 5 shall be required if the Permittee or the Department has made any of the following determination:

a. Significant changes must be made to the remedial measures contained in this Permit to protect human health and the environment (**Permit Condition VI.B.5**);

b. The corrective measure contained in this permit, e g., MNA, is no longer effective in remediating groundwater at the POC and the GPSs are still being exceeded. A modification incorporating a different alternate remedial measure is required (**Permit Condition VI.B.8**) to meet the requirements of 40 CFR 264.100; or

c. A GPS has been exceeded for a constituent for which the current corrective measure contained in the Permit will not achieve the remediation goals (see **Permit Condition VI.I.2** above).

VI.M.2. If the Permittee or the Department determines the CA Monitoring Program no longer satisfies the requirements of 40 CFR 264.99 and 264.100, then within 90 days, the Permittee must submit an application for a permit modification to make any major changes.

VI.N. CA SCHEDULE

Upon addition of **Permit Module VI** and associated attachments to this permit, the following actions will be taken:

VI.N.1. Within 120 days from the effective date of the permit modification, monitoring well 5W12A specified under **Permit Conditions VI.B.1 and VI.C.1.b** will be installed. In accordance with **Permit Conditions VI.D.3 and VI.J.2.**, details of the wells installation shall be provided in the subsequent Annual Monitoring Report.

VI.N.2 Upon completion of the installation of well 5W12A, the first CA Monitoring event, defined under **Permit Section VI.C.**, will be conducted in place of the compliance monitoring event scheduled for second quarter 2010. Thereafter, the CA Monitoring Program will replace the Compliance Monitoring Program until such time as **Permit Condition VI.B.9** and/or **Permit Condition VI.B.10**, has been met. Additionally, meeting the requirements of **Permit Condition I.J.1 (Post-Closure Period Reduction)** will allow the cessation of the MNA remedy.

MODULE VII

SITE-WIDE CORRECTIVE ACTION

VII.A. CORRECTIVE ACTION FOR CONTINUING RELEASES; PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The requirements of 40 CFR 264.101 are addressed by the Corrective Action Permit issued to the Permittees by EPA Region III which became effective on October 31, 2000 and shall remain in effect until October 31, 2010. The terms and conditions of the Corrective Action Permit issued by EPA are adequate to fulfill the Department's requirements for facility-wide corrective action as specified in 40 CFR 264.101 as made applicable by 9 VAC 20-60-264.

A list of SWMUs addressed by the EPA Site Wide Corrective Action Permit and a map depicting the locations of the SWMUs are contained within the Part A Permit Application.

VII.B REPORTS, NOTIFICATIONS, AND SUBMISSIONS TO THE DEPARTMENT

Copies of all notifications, cover letters for reports, and submissions made in compliance with the EPA permit shall be provided to the Director of Waste Permits in accordance with the EPA permit Part I.B.8.

MODULE VIII.

SCHEDULE OF COMPLIANCE

(RESERVED)

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 1

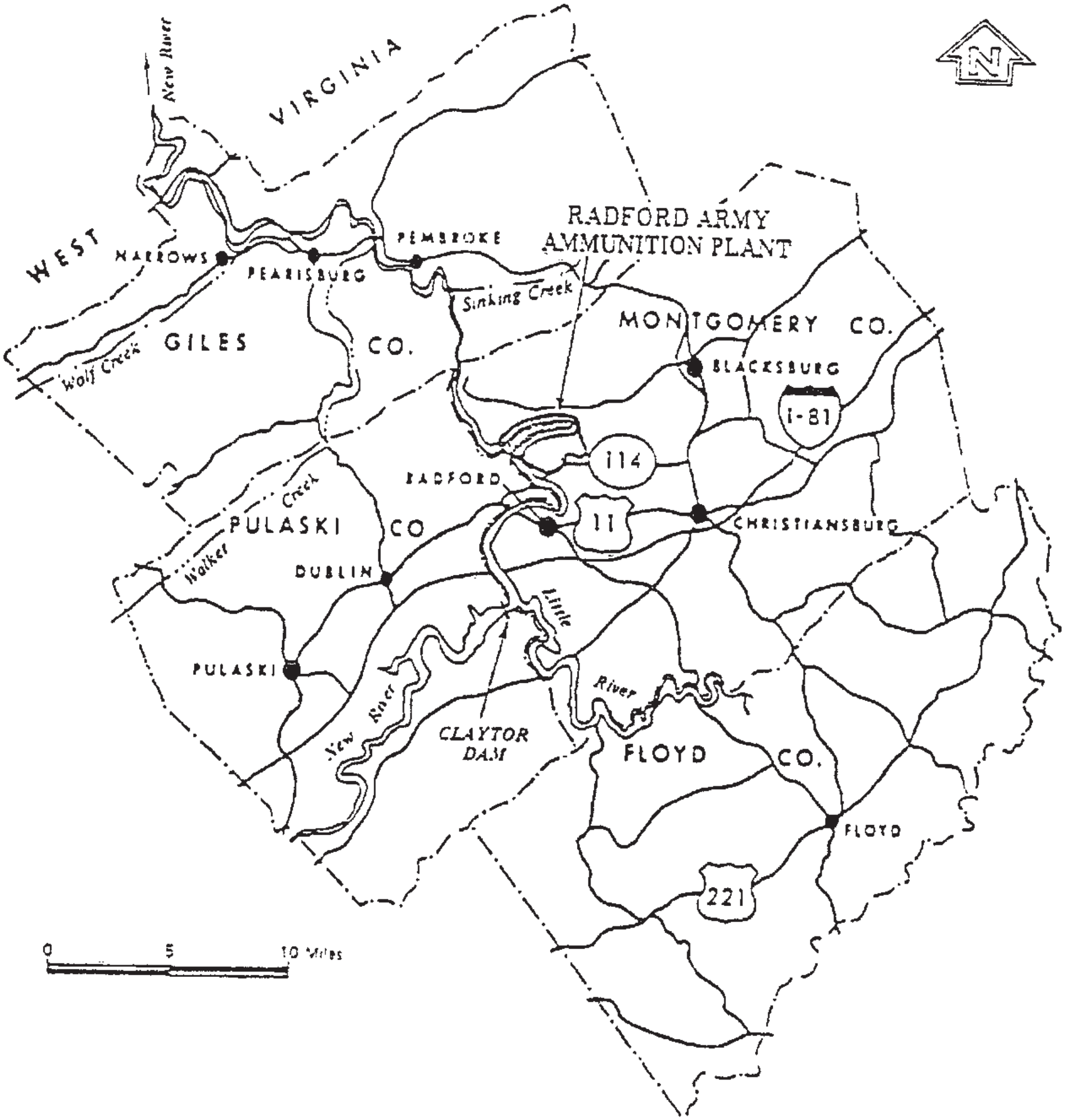
APPENDIX A

FACILITY MAPS

ATTACHMENT 1

APPENDIX A.1

FACILITY LOCATION MAP



Location of the Radford Army Ammunition Plant Hazardous Waste Management Facility

ATTACHMENT 1

APPENDIX A.2

GEOLOGICAL/TERRACE MAP

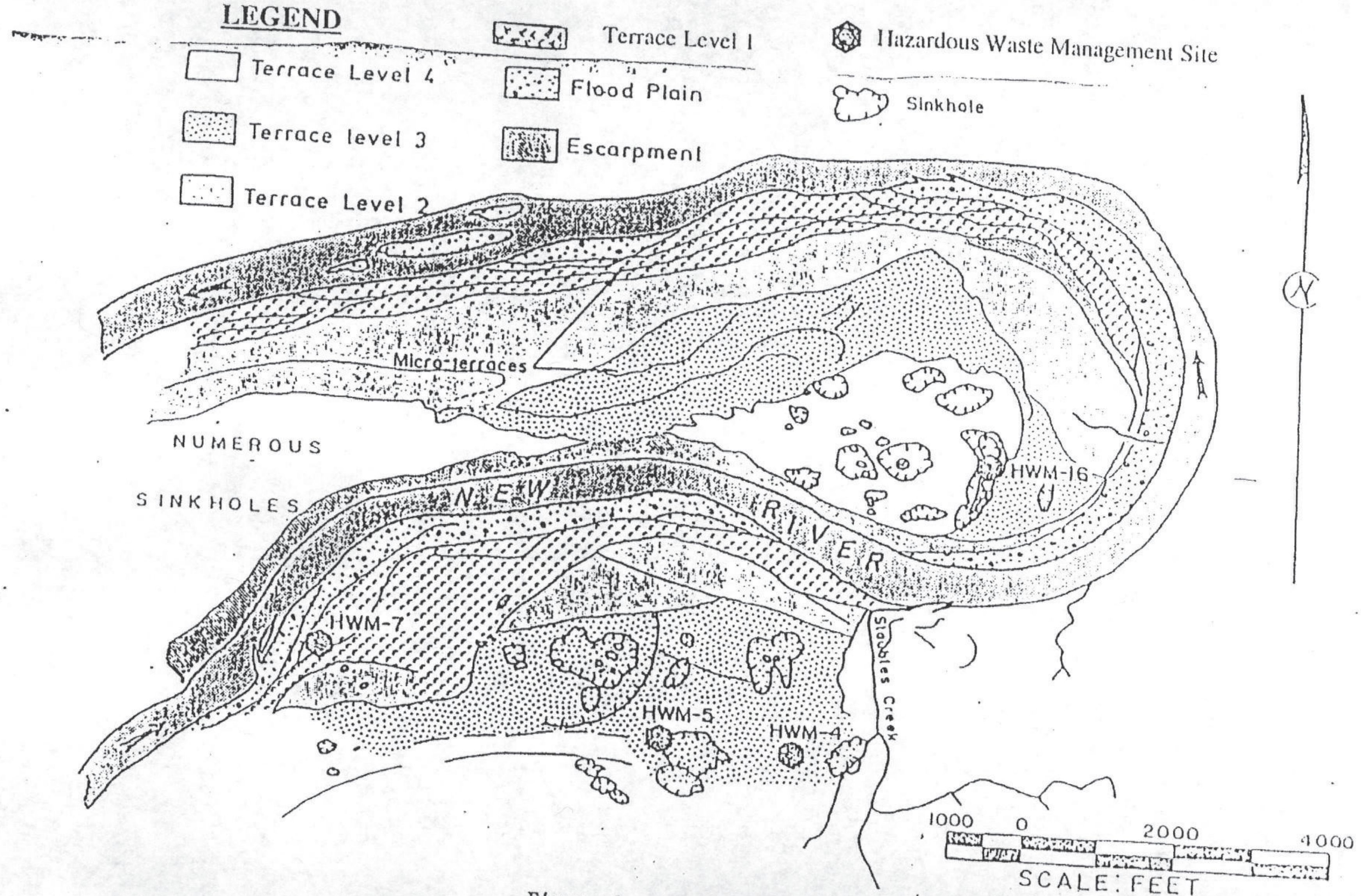


Figure 3. Terrace map.

ATTACHMENT 1

APPENDIX A.3

FRACTURE TRACE MAP

Fracture Trace Map
Radford Army Ammunition Plant
Radford, Virginia

LEGEND

- ——— PROPERTY LINE
- ······ FRACTURE TRACE
- ⁞⁞⁞⁞ BEDDING PLANE LEDGE
- ● SINKHOLE
- ⬅ FLOW ROUTE AS DETERMINED BY DYE TRACE AND SUGGESTED BY FRACTURE TRACES AND REGIONAL POTENTIOMETRIC CONTOURS
- • DYE MONITORING POINT
- ∾ SPRING LOCATION
- ⊙ DYE INJECTION LOCATION

NOTE: SMP STREAM MONITORING POINT
SPG SPRING MONITORING POINT
WMP WELL MONITORING POINT
RMP RIVER MONITORING POINT

SOURCE: USEPA, 1992
USGS, RADFORD (NORTH)
VIRGINIA QUADRANGLE

SCALE 1:24,000

USGS 7.5' Topographic Series: Radford North; Copyright: © 2009 National Geographic Society, licensed via ESRI ArcGIS Online
Site Boundary from Montgomery County and Pulaski County GIS Departments
Copyright:© 2013 National Geographic Society, i-cubed

Site Location Map
Hazardous Waste Management Units 5 & 16
Radford Army Ammunition Plant - Montgomery and Pulaski Counties, Virginia

SCALE 1" = 2000'

PLAN NO. B03204-308

Draper Aden Associates
Engineering ◆ Surveying ◆ Environmental Services

2206 South Main Street
Blacksburg, VA 24060
540-552-0444 Fax: 540-552-0291

Richmond, VA
Charlottesville, VA
Hampton Roads, VA

DESIGNED RGM
DRAWN SMF
CHECKED MDL
DATE 10-02-13

FIGURE

ATTACHMENT 1

APPENDIX B

CONTINGENCY PLAN

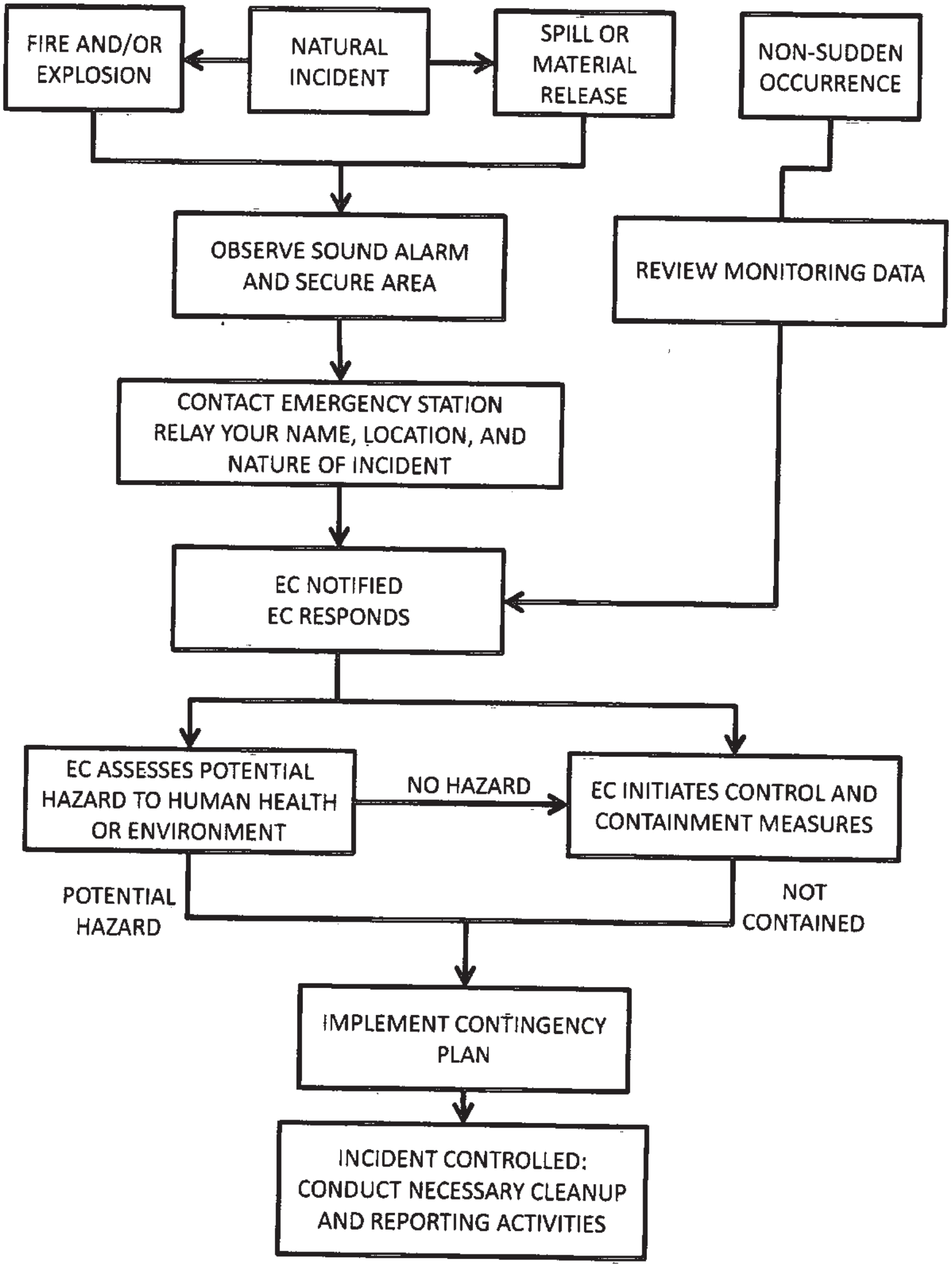
Please note: In addition to the Contingency Plan for the Post-closure Care Permit for HWMUs 5 and 16, the Permittees also maintain Contingency Plans for the Subpart O Incinerator and for the Subpart X Open Burning Ground.

ATTACHMENT 1

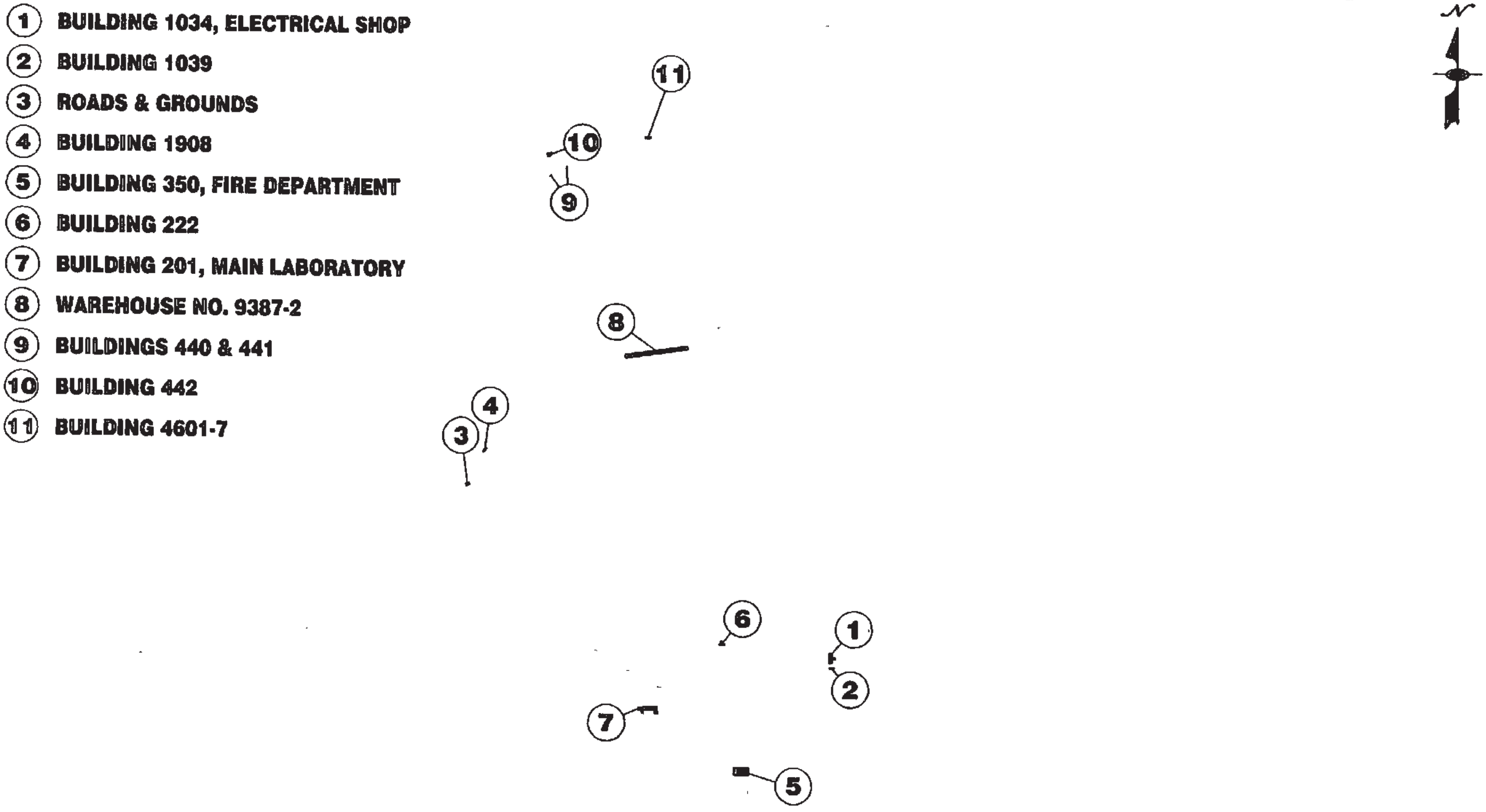
Appendix B.1

Tables and Figures

FIGURE 1
CONTINGENCY PLAN IMPLEMENTATION LOGIC DIAGRAM



EC: Emergency Coordinator



NOTE
THE EQUIPMENT AVAILABLE AT EACH LOCATION IS LISTED IN TABLE 5

FIGURE 2
EMERGENCY EQUIPMENT LOCATIONS
NOT TO SCALE

TABLE 1

EMERGENCY PROCEDURES

RFAAP Disaster Control Plan (RFAAP-DCP) provides plans for:

1) Hazardous material emergency response
2) Pollution incident reporting
3) Chemical, nuclear or radiological accident/incident control
4) Emergency situation reporting
5) Bomb threats
6) Crisis emergency/relocation plan
7) Flood watch

Spill Prevention, Control, and Countermeasures Plan (SPCC) and Management Manual (MM) 3-1.1 Environmental, Quality, and Safety Incident Reporting for spills other than hazardous waste described in the Part B permit.

SPCC provides area specific plans including:

1) Description of physical layout and processes performed
2) Inventory of tanks, drums, and containment structures
3) Identification of potential spill scenarios and volumes
4) Flow path(s) for spills
5) Any area specific response measures, which may be required
6) Listing of any treatment facilities servicing the area

MM 3-1.1 Environmental, Quality, and Safety Incident Reporting is concerned with the recognition, reporting, containment and notification procedures in the event of leaks and spills

Fire Prevention and Protection Program describes:

1) Employee and Fire Department personnel responsibilities for fire prevention and protection
2) Inspection and use of equipment and supplies
3) Fire Department training program
4) Building evacuation procedures
5) Annual Fire Prevention and Protection Program
6) Prefire plan and other fire plans

TABLE 1
EMERGENCY PROCEDURES (continued)

Plant Protection Plan (PPP) outlines plan protection/security procedures including the security of explosives, intrusion detection systems, protective communications and key and lock control.

Plant Operating Procedures:

MOP 4-27-2:	Maintenance Responsibilities During Disaster and Major Emergencies
4-27-008	Electrical Distribution System Switching, Shutdowns, & Safe Clearannces
MOP 4-27-111.	Protective clothing and Equipment
MMP 02-1-09	Flood Watch :
GOP 4-A-012:	Negative Pressure Respiratory Protective Equipment
GOP 4-A-012A:	Positive Pressure Respiratory Protective Equipment
GOP 4-117:	Clean-up Procedures for Liquid Explosive Spills
GOP 4-A-049:	Operation of Two-Way Radio Mobile Units and Fixed Base Central
GOP 4-3-2:	Area General Waste Propellant Incinerator Facility

TABLE 2
NOTIFICATION ACTION SUMMARY

ON-SITE Emergency Contacts
Contacts to be made in accordance with Management Manual 3-1.1

Emergency Coordinator	Office Phone	Home Phone	Home Address
Plant Security	Ext 7323	NA	NA
Plant Fire	Ext 16	NA	NA
Environmental Emergency Contact-Primary Emergency Coordinator	Security will Contact	NA	NA
Safety On-Call Representative	Security will Contact	NA	NA
Environmental Manager – Jay Stewart	Cell 540-200-9536	Use cell phone	
Environmental Contact – Matt Alberts	Ext 8722 Cell 540-383-5463	Use cell phone	
Safety Manager – Joseph Betteken	Ext 8781 Cell 540-239-6562	Use cell phone	

ON-SITE Notifications
The following managers should be notified in the event of major emergencies:

Title	Name	Contact Number
Director of Safety, Mission Assurance, Environmental, and Security	Anthony Miano	Cell (540) 239-6378
Director of Operations	MD Guynn	Cell 540-230-5408

OFF-SITE Notifications
To be made by the Environmental Manager or a designated representative as needed:

1. Army Administrative Contracting Officer – Operations Division Chief Cell (540) 239-4475
2. Virginia Department of Environmental Quality Blue Ridge Regional Office 540-562-6700
3. National Response Center (for releases above an RQ) 1-800-424-8802
4. Virginia Department of Emergency Management 1-800-468-8892
5. U.S. Environmental Protection Agency Region 3 (215) 814-5000
6. Montgomery County Local Emergency Planning Committee (LEPC) (540) 382-2951
7. Pulaski County Local Emergency Planning Committee (LEPC) (540) 980-7705
8. Emergency Service Resources (Fire, Ambulance, Police) 911
9. Chemtrec 1-800-424-9300

TABLE 3

EVALUATION CRITERIA FOR IMPLEMENTATION OF CONTINGENCY PLAN

In accordance with the Contingency Plan Implementation Logic Diagram (Figure 1), the following are examples of when the contingency plan would need to be implemented

- For a fire and/or explosion If the fire causes a release of toxic fumes that go off plant or impacts personnel
- If the fire could spread (is not contained), thereby possibly igniting materials in other locations on-site or off-site, or could cause heat induced leaks or explosions
- If the use of fire suppressant could result in contaminated runoff that cannot be contained
- If an explosion has or could.
  - Result in damage from flying fragments or shock waves
  - Ignite other hazardous waste at the facility
  - Release toxic materials

  that could cause harm to human health or the environment or cannot be contained
- Or if a fire or explosion endangers human health or the environment for any other reason.

For spills or material releases

- If a spill could release toxic or explosive liquids, thus causing a fire or explosion hazard
- If a spill could result in off-site or on-site soil contamination and/or ground or surface water contamination
- If a spill constitutes a release of a "reportable quantity" of a hazardous substance under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- Or if a spill endangers human health or the environment for any other reason

TABLE 4

SPILL RESPONSE MEASURES

The spill response program will be coordinated by the Emergency Coordinator or designated representative Guidelines are provided concerning safety, containment, evaluation, notification, treatment and monitoring as related to each spill incident.

1 Safety

   a. Evaluate the hazard of the spilled chemical to personnel which may be involved in containment, clean up, treatment and monitoring operations

   b Assure proper clothing and protective equipment is available and used by personnel involved in the spill response

2 Containment

   a Establish the expected flow path of the spilled material

   b Locate the nearest proposed damming site.

   c Erect a dam — notify Roads and Grounds regarding construction of dam.

3. Evaluation of Spill Extent

   a Obtain pH readings at site if chemical spilled was an acid or base

   b Confirm stoppage of leak at source

4. Initial Notification

   a. Delegated to the Emergency Coordinator

   b Notify appropriate agencies (see Notification Action Summary)

5 Treatment

   a. Straw or other absorbers will be supplied to entrap hazardous wastes which are spilled Sites/locations within the plant containing straw and other entrapment materials are controlled by Roads and Grounds

TABLE 4
SPILL RESPONSE MEASURES (cont)

6 Monitor Program

Upon receiving notification of an accidental loss to the industrial sewer or surface streams, personnel will obtain grab samples at specified locations and time intervals as determined by the Emergency Coordinator.

a In-Plant Sites

i Suggested sampling sites will be determined based on the location of the spill

ii Samples will be collected at internal locations designated

b New River Site

i Sampling at the New River site will be performed on a staggered basis since the river flow approximates one mile per hour. Sampling will be performed by the operator at Building 4330

7 Final Treatment

a Determine disposition of impounded material depending on type and quantity of spill. Ensure EPA and DEQ concur with disposition

b Provide monitoring for duration of disposition

8. Explosion fragments and materials as well as contaminated soils will be decontaminated in either the decontamination oven or the decontamination incinerator on-site at Radford AAP provided they are not TCLP toxic or reactive The decontaminated materials will then be disposed of in a permitted landfill or as decontaminated scrap

TABLE 5

EMERGENCY EQUIPMENT LOCATIONS AT RFAAP

Location # on Figure 2	Location Description	Equipment Available
1	Bldg. 1034, Electric Shop	Rubber gloves and respirators
2	Bldg 1039	Self-contained breathing apparatus (2)
3	Roads and Grounds Bldg	Respirators, goggles, air fed respirators, safety belts, shoe cleats, air compressors (250 and 700 CFM ratings), portable pumps (50, 100, and 700 GPM capacities), cranes, bulldozers, movers, graders, tow tractors, portable electric generators
4	Bldg. 1908	Absorbent materials and booms
5	Bldg. 350, Fire Department	• Ladder truck, engine, utility truck, brush truck, ATV's, command vehicle, and ambulance
6	Bldg 222	HAZMAT trailer with response gear, special operations trailer, and 2boats
7	Bldg 201, Main Laboratory	Nitroglycerin remover
8	Warehouse No 9387-2	Soda ash
9	Bldgs 440 and 441 (incinerators	Ansul Sentry Fire Extingushers (Model SY-0614 Dry Chemical).
10	Bldg 442	Telephone access
11.	Bldg 4601-7	Telephone access and spill cleanup equipment

ATTACHMENT 1

Appendix B.2

Examples of Agreements

Memorandum of Understanding with Federal Bureau of Investigations (FBI)

U.S. Department of Justice

Federal Bureau of Investigation

In Reply, Please Refer to
File No. 66F-RH-47299

1970 East Parham Road
Richmond, Virginia 23228
June 17, 2003

Wayne H. Kirk
Industrial Security Specialist
Radford Army Ammunition Plant
SJMRF-RM SE, P.O. Box 2
Radford, Virginia 24143-0002

RE: Memorandum of Understanding (MOU)

Dear Wayne:

Enclosed please find one original executed MOU. I have retained the second executed copy for our records. Thank you for your assistance in this matter.

Sincerely,

Larry

Lawrence J. Barry
Chief Division Counsel

Enclosure

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P.O. BOX 2
RADFORD, VIRGINIA 24143-0002

SJMRF-RM-SE

9 June 2003

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE FEDERAL BUREAU OF INVESTIGATION, RICHMOND VIRGINIA
AND
RADFORD ARMY AMMUNITION PLANT, RADFORD VIRGINIA

SUBJECT Federal Bureau of Investigation Assumption of the Special Reaction Team (SRT) Mission on Radford Army Ammunition Plant

1 References

a Army Regulation 525-13, Antiterrorism, dated 4 January 2002

b Army Regulation 190-58, Personal Security, dated 22 March 1989

2 Purpose. The purpose of this Memorandum of Understanding (MOU) is to enter into an agreement with the Federal Bureau of Investigation (FBI), Richmond Division, Richmond, Virginia, whereby the FBI assumes primary responsibility for responding to major disruptions or special threat situations arising at Radford Army Ammunition Plant (RFAAP)

3 Problem The Army requires the RFAAP Commander to maintain the capability to respond to major disruptions or special threat situations with specialized team of law enforcement personnel within two hours or less from the time of notification RFAAP does not have the resources to maintain or staff a special response team The Army therefore, allows the Commander to enter into an agreement with the FBI to provide this response capability

4 Scope This agreement is for the transfer of various aspects of an Army SRT mission, to include barricaded subjects, hostage situation, sniper incidents, combating terrorism operations, high threat raids and warrant apprehension of dangerous individuals on RFAAP This agreement compensates for the absence of military police SRT resources, and identifies initial response, threat assessment, and crisis management responsibilities

5 Agreement Whereas RFAAP has asked the FBI to assume the primary responsibility to major disruptions or special threat situations at RFAAP, NOW THEREFORE, in consideration of said request, it is hereby agreed by and between the FBI and RFAAP as follows.

a The FBI is the primary response force to major disruptions or special threat situations at RFAAP The FBI is the primary operational agency for the management of terrorist incidents occurring within the United States So recognized. the signatories to this agreement acknowledge and agree that the FBI will be notified as soon as possible of all terrorist incidents, major disruptions, and special threat situations that occur or affect RFAAP

b RFAAP continues to be responsible for all remaining security activities within their capabilities. and will, for as long as practicable, provide first response assistance to the FBI when conducting counter threat services on RFAAP This support service shall include

(1) The dispatch of security personnel and equipment for initial response to any special threat situation.

(2) Limited intelligence and logistical support

(3) Site briefing and installation vulnerability assessments as necessary

(4) Operational support as requested by FBI.

c. The FBI agrees to

(1) Provide a qualified response team when RFAAP is confronted with a major hostile situation

(2) Provide a qualified hostage negotiator when RFAAP is confronted with a hostage situation

(3) Provide all equipment. supplies and transportation necessary to accomplish its mission at RFAAP.

(4) Respond to RFAAP request for assistance Supervisory Senior Resident Agent. Roanoke Resident Agency, will make determination for SRT response and notify the Special Agent in Charge and/or Assistant Special Agent in Charge in Richmond This will be done in a reasonable amount of time, normally two (2) hours

(5) Coordinate its actions with the RFAAP Commander or his designee It is recognized that when the FBI assumes the mission, control of tactical and investigative

operations is relinquished by RFAAP RFAAP agrees to provide support to the FBI within the capability of the installation

d To conduct an annual exercise on RFAAP ACO Security Officer maintains the primary planning responsibility for this exercise.

e Post Incident Responsibilities Upon termination of the tactical phase of the incident

(1) The FBI may elect to retain incident command and control if one of the perpetrators is a civilian. If all subjects are military personnel, the FBI will relinquish control of the subjects to military authorities.

(2) The FBI and military personnel may be requested to remain briefly on site if their continued presence is necessary to protect the integrity of the investigative process

(3) The FBI will make every reasonable effort to expedite interviews of military and Department of Defense civilian personnel.

(4) The FBI will protect the identity of any military personnel as may be appropriate to the extent of the law

f Public Affairs

(1) Primary responsibility for media inquiries rests with the FBI who assumes control of the situation

(2) RFAAP Public Affairs Office is responsible for coordination with the FBI public affairs representative

g Liability Between Federal Agencies

(1) Each party agrees that should a claim arise under the terms and conditions of the Federal Torts Claim Act (FTCA), Title 28, United States Code, Sections 1346 and 2671 <u>et seq</u>, for the negligent or wrongful acts or omissions by its respective federal employee(s). that party shall be responsible for the investigation and disposition of said claim The parties further agree that the FBI shall assume responsibility for the investigation and disposition of an administrative claim arising out

of a criminal investigation prompted by this MOU and in which the FBI is the primary investigating agency. For all other administrative claims involving multiple federal parties and arising out of an activity conducted pursuant to this MOU, the federal entity responsible for supervising the activity which resulted in the administrative claim shall assume primary responsibility for the investigation and disposition of the claim

(2) Each federal party agrees to notify the other federal party of any administrative claim arising out of an activity conducted pursuant to this MOU.

(3) Nothing in this section prevents any party from conducting an independent administrative review of the incident giving rise to the claim; however, final disposition of the claim will be handled as provided in the Paragraph.

(4) Nothing in this section should be construed as supplanting any applicable statute rule or regulation.

(5) Unless specifically addressed by the terms of this MOU, the parties agree to be responsible for the negligent or wrongful acts or omissions of their respective employees. Legal representation by the United States is determined by Department of Justice (DOJ) on a case-by-case basis The FBI cannot guarantee the United States will provide legal representation to any Federal, state or local law enforcement officer.

(6) Each participating agency acknowledges that its liability, if any, for the negligent or wrongful acts or omissions by its employees while they are participating pursuant to this MOU is governed by applicable local law Participating agencies and their individual members agree that they will not be responsible or liable for acts performed by personnel or other member agencies during the duration of this MOU

(7) Each participating agency acknowledges that the federal government does not contract or promise to consider indemnifying the individual participating officer, substituting the United States as a party defendant in civil litigation, or providing representation to state and local law enforcement officers who cooperate with the FBI, or any other Federal agency, on an informal basis as part of their state or local duties unless they have been deputized as a federal law enforcement officer or have been detailed to a federal agency under the Intergovernmental Personnel Act (IPA), 5 U S C § 3374(c)(2).

h Each party hereby waives all claims against every other party for compensation for expenses. salaries. or other benefits occurring as a consequence of the performance of this agreement

6 Effective Date This agreement will become effective immediately upon signature unless terminated by any upon notice in writing to all parties This agreement will be reviewed annually

Amendments or modifications to this agreement may be made upon written agreement by all parties to the agreement. This agreement may be terminated by a thirty day notification from any of the parties.

Brian A. Butler
Lieutenant Colonel U S Army
Commanding Officer

Donald W. Thompson Jr
Special Agent in Charge
Federal Bureau of Investigation
Richmond. Virginia Office

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P O BOX 2
RADFORD, VIRGINIA 24143-0002

DEPARTMENT OF THE ARMY LETTER OF AGREEMENT

This letter of agreement, entered in to the 7th day of JULY, 2011 between the Secretary of the Army acting according to the authority of Section 1856a, Title 42 of United States Code (USC), Radford Army Ammunition Plant ("RFAAP") by their representatives and LewisGale Hospital Pulaski, ("Hospital") details the responsibilities and expectations of each party relative to a condition of natural or manmade disaster

It is agreed that, in the event of an accident or other occurrence which may create an unknown number of casualties at RFAAP, RFAAP agrees to provide to the Hospital Emergency Room through the designated office or individual, information relative to the nature of the accident or occurrence, type of hazardous material involved, known or estimated number of casualties, and type(s) of or extent of injuries Such communications shall be transmitted via radio, in person or telephone as conditions dictate.

Upon notification, Hospital will determine the extent of mobilization necessary to accommodate the number of casualties anticipated. If, upon evaluation by Hospital's Emergency Room physician on duty, the Charge Nurse in the ER and the Administrative Nursing Supervisor, current staffing is inadequate to provide adequate care to the incoming casualties, Hospital's Emergency Action Plan will be implemented. Hospital agrees to provide triage for all casualties, management of casualties are defined in the Hospital Emergency Action Manual.

The provision of triage, admission and management of casualties is extended on behalf of Hospital to all civilian, military employees and agents of RFAAP so affected by the accident or other occurrence without regard to the nature of the occurrence. In a mass casualty event, On-Scene first responders will initiate the triage process to determine level of care needed and bed availability of local providers.

Strict adherence to the principles of security and patient confidentiality is assured by both parties. RFAAP agrees to comply with the Health Insurance Portability and Accountability Act of 1996, as codified at 42 USC § 1320d ("HIPPA") and any current and future regulations promulgated there under including without limitation the federal privacy regulations contained in 45 CFR parts 160 and 164 (the "Federal Privacy Regulations"), the Federal Security Standards contained in 45 CFR part 142 (the "Federal Security Regulations"), and the federal standards for electronic transactions contained in 45 CFR Parts 160 and 162, all collectively referred to herein as "HIPPA Requirements" RFAAP agrees not to use or further disclose any Protected Health Information (as defined in 45 CFR Section 164.501) or Individually Identifiable Health Information (as defined in 42 USC Section 1320d), other than as permitted by HIPPA Requirements and the terms of this Agreement. RFAAP will make its internal practices, books, and records relating to the use and disclosure of Protected Health Information available to the Secretary of Health and Human Services to the extent required for determining compliance with the Federal Privacy Regulations.

RFAAP represents and warrants that it is not an Excluded Provider. For purposes of this Section, the term "Excluded Provider" means a person or entity that either (1) has been convicted of a crime related to health care or (2) is currently listed by a federal agency as debarred, excluded or otherwise ineligible for participation in federally funded programs (including without limitation federally funded health care programs such as Medicare and Medicaid). Further, RFAAP agrees to immediately disclose to the hospital and debarment, exclusion or other event that makes RFAAP or any individual employed by RFAAP and Ineligible Person with respect to participation in any federal health care program, upon which disclosure Hospital may, without penalty, immediately terminate this Agreement.

This agreement shall become effective upon the date hereof and remain in full force until cancelled by mutual agreement of the parties hereto, or by written notice by one party to the other party, giving thirty days notice of said cancellation.

LEWISGALE HOSPITAL PULASKI

BY: ______________________

Mark Nichols, FACHE
Chief Executive Officer

UNITED STATES OF AMERICA

BY: ______________________

Wm Byron Penland
Lieutenant Colonel, U S. Army
Commanding

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P O BOX 2
RADFORD, VIRGINIA 24143-0002

27JUN11

DEPARTMENT OF THE ARMY MUTUAL AID AGREEMENT

WHEREAS, Radford Army Ammunition Plant (RFAAP), a Government Owned Contractor Operated (GOCO) facility agrees to be bound by this Mutual Aid Agreement and, further, all parties hereto agree that the organization will be collectively identified herein as the "RFAAP Fire Department/EMT," although there shall be no, nor is there any assumption of liability between or among the two for any purpose whatsoever

NOW, THEREFORE:

This Mutual Aid Agreement (MAA) entered into the 20 day of JUNE, 2011, between the Secretary of the Army acting according to the authority of section 1856a, title 42, United States Code, RFAAP and the Riner Volunteer Rescue Squad to secure for each the benefits of mutual aid in the prevention of loss of life and property from fire or natural disaster It is agreed that

a On request to a representative of RFAAP, by a representative of participating agency personnel of RFAAP Fire Department/EMT will be dispatched when available to any point within the area for which the agency normally provides Emergency Medical Service (EMS) protection as designated by the representative of participating agency

b On request to a representative of participating agency by a representative of RFAAP, EMS equipment, and personnel of that agency will be dispatched when available to any point within the jurisdiction of RFAAP Fire Department/EMT

c The rendering of assistance under the terms of this agreement shall not be mandatory but the party receiving the request for assistance should immediately inform the requesting department if, for any reason, assistance couldn't be rendered

d Any dispatch of equipment and personnel pursuant to this agreement is subject the following conditions

1 Any request for aid under this agreement will specify the location to which the equipment and personnel are to be dispatched, however, the amount and type of equipment and number of personnel to be furnished will be determined by the responding organization

2 The responding organization will report to the officer in charge of the requesting organization at the location to which the equipment is dispatched and will be subject to the orders of the official

3 A responding organization will be released by the requesting organization when the services of the responding organization are no longer required, or when the responding organization is needed within the area for which it normally provides fire protection

4 If a crash of aircraft owned or operated by the United States or Military aircraft of any foreign nation occurs within the area for which the participating agency normally provides EMS RFAAP, or a representative may assume full command on arrival at the scene of the crash

e Each party hereby waivers all claims against every other party for compensation for any loss, damage, injury, or death occurring as a consequence of the performance of this agreement except those claims under 15 U S C 2210

f The officers and personnel of the EMT/EMS squads of both parties to this agreement are invited and encouraged on a reciprocal basis, to frequently visit each other's activity for guided familiarization tours consistent with local security requirements and, as feasible, to jointly conduct planning inspections and drills

g The technical heads of the EMT/EMS departments of the parties to this agreement are authorized and directed to meet and draft any detailed plans and procedures of operations necessary to effectively implement this agreement. Such plans and procedures of operations shall become effective by the signatory parties

h All equipment used in carrying out this agreement will be owned by the participating agency and all personnel supporting this request will be an employee or volunteer member of the participating agency

i This agreement shall become effective upon the date hereof and remain in full force until canceled by mutual agreement of the parties hereto, or by written notice by one party to the other party, giving thirty days notice of said cancellation

RINER VOLUNTEER RESCUE SQUAD

BY ______________________

Jason Roop
Captain

UNITED STATES OF AMERICA

BY ______________________

Wm Byron Penland
LTC, CM
Commanding

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P.O BOX 2
RADFORD, VIRGINIA 24143-0002

27JUN11

DEPARTMENT OF THE ARMY MUTUAL AID AGREEMENT

WHEREAS, Radford Army Ammunition Plant (RFAAP), a Government Owned Contractor Operated (GOCO) facility agrees to be bound by this Mutual Aid Agreement and, further, all parties hereto agree that the organization will be collectively identified herein as the "RFAAP Fire Department/EMT," although there shall be no, nor is there any assumption of liability between or among the two for any purpose whatsoever

NOW, THEREFORE:

This Mutual Aid Agreement (MAA) entered into the 30th day of June, 2011, between the Secretary of the Army acting according to the authority of section 1856a, title 42, United States Code, RFAAP and the Riner Volunteer Fire Company to secure for each the benefits of mutual aid in the prevention of loss of life and property from fire or natural disaster It is agreed that

a On request to a representative of RFAAP, by a representative of participating agency firefighting equipment and personnel of RFAAP Fire Department/EMT will be dispatched when available to any point within the area for which the agency normally provides fire protection as designated by the representative of participating agency

b On request to a representative of participating agency by a representative of RFAAP, firefighting equipment, and personnel of that agency will be dispatched when available to any point within the firefighting jurisdiction of RFAAP Fire Department/EMT

c The rendering of assistance under the terms of this agreement shall not be mandatory but the party receiving the request for assistance should immediately inform the requesting department if, for any reason, assistance couldn't be rendered

d Any dispatch of equipment and personnel pursuant to this agreement is subject the following conditions

1 Any request for aid under this agreement will specify the location to which the equipment and personnel are to be dispatched, however, the amount and type of equipment and number of personnel to be furnished will be determined by the responding organization

2 The responding organization will report to the officer in charge of the requesting organization at the location to which the equipment is dispatched and will be subject to the orders of the official

3 A responding organization will be released by the requesting organization when the services of the responding organization are no longer required, or when the responding organization is needed within the area for which it normally provides fire protection

4 If a crash of aircraft owned or operated by the United States or Military aircraft of any foreign nation occurs within the area for which the participating agency normally provides fire protection, RFAAP, or a representative may assume full command on arrival at the scene of the crash

e Each party hereby waivers all claims against every other party for compensation for any loss, damage, injury, or death occurring as a consequence of the performance of this agreement except those claims under 15 U S C 2210

f The chief fire officers and personnel of the fire department of both parties to this agreement are invited and encouraged on a reciprocal basis, to frequently visit each other's activity for guided familiarization tours consistent with local security requirements and, as feasible, to jointly conduct pre-fire planning inspections and drills

g The technical heads of the fire departments of the parties to this agreement are authorized and directed to meet and draft any detailed plans and procedures of operations necessary to effectively implement this agreement. Such plans and procedures of operations shall become effective by the signatory parties

h All equipment used in carrying out this agreement will be owned by the participating agency and all personnel supporting this request will be an employee or volunteer member of the participating agency

i This agreement shall become effective upon the date hereof and remain in full force until canceled by mutual agreement of the parties hereto, or by written notice by one party to the other party, giving thirty days notice of said cancellation

RINER VOLUNTEER FIRE COMPANY

BY ______________________________
Joe Lucas
Fire Chief

UNITED STATES OF AMERICA

BY ______________________________
Wm Byron Penland
LTC, CM
Commanding

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P.O. BOX 2
RADFORD, VIRGINIA 24143-0002

DEPARTMENT OF THE ARMY MUTUAL AID AGREEMENT

WHEREAS, Radford Army Ammunition Plant (RFAAP), a Government Owned Contractor Operated (GOCO) facility agrees to be bound by this Mutual Aid Agreement and further, all parties hereto agree that organization will be collectively identified herein as the "RFAAP Fire Department/EMT" although there shall be no, nor is there any assumption of liability between or among the two for any purpose whatsoever

NOW, THEREFORE:

This Mutual Aid Agreement, entered into the 11th day of July, 2011, between the Secretary of the Army acting according to the authority of Section 1856a, Title 42 of United States Code (USC), Radford Army Ammunition Plant ("RFAAP") by their representatives and the City of Radford to secure for each the benefits of mutual aid in the prevention of loss of life and/or property damage from manmade or natural disasters It is agreed that

a On request to a representative of RFAAP, by a representative of the participating organization/agency, firefighting equipment and personnel of RFAAP Fire Department/EMT will be dispatched, when available to any point within the area for which the organization/agency normally provides fire protection, as designated by the representative of the participating organization/agency

b On request to a representative of the participating organization/agency by a representative of RFAAP, firefighting equipment, and personnel of that organization/agency will be dispatched when available to any point within the firefighting jurisdiction of RFAAP Fire Department/EMT

c The rendering of assistance under the terms of this agreement shall not be mandatory, but the party receiving the request for assistance should immediately inform the requesting organization/agency if, for any reason, assistance could not be rendered

d. Any dispatch of equipment and personnel pursuant to this agreement is subject the following conditions

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3 A responding organization will be released by the requesting organization when the services of the responding organization are no longer required, or when the responding organization is needed within the area for which it normally provides fire protection

4 If a crash of aircraft owned or operated by the United States or Military aircraft of any foreign nation occurs within the area for which the participating agency normally provides fire protection, RFAAP or a representative may assume full command on arrival at the scene of the crash

e Each party hereby waivers all claims against every other party for compensation for any loss, damage, injury, or death occurring as a consequence of the performance of this agreement except those claims under 15 U S C 2210

f The chief fire officers and personnel of the fire department of both parties to this agreement are invited and encouraged on a reciprocal basis, to frequently visit each other's activity for guided familiarization tours consistent with local security requirements and, as feasible, to jointly conduct pre-fire planning inspections and drills

g The technical heads of the fire departments of the parties to this agreement are authorized and directed to meet and draft any detailed plans and procedures of operations necessary to effectively implement this agreement Such plans and procedures of operations shall become effective by the signatory parties

h All equipment used in carrying out this agreement will be owned by the participating agency and all personnel supporting this request will be an employee or volunteer member of the participating agency

i This agreement shall become effective upon the date hereof and remain in full force until canceled by mutual agreement of the parties hereto, or by written notice by one party to the other party, giving thirty days notice of said cancellation.

CITY OF RADFORD

BY

Dr. Bruce E Brown
Mayor

David C Ridpath
City Manager

UNITED STATES OF AMERICA

BY

Wm Byron Penland
Lieutenant Colonel, U S Army
Commanding

DEPARTMENT OF THE ARMY
RADFORD ARMY AMMUNITION PLANT
P.O BOX 2
RADFORD, VIRGINIA 24143-0002

DEPARTMENT OF THE ARMY MUTUAL AID AGREEMENT

WHEREAS, Radford Army Ammunition Plant (RFAAP), a Government Owned Contractor Operated (GOCO) facility agrees to be bound by this Mutual Aid Agreement and further, all parties hereto agree that organization will be collectively identified herein as the "RFAAP Fire Department/EMT", although there shall be no, nor is there any assumption of liability between or among the two for any purpose whatsoever

NOW, THEREFORE:

This Mutual Aid Agreement, entered into the 11 day of July, 2011, between the Secretary of the Army acting according to the authority of Section 1856a, Title 42 of United States Code (USC), Radford Army Ammunition Plant ("RFAAP") by their representatives and the Fairlawn Volunteer Fire Company, to secure for each the benefits of mutual aid in the prevention of loss of life and/or property damage from manmade or natural disasters It is agreed that·

a On request to a representative of RFAAP, by a representative of the participating organization/agency, firefighting equipment and personnel of RFAAP Fire Department/EMT will be dispatched, when available to any point within the area for which the organization/agency normally provides fire protection, as designated by the representative of the participating organization/agency

b On request to a representative of the participating organization/agency by a representative of RFAAP, firefighting equipment, and personnel of that organization/agency will be dispatched when available to any point within the firefighting jurisdiction of RFAAP Fire Department/EMT

c The rendering of assistance under the terms of this agreement shall not be mandatory, but the party receiving the request for assistance should immediately inform the requesting organization/agency if, for any reason, assistance could not be rendered.

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3. A responding organization will be released by the requesting organization when the services of the responding organization are no longer required, or when the responding organization is needed within the area for which it normally provides fire protection.

4 If a crash of aircraft owned or operated by the United States or Military aircraft of any foreign nation occurs within the area for which the participating agency normally provides fire protection, RFAAP, or a representative may assume full command on arrival at the scene of the crash

e. Each party hereby waivers all claims against every other party for compensation for any loss, damage, injury, or death occurring as a consequence of the performance of this agreement except those claims under 15 U S C 2210

f. The chief fire officers and personnel of the fire department of both parties to this agreement are invited and encouraged on a reciprocal basis, to frequently visit each other's activity for guided familiarization tours consistent with local security requirements and, as feasible, to jointly conduct pre-fire planning inspections and drills

g The technical heads of the fire departments of the parties to this agreement are authorized and directed to meet and draft any detailed plans and procedures of operations necessary to effectively implement this agreement Such plans and procedures of operations shall become effective by the signatory parties

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i This agreement shall become effective upon the date hereof and remain in full force until canceled by mutual agreement of the parties hereto, or by written notice by one party to the other party, giving thirty days notice of said cancellation

FAIRLAWN VOLUNTEER FIRE COMPANY

BY James R. Miles Chief

UNITED STATES OF AMERICA

BY

Wm Byron Penland
Lieutenant Colonel, U S Army
Commanding

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 1

APPENDIX C

CLOSURE NOTICES AND POST-CLOSURE PLANS

ATTACHMENT 1

APPENDIX C.1

UNIT POST-CLOSURE NOTICES

COMMONWEALTH of VIRGINIA

DEPARTMENT OF WASTE MANAGEMENT
11th Floor Monroe Building
101 N. 14th Street
Richmond, VA 23219
804-225-2667

MAY 17 1988

CERTIFIED-RETURN
RECEIPT REQUESTED

G. J. Savitske
Lieutenant Colonel, Ordinance Corps
COMMANDING OFFICER
Radford Army Ammunition Plant
Radford, Virginia 24140

RE Closure Plans
(HWM #5, #7, #16)
EPA ID# VA1210020730

Dear Colonel Savitske,

Enclosed, please find a copy of the Approved Closure plans developed for Hazardous Waste Management Units #5, #7, and #16. The approved plans are essentially the same as those plans submitted to our office dated November 1986 with the agreed to changes detailed in your letter dated May 11, 1988. Please note that the completion date of closure must be 180 days from the date of this letter.

Should you have any questions, please contact Kevin Greene at (804) 225-2466.

Sincerely,

Karol A. Akers
Technical Services Chief
Division of Technical Services

Enclosure

OLVER
INCORPORATED [illegible]
[illegible]

January 4, 1989

Mr. Kevin L. Greene, Geologist
Division of Technical Services
Department of Waste Management
101 North 14th Street, 11th Floor
Richmond, VA 23219

Re: Radford Army Ammunition Plant,
Closure Certification, HWMU 5, [illegible] and
16, EPA ID No. VA1210020730, Job
No. 11074

Dear Kevin:

This letter is to provide certification to the Department of Waste Management that the three above-referenced sites were closed in accordance with the approved closure plan dated May 27, 1988. Olver Incorporated had a professional engineer, Kevin Murray, on site from September 19, 1988, through October 14, 1988, which was every day that the contractor worked, and throughout the entire length of time that the contractor was on the referenced project sites. Additional inspections were accomplished on each of the hazardous waste management units on the dates indicated in the table previously sent to you. All inspection trips met the requirements of the closure plan. I have reviewed all of Mr. Murray's notes and memoranda concerning the above-referenced project and, as he no longer works for Olver Incorporated, I am certifying that the work was completed in conformance with the approved closure plan.

If you should have any questions concerning this matter, please do not hesitate to contact me.

Sincerely,

Robert M. Roberts, P.E.
Vice President

RMR/ma

cc: Mr. Patrick J. Golden, Radford Army Ammunition Plant

FILE COPY

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

James S Gilmore, III
Governor

John Paul Woodley, Jr
Secretary of Natural Resources

Street address 629 East Main Street, Richmond, Virginia 23219
Mailing address P O Box 10009, Richmond, Virginia 23240
Fax (804) 698-4500 TDD (804) 698-4021
http //www deq state va.us

Dennis H Treacy
Director

(804) 698-4000
1-800-592-5482

Certified Mail
Return Receipt Requested

November 4, 1998

C A Jake
Environmental Manager
Alliant Techsystems Inc.
Radford Army Ammunition Plant
P.O Box 1
Radford, VA 24141-0100

RE: Radford Army Ammunition Plant [RAAP]
HWMU 5, 7, and 16 Closure Verification
EPA ID# VA12100207306

Dear Ms. Jake.

On November 3, 1989, the professional engineer's closure certifications for RAAP's hazardous waste management units 5, 7, and 16 were submitted. Additionally, it should be noted that the information required per 9 VAC 20-60-580 G and 580 K was submitted to the local zoning authorities via a letter dated September 15, 1998. However, review of DEQ's records indicate that no closure verification was performed As these units are currently in the post-closure permitting process, the closure verification needs to be completed per the requirements of 9 VAC 20-60-1010

Based on the information submitted and the closure verification inspection performed on April 22, 1998, closure of HWMUs 5, 7, and 16 as landfills in accordance with the *Virginia Hazardous Waste Management Regulations* [VHWMR] and the approved closure plan dated May 27, 1988, is deemed acceptable and approved The units closed as hazardous waste landfills in accordance with the VHWMR and, are therefore, subject to the post-closure requirements of these regulations These units are now subject to post-closure care in accordance with the VHWMR Parts IX, X, and XI The Part B permit application for post-closure maintenance of these units was received on November 7, 1985 Currently, post-closure permitting of HWMU 7 is actively being pursued

If there are any additional questions, please contact Debra Miller, Environmental Engineer Senior, of my staff at (804) 698-4206

Sincerely,

Leslie A Romanchik

for Dennis H Treacy
Director

cc: Debra Miller, DEQ
Glenn Von Gonten, DEQ
Claire Ballard, DEQ
Melissa Porterfield, DEQ
Aziz Farahmand, DEQ-RRO

FILE COPY

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
Street address: 629 East Main Street, Richmond, Virginia 23219
Mailing address: P.O. Box 10009, Richmond, Virginia 23240
Fax (804) 698-4500 TDD (804) 698-4021
http://www.deq.state.va.us

James S. Gilmore, III
Governor

John Paul Woodley, Jr
Secretary of Natural Resources

Dennis H. Treacy
Director

(804) 698-4000
1-800-592-5482

December 8, 1998

C.A. Jake
Alliant Techsystems Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

RE: **Radford Army Ammunition Plant (RAAP)**
EPA ID# VA12100207306
Equalization Basin Closure
Closure Verification

Dear Ms. Jake,

On August 7, 1998, RAAP submitted the required closure certifications and report for its Equalization Basin. Additionally, on March 27, 1998, RAAP's Equalization Basin, SWMU #10, was visited by Mike Scott of the Virginia Department of Environmental Quality's (DEQ) West Central Regional Office. This information has been reviewed.

Based on this closure inspection and the closure certifications and report, clean closure by background comparison was achieved for all constituents, except Fluoranthene. Clean closure to a residential risk-based determination was achieved for Fluoranthene. Therefore, the DEQ concurs that clean closure for soils only has been achieved for RAAP's Equalization Basin. Please note, however, that the U.S. Environmental Protection Agency retains the authority to address possible corrective action or continuing releases pursuant to the Hazardous and Solid Waste Amendments of 1984. The groundwater underneath the Sludge Drying Beds is still undergoing closure and may be subject to the post-closure permit process established under Title 9 of the Virginia

Administrative Code, Chapter 20-60 (9 VAC 20-60 et seq.), if clean closure cannot be achieved

If you have any questions regarding this letter, please contact Debra A. Miller, Environmental Engineer Senior, of my staff at (804) 698-4206.

Sincerely,

Leslie A Romanchik

for Dennis H. Treacy

c: Claire Ballard - DEQ
Melissa Porterfield- DEQ
Glenn VonGonten-DEQ
Aziz Farahmand-DEQ/WCRO
Central Hazardous Waste File

ATTACHMENT 1

APPENDIX C.2

POST-CLOSURE PLAN
FOR UNITS 5, 7, AND 16

POST CLOSURE CARE AND GROUNDWATER MONITORING

HAZARDOUS WASTE SURFACE IMPOUNDMENTS

In accordance with the Virginia Hazardous Waste Regulations, this section presents the post-closure plan for, HWM 5 and 7 based on the closure of both sites as hazardous units. Unless otherwise determined by the State Executive Director post-closure care is to extend over a 30-year period (10.6.H). The major components of post-closure care as proposed in this plan are groundwater monitoring, inspection and maintenance. Possible contingency activities are also described in this section. This plan will extend until such time as a post closure care permit is issued.

<u>Post Closure Contact</u>

Regginald Tyler
RADFORD ARMY AMMUNITION PLANT
(703) 639-8641

<u>Groundwater Monitoring</u>

Results of the Groundwater Quality Assessment Program conducted at the sites indicate that groundwater contamination has occurred. In response to these monitoring results a Compliance Monitoring program will be instituted under 10.5.B and will continue during the post-closure period.

This Compliance Monitoring Program will be implemented using a minimum of four wells (one upgradient and three downgradient), constructed in accordance with 10.5.H. The wells to be used will be selected after final review of the Groundwater Quality Assessment Program.

Samples will be collected in accordance with 10.5.H.4 and (5) on a quarterly basis. Background groundwater quality will be determined for each constituent as specified in 10.5.H.7. The water quality parameters that will be analyzed as part of this program include:

- Specific conductance
- Total organic carbon (TOC)
- Total organic halogen (TOX)
- pH
- Any additional parameters as agreed

For quality control purposes, samples will be split into four portions for analysis. Groundwater elevations will be measured for each sampling event and the direction and rate of groundwater flow will be determined on an annual basis. Additionally, all monitoring wells will be analyzed for Virginia Regulations Appendix 3.6 hazardous constituents on an annual basis.

It is anticipated that because of the nature of the wastes in the surface impoundments and the closure activities to be conducted as described in Section 6.0, the Radford AAP may elect after several years of groundwater monitoring to discuss with the State the requirement for monitoring over a 30-year period. It is probable that the groundwater quality at these sites will improve to ambient levels after several years. If monitoring confirms this then groundwater monitoring could be terminated or reduced in scope.

Inspection

In accordance with 10.6.I.2.(a) regular post-closure inspections of the sites will be made to ensure the integrity of the cover system and all associated structures. Inspections will be conducted by qualified personnel on a monthly basis, with additional inspections following inclement weather or catastrophic events (e.g., fire or explosion elsewhere at the Radford AAP). To ensure that all items of interest are addressed during the inspection, an inspection log will be used during each inspection. This inspection log will list the potential problems/conditions that the inspector should note while conducting the inspection. The inspector will be asked to identify the existence or absence of each problem and, if present, to address its degree of severity (e.g., low, moderate or high). Table 7.1, discussed in the following paragraphs, provides a listing of all items to be inspected.

Because failure of the soil cover or the underlying PVC liner could result in increased infiltration and leachate generation, it is necessary to inspect the cover for surface erosion, subsidence, or ponding; plant root penetration, or exposure of the liner. The grass cover should be inspected for general health and the presence of undesirable competitive species, particularly deep-rooted plants or shrubs. Vegetation should be kept trimmed to prevent encroachment on access controls, roads and signs. Stormwater drainage controls (i.e., slopes and swales) should be inspected for erosion, subsidence, and in the case of swales, accumulated sediment that might block the flow of stormwater. Locks and caps on groundwater monitoring wells should be inspected for damage.

The need for additional security is expected to be minimal due to the overall secure nature of the Radford plant. Therefore, the installation of warning signs will be the only additional security measure taken during the post-closure care period, as only authorized personnel are allowed to enter the restricted portion of the Radford AAP.

Maintenance

The nature and degree of post-closure maintenance of the site will be primarily determined by observations made during the routine inspections. However, since the Radford AAP will remain in operation, plant personnel will have the opportunity to observe the need for maintenance on a more frequent basis. A description of the expected maintenance activities that will be performed in accordance with 10.6.I 's discussed below.

The cover, drainage slopes, and vegetation will be maintained as needed. Damage due to erosion and subsidence will be corrected by adding soil and regrading the site. It is expected that no significant subsidence will occur following closure, and thus only erosion would be the major long term concern. Maintenance of vegetation necessary to control erosion will include removing deep-rooted plants and adding fertilizer to enhance growth as necessary. Overgrowth into drainage swales and access roads will be controlled. Swales will be cleared of any accumulated material. These precipitation run-off pathways will be tested annually for the constituents of which were disposed in the units to determine if precipitation run-off is becoming contaminated.

Security will be maintained by immediately repairing or replacing any damaged signs or access roads. Damaged monitoring wells will be repaired if possible. If it is determined that the integrity of the well has been destroyed, then the well will be replaced. Surveyed benchmarks used to indicate the location of the site will be protected and maintained as necessary. The general perimter of the surface impoundment will be easily recognizable due to the presence of riprap for slope protection.

Contingency Activities

In the event of major damage, contingency measures will be promptly taken erosion will be repaired by the most appropriate of the following measures: replacement of cover or fill soil; restoration of original grade design or replacement with new grade design; and/or installation of riprap. Any other cover deterioration due to deep-rooted plants, cracking, cold weather, or slope instability will be promptly corrected by filling, regrading and reseeding, as appropriate. Damage to vegetation will be controlled by the addition of nutrients, manual watering (in the event of drought), and/or pest control as appropriate.

HAZARDOUS WASTE LANDFILL TRENCH

Since post-closure care is also required for HWM 16, groundwater monitoring and inspection programs similar to those outlined will be implemented. An additional inspection item for HWM 16 would be the leachate collection sump. If any leachate is found to have accumulated in the sump, it will be removed and managed as a listed hazardous waste and more frequent inspections will be conducted. If it is deemed necessary, a routine leachate removal program will be implemented. As in the case of the surface impoundments, surface water monitoring will be performed annually along drainage ditches to determine if surface water run-off has become contaminated to ensure that there will be no release to surface water from the site. Post-closure care will continue for 30 years, unless otherwise determined by the Executive Director. This plan will remain in effect until such time as a Post Closure Permit is issued.

FUTURE USE RESTRICTIONS

In accordance with 10.6.H.3., there will be no use of the disposal areas (HWM #5, HWM #7, and HWM #16) which would allow any disturbance of the integrity of the final cover, liner(s) or any other components of any containment system, or of the function of the associated monitoring systems. Land use activities that will be prohibited at each facility include:

- On-site construction
- Excavation (except as necessary for major maintenance activities)
- Well construction on or near the site
- Agricultural use
- Silvicultural use
- Water infiltration (run-on, ponding, irrigation)
- Recreational use
- Disposal operations
- Vehicular traffic (except as necessary for major maintenance activities)
- Housing on or near the site.

NOTICE TO LOCAL LAND AUTHORITY

As required by 10.6.J, the Radford AAP will submit to the local land authority survey plans prepared and certified by a professional land surveyor which show the disposal areas (HWM #5,

#7, and #16) with respect to permanently surveyed benchmarks. These plans shall contain a note stating that there will be no disturbance of the disposal areas by Radford AAP.

NOTICE IN DEED TO PROPERTY

As required by 10.6.J, a notation (HWM #5, #7, and #16) will be made on the deed to the facility property that will notify, in perpetuity, any potential purchaser of the property that: (1) the land has been used to manage hazardous waste; (2) its use is restricted to that of open space; and (3) the survey plan and record of the type, location, and quantity of hazardous wastes disposed on site has been filed with the Executive Director and local land authority.

INSPECTION CHECKLIST FOR CLOSED ON-SITE FACILITIES

Inspector Name:

Date:

Unit #:

Correction Action:

Item	Problem	Problem Exists? (Yes or No)	Degree of Problem? (e.g., Low)
Soil Cover	erosion		
	subsidence		
	ponding		
PVC Liner	exposed		
Grass Cover	inadequate growth/health		
	deep-rooted vegetation		
	presence of undesirable species		
	inadequate trimming		
Stormwater Drainage			
slopes	erosion		
	subsidence		
drainage swale	erosion		
	subsidence		
	vegetation growth		
	accumulated sediment		
Monitoring Wells			
locks	damage		
caps	damage		
Security			
warning signs	missing		
	defaced		
	obscured		
access road	disrepair		
LEACHATE COLLECTION SYSTEM (HWM #16)	BASIN FULL		
	OPERATING EFFECTIVLY		

ATTACHMENT 1

Appendix D

FACILITY CONTACT REPRESENTATIVES

ATTACHMENT 1

Appendix D

FACILITY CONTACT REPRESENTATIVES

The post-closure care contact representative for the Naval Surface Warfare Center- Dahlgren Sites is noted below:

On-site Operator Contact:

Mr. Jay Stewart
Environmental Manager
BAE Systems Ordnance Systems Inc.Radford Army Ammunition Plant
Route 114, P.O. Box 1
Radford, VA 24141-0100

Owner Contact:

Mr. Robert Davie, II
Chief Operations
United States Army
Route 114, PO Box 2
Radford Army Ammunition Plant
Radford, VA 24141

United States Army (Owner) **BAE Systems Ordnance Systems Inc. (Operator)**

Radford Army Ammunition Plant
Route 114
Radford, Virginia, 24141-0100

ATTACHMENT 1

Appendix E

SECURITY PROVISIONS AND MAINTENANCE

1. INTRODUCTION

Protection of plant personnel, property, resources and operations at the Radford Army Ammunition Plant (RFAAP), a Government-owned, contractor-operated (GOCO) manufacturing facility, is provided under contract by BAE Systems Ordnance Systems Inc. (BAE) in accordance with Department of the Defense (DOD), Department of the Army (DA), United States Army Joint Munitions Command (USAJMC) and other regulatory guidance and standards. A subcontractor security guard force, G4S Government Solutions , is used to perform and enforce prescribed physical security measures.

2. SECURITY PROCEDURES AND EQUIPMENT

Security areas on the installation have been designated as Limited and Posted Areas. These areas and corresponding control measures are documented in Chapter 2 of the Plant Protection Plan (PPP). RFAAP is considered a "closed post" in that access is controlled at all times by perimeter barriers with limited, manned entry control points. The PPP also contains Security Guard orders, Security Guard standing operating procedures (SOPs) and numerous plans for execution in specific situations such as bomb threat, installation closure, work stoppage and civil disturbance. SOPs cover a range of subjects such as property movement, personnel and visitor identification and control, vehicle and personnel searches, perimeter inspections, key and lock control, and use of force. Security Guard Orders cover specific duties and requirements at assigned Security Guard posts, gates and stations. Physical security measures at RFAAP include Security Guard patrols, manned security posts, perimeter fencing, badge identification system, lock and key accountability and rotation, vehicle registration, pre-employment background investigations, security lighting, warning signs and physical barriers. At storage sites, tank inlets and disbursing valves are secured with security padlocks.

3. SECURITY GUARD FORCE

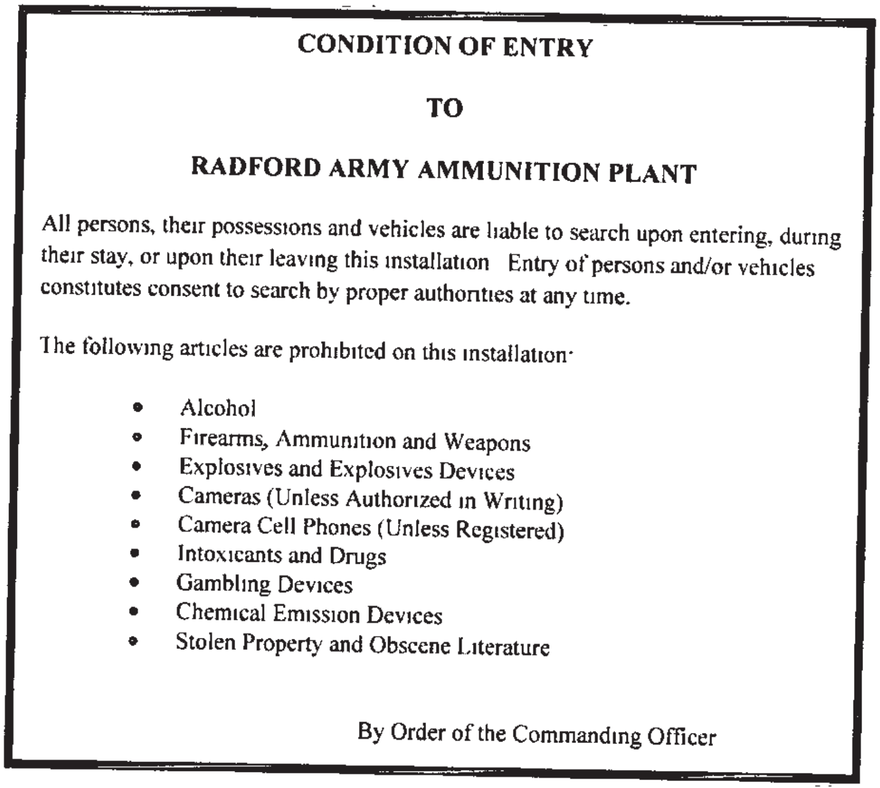
The Security Guard Force provides 24 x 7 security coverage and is divided into three (3) shifts. Each shift consists of manned posts, roving patrols and management personnel. The roving patrols perform random checks each shift of manufacturing areas, locked explosive storage buildings and road-visible perimeter fencing.

4. BARRIERS AND ENTRY CONTROL

Entry to the Radford Army Ammunition Plant is restricted. Personnel must be in possession of a valid personnel identification badge or visitor badge. If the person has valid official business at the plant or is accompanying a person who does have such business, posted area visitor badges are issued and the time and date of entry is recorded. Entry onto any of the HWMUs by anyone other than environmental or sampling personnel requires an Area Entry Permit.

5. WARNING SIGNS

At all plant entrances and in areas designated as posted, the following "Condition of Entry" signs have been erected:



CONDITION OF ENTRY

TO

RADFORD ARMY AMMUNITION PLANT

All persons, their possessions and vehicles are liable to search upon entering, during their stay, or upon their leaving this installation Entry of persons and/or vehicles constitutes consent to search by proper authorities at any time.

The following articles are prohibited on this installation·

- Alcohol
- Firearms, Ammunition and Weapons
- Explosives and Explosives Devices
- Cameras (Unless Authorized in Writing)
- Camera Cell Phones (Unless Registered)
- Intoxicants and Drugs
- Gambling Devices
- Chemical Emission Devices
- Stolen Property and Obscene Literature

By Order of the Commanding Officer

Signs reading "U.S. Government Property-No Trespassing" are located approximately every 500 feet on the installation boundary, except where designated Limited Area fences are not located on or reasonably adjacent to the property boundary.

Every 500 feet on Limited Area fencing and at other highly visible locations, such as corners and gates, the following sign is located on the fence facing outward:

U.S. ARMY

RESTRICTED AREA

WARNING

This area has been declared a restricted Area by authority of the Commanding Officer, in accordance with provisions of the Directive issued by the Secretary of Defense on 20 August 1954, pursuant to the provisions of Section 21, Internal Security Act of 1950. Unauthorized entry is prohibited. All persons and vehicles entering heron are liable to search. Photographing, making notes, drawings, maps, or graphic representations of this area or test activities are prohibited unless specifically authorized by the Commanding Officer. Any such material found in the possession of unauthorized persons will be confiscated.

In addition, information signs warning against smoking and the introduction of matches and other flame-producing devices are displayed at all normally used gates.

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 1

Appendix F

INSPECTION REQUIREMENTS

Attachment F

INSPECTION REQUIREMENTS

Appendix F. 1-	Example Semi-annual Inspection Log
Appendix F. 2-	Facility Benchmark Location Maps

PERMIT ATTACHMENT 1 APPENDIX F

INSPECTION AND MAINTENANCE PLAN

1.0 HIGHLIGHTS

In accordance with 40 CFR 264.15, the Permittees shall follow a written inspection schedule for each Unit, shall maintain a signed and dated Inspection Log, and shall implement remedial action when necessary to remediate any observed malfunctions, deterioration, operational errors, and discharges from the erosion controls, final cover system, and peripheral drainage swales; the security controls; the ground water monitoring system; and, the condition of benchmarks.

The Inspection Log shall be maintained at the facility and shall be made available to the Department for inspection upon request. The Inspection Log shall provide inspection observations, deficiencies noted, and corrective action taken. All inspections shall be performed by persons properly trained for this task, as specified in Permit Attachment 1 Appendix G, at the frequencies specified in Permit Attachment 1 Appendix F Table 1 (Table 1).

2.0 GENERAL INSPECTION REQUIREMENTS

Inspections function as a preventative measure to help ensure safe operations and to identify potential problems before they can become serious problems. All Units will be inspected as specified in this Inspection Schedule.

All inspection results will be recorded by the individual who performs the inspection, at that time of the inspection, on an inspection form. The individual performing the inspection will sign and date each completed inspection form. Separate inspection forms are used for each unit and are documented on *DUP 6057F, Inspection of Closed Hazardous Waste Management Unit* (see Appendix F.1).

Only personnel who have completed appropriate training and are approved for the task shall conduct inspections pursuant to this Inspection Schedule.

3.0 INSPECTION SCHEDULE

The Permittees shall inspect the final soil cover, vegetative cover, peripheral drainage swales, PVC liner, stormwater drainage areas, fence, warning signs, access road, monitoring wells, and benchmarks at least semi-annually, in accordance with the schedule specified in Table 1. The Inspection Item's and their associated Types of Problems listed in Table 1 are important due to their role in preventing, detecting, or responding to environmental or human health hazards.

For each Inspection Item subject to inspection, a list of problems normally encountered is identified in Table 1. Inspections will explicitly examine each item for the presence of the potential problems for each inspection item as specified in Table 1. Inspections of each item will be conducted at the frequency specified.

TABLE 1 - INSPECTION SCHEDULE

INSPECTION ITEM	TYPES OF PROBLEMS	FREQUENCY OF INSPECTION
Final Soil Cover	Erosion, Settlement, Subsidence, or Displacement, and Ponding	Semi-annually
Vegetative Cover	Dead vegetation, or inadequate growth, presence of trees, shrubs, or deep rooted vegetation, need to fertilize, irrigate, or cut grass	Semi-annually
Peripheral Drainage Swales	Erosion, Subsidence, Pooling	Semi-annually
PVC Liner	Exposure	Semi-annually
Stormwater Drainage Areas	Erosion, Subsidence, Vegetation growth, Accumulated Sediment	Semi-annually
Monitoring Wells (Outer protective casing, well caps and locks, concrete pad, and inner cap and riser)	Damage to Locks and Caps and cracks or settlement	Semi-annually
Security	Damage to Fencing, Warning Signs, and Access road	Semi-annually
Benchmarks	Damage to monument	Semi-annually

4.0 SECURITY CONTROLS

4.1 Fencing

Access to Units shall be restricted by the Permittees' Security System, as specified in Permit Attachment 1 Appendix E. The Permittees shall inspect the installation fencing at least semi-annually and any damage shall be noted in the Semi-annual Inspection Log (see Appendix F.1) and repaired or replaced as necessary.

4.2 Warning Signs

"U.S. Government Property-No Trespassing" signs and as specified in Permit Attachment 1 Appendix E, shall be posted on the fences at the installation boundary near Units. The Permittees shall inspect the condition of the warning signs at least semi-annually during security inspections.

5.0 GROUND WATER MONITORING SYSTEM INSPECTION AND MAINTENANCE PLAN

5.1 Inspection

During the post-closure care period all monitoring wells and piezometers shall be inspected at least semi-annually during ground water sampling events for general condition and integrity. All inspection observations shall be recorded on an inspection log sheet similar to that given in Appendix F.1. Copies of the inspection log sheets shall be maintained on file for a minimum of three years. The inspection shall consist of the following:

5.1.1 Inspection of outer protective casing

The outer protective casing shall be visually inspected to determine casing integrity.

5.1.2 Well caps and locks

Well caps and locks shall be visually inspected to insure that both are in place and functioning properly.

5.1.3 Concrete pad.

The concrete pad shall be visually inspected for the presence of cracks and settlement.

5.1.4 Inspection of inner cap and riser pipe.

The inner cap and riser pipe shall be visually inspected to insure that they are intact and functioning properly.

5.2 Preventive/Corrective Maintenance

Based on the visual inspections, monitoring wells shall be maintained by conducting the following as required:

- Replacement of well caps.
- Lubrication of locks.
- Replacement of locks.
- Painting of outer protective casing in high visibility color.
- Replacement of concrete pad.
- Replacement of well.

5.3 Inspection Record Keeping

The operators involved with ground water monitoring will record each inspection on a Semi-annual Inspection Log. These forms will be maintained as part of the facility operating record for at least three years from the date of inspection. These records will include the date and time of inspection, the name of the inspector (including full signature), a notation of the observations made, and the date and nature of any repairs or remedial actions.

6.0 BENCHMARKS

The Permittees shall inspect all surveyed benchmarks (see Appendix F.2) at least annually . The benchmarks shall be maintained, repaired, or replaced as necessary. The benchmarks shall be clearly identified and protected.

Permanent survey benchmarks are constructed of concrete. These units are not typically degradable and should not require replacement during the post-closure care period.

7.0 MAINTENANCE PLAN - REMEDIAL ACTION FOR EROSION CONTROLS, FINAL COVER SYSTEM, AND PERIPHERAL DRAINAGE SWALES

If the Permittee discovers any problems or deficiencies with the erosion controls, final cover system, and peripheral drainage swales during an inspection, then that problem or deficiency will be recorded on the Semi-annual Inspection Log (see Appendix F.1). Any necessary remediation actions will also be noted on the form and the problem or deficiency will be brought to the attention of the appropriate supervisor. After repairs or remedial actions have been completed, the date and nature of the repairs or remedial actions will be recorded on the same inspection form on which the problem or deficiency was originally noted.

If the Inspector discovers any problems or deficiencies that could lead to a release of hazardous waste or which could threaten personnel safety, operations will cease until the problem or deficiency is rectified. In no case will operations resume until all spill and emergency response equipment is operable and adequately stocked.

7.1 Erosion Controls

The Permittees shall inspect the peripheral drainage swales and riprap at each Unit at least semi-annually or after every major rainfall (approximately 2 inches per 8-hour period) or catastrophic events (e.g, fire or explosion elsewhere at the installation. The erosion controls (riprap and drainage swales) shall be maintained/repaired in accordance with the approved Closure/Post-Closure Plan (see Permit Attachment E).

7.2 Final Cover System

All Units were capped with a composite liner consisting of (from ground surface to base of cap):

- vegetative cover;
- riprap perimeter;
- filter fabric between the riprap and the cover soil;
- two feet of topsoil;
- one foot of drainage layer (10^{-3} cm/sec permeability);
- a 30 mil PVC membrane liner; and
- two feet of clay (10^{-7} cm/sec permeability).

The final cover system is designed to ensure the integrity and to minimize surface water run-on and run-off with a minimum of maintenance. No heavy equipment or vehicles shall be permitted on the final cover area unless involved in maintenance or repair activities.

7.2.1 Settlement, Subsidence, and Displacement

The Permittees will maintain the final cover at the approximate slope and gradients specified in the Post-Closure Plan. Slope and gradient shall be checked when there is an apparent change detected during inspections due to settling, subsidence, or displacement

7.2.2 Erosion Damage/Water Pooling

The Permittees shall inspect the final cover at least semi-annually or after every major rainfall (approximately 2 inches per 8-hour period) or catastrophic event (e.g, fire or explosion elsewhere at the installation) for erosion, pooling of water, and visible damage. Erosion or pooling of water shall be corrected.

7.2.3 Vegetative Cover

The Permittees shall inspect the vegetative cover at least semi-annually or after every major rainfall (approximately 2 inches per 8-hour period) or catastrophic event (e.g, fire or explosion elsewhere at the installation). Maintenance shall be performed as needed. Damaged or dead vegetation shall be removed and replaced with equivalent vegetation. No trees, shrubs, or other deep-rooted plants shall be allowed to grow on any Unit. Areas damaged by erosion shall be repaired and re-vegetated.

The vegetative layer shall be maintained by fertilizing, irrigating, and cutting, if necessary. Fertilizing shall be performed as often as necessary to maintain the layer. Irrigating and cutting are seasonally dependent and shall be performed as often as necessary.

7.3 Peripheral Drainage Swales

The Permittees shall inspect the peripheral drainage swales at least semi-annually or after every major rainfall (approximately 2 inches per 8-hour period) or catastrophic event (e.g, fire or explosion elsewhere at the installation).

All peripheral drainage swales shall be maintained and kept free of debris or other blockage. Drainage controls shall be inspected semi-annually and after major storms (approximately 2 inches of rain over an 8-hour period) and cleaned, as necessary. Repairs shall include regrading and re-vegetation, if necessary.

APPENDIX F.1
EXAMPLE SEMI-ANNUAL INSPECTION LOG

DUP 6057F (Rev Lev 0, 11/1/2000)

INSPECTION OF CLOSED HAZARDOUS WASTE MANAGEMENT FACILITIES

Name of Hazardous Waste Management Facility ____________________
HWMU Facility No ____________________
EPA Permit No. ____________________
Date of Inspection _____ /_____ /_____ Time of Inspection _____ _____ AM/ PM
Reason for Inspection. Semiannual/ Major rainfall event (2" in 8 hr period)/ catastrophic event

ITEM	INSPECT FOR	DEFICIENCIES NOTED	REMEDIAL ACTION REQUIRED
Final Soil Cover	• Erosion • Settlement, Subsidence, or Displacement • Pooling		
Vegetative Cover	• Dead vegetation, or inadequate growth • Presence of trees, shrubs, or deep rooted vegetation • Need to fertilize, irrigate, or cut grass		
PVC Liner	• Liner exposed		
Peripheral Drainage Swales	• Erosion • Subsidence • Pooling		
Stormwater Drainage Areas	• Erosion • Subsidence • Vegetation growth • Accumulated sediment		
Security	• Access road in place • Warning signs legible and in place • Fences not breached and no visible damage		
Monitoring Wells • Outer protective casing • Well caps and locks • Concrete pad • Inner cap and riser	• Casing in good condition • In place and functioning • Cracks or settlement • Intact and functioning		
Benchmarks (3)	• Monuments present and visible • Damage to monument		

Date and nature of repairs or remedial action ____________________
____
____

Printed Name of Inspector ____________ Signature of Inspector ____________

Company ____________________

Date remedial action completed ____________ Remedial action approved by ____________

Appendix F. 2

Radford Army Ammunition Plant Benchmark Location Maps

RADFORD ARMY AMMUNITION PLANT
HERCULES INCORPORATED
RADFORD, VIRGINIA

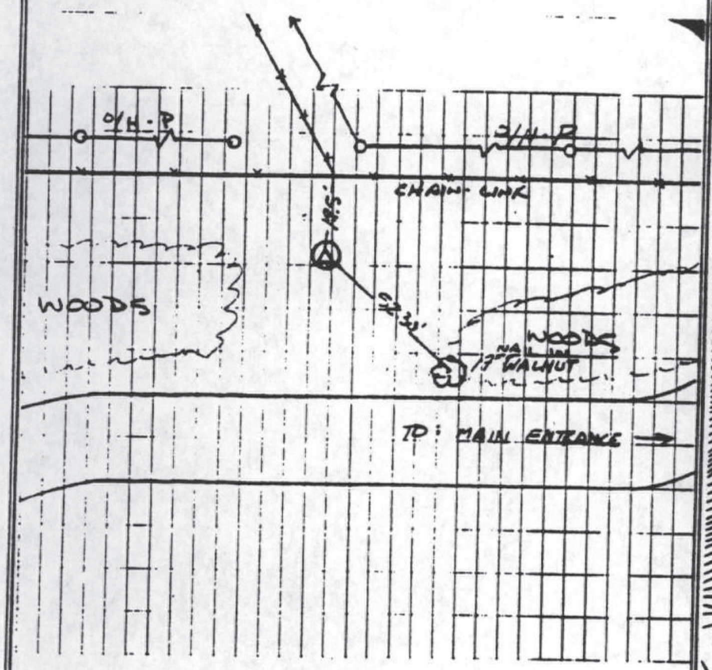
1991 GEODETIC GROUND CONTROL NETWORK MONUMENT SURVEY

REFERENCE AND RECOVERY DATA SHEET

VIRGINIA COORDINATE SYSTEM OF 1983 - SOUTH ZONE			
STATION	UNITS	NORTHING (Y)	EASTING (X)
Flip	METERS	1095506.5627	3317792.2313
	U.S. SURVEY FT.	3594174.448	10885123.346
LATITUDE		LONGITUDE	
37-10-33.984691		80-33-07.249064	

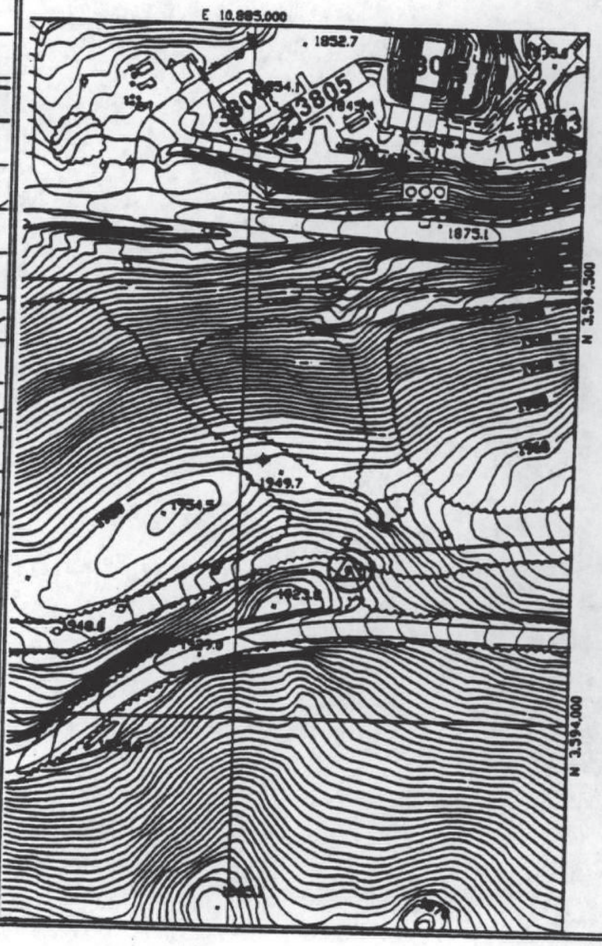
VERTICAL DATA	
ELEVATIONS REFER TO UNITED STATES GEODETIC SURVEY VERTICAL DATUM (1988)	
ELEVATION OF STATION IN FEET = 1934.813	
STATION Flip	FIELD BOOK 6452.03R V.C. 1 of 2 pg. 66
COUNTY/STATE Montgomery County, VA	USGS QUADRANGLE Radford North

LOCATION SKETCH (NOT TO SCALE)



A 3" disk set in concrete flush with ground surrounded by 3 metal fence posts forming a triangular configuration.

LOCATION MAP (SCALE 1"=200)



Draper Aden Associates
CONSULTING ENGINEERS
BLACKSBURG - RICHMOND, VIRGINIA
NASHVILLE, TENNESSEE

RADFORD ARMY AMMUNITION PLANT
HERCULES INCORPORATED
RADFORD, VIRGINIA

1991 GEODETIC GROUND CONTROL NETWORK MONUMENT SURVEY

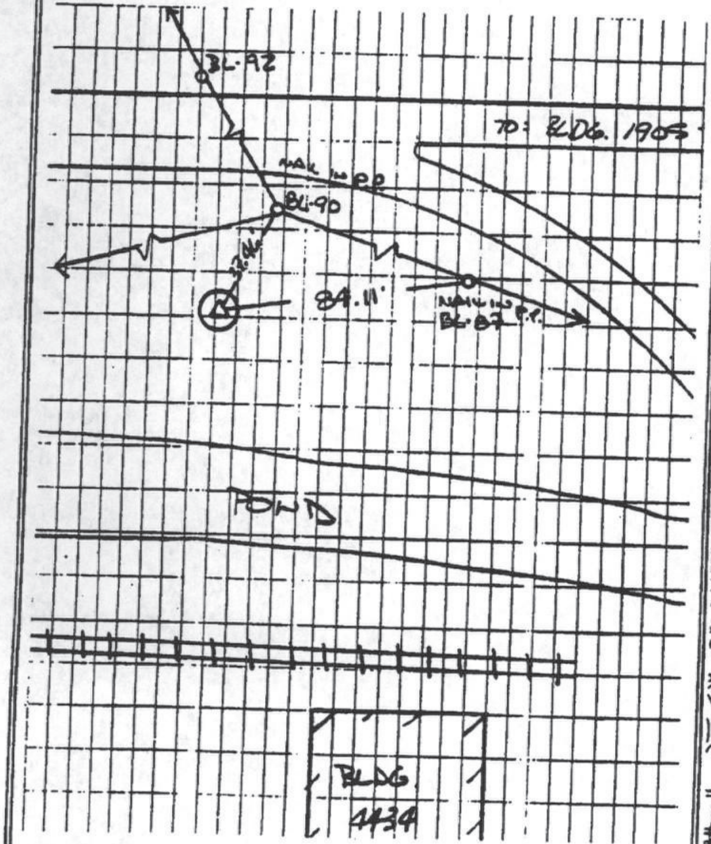
REFERENCE AND RECOVERY DATA SHEET

VIRGINIA COORDINATE SYSTEM OF 1983 - SOUTH ZONE			
STATION	UNITS	NORTHING (Y)	EASTING (X)
Klutz	METERS	1096461.7814	3317529.5764
	U.S. SURVEY FT.	3597308.361	10884261.619

LATITUDE	LONGITUDE
37-11-04.778915	80-33-18.737496

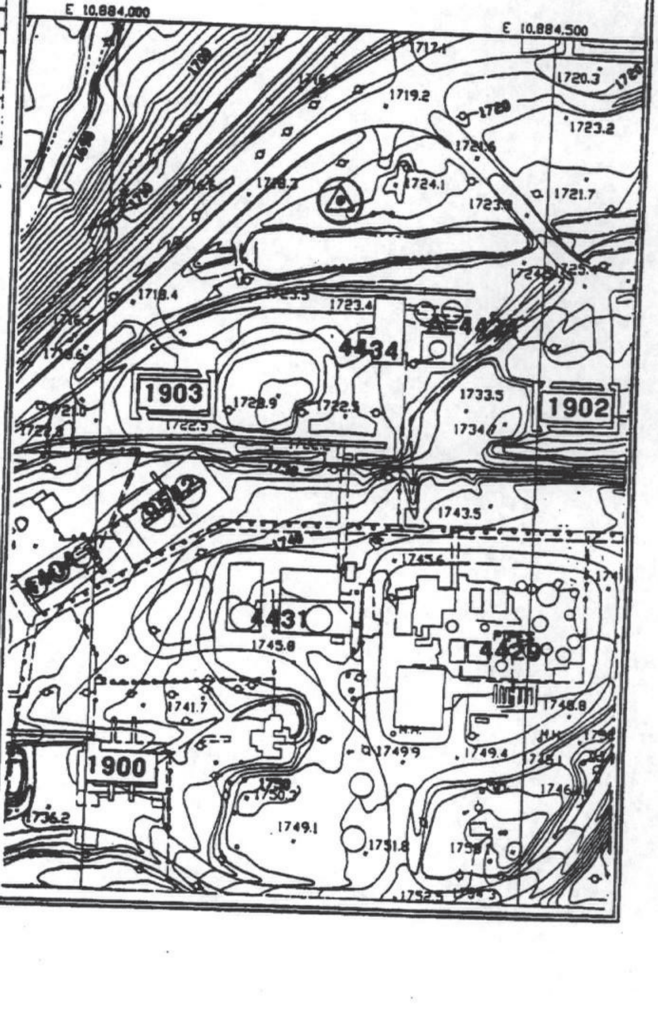
VERTICAL DATA	
ELEVATIONS REFER TO UNITED STATES GEODETIC SURVEY VERTICAL DATUM (1988)	
ELEVATION OF STATION IN FEET = 1720.849	
STATION	FIELD BOOK
Klutz	6452.03R V.C. 1 of 2 pg. 75
COUNTY/STATE	USGS QUADRANGLE
Montgomery County, VA	Radford North

LOCATION SKETCH (NOT TO SCALE)



A 3" disk set in concrete flush with ground surrounded by 3 metal fence posts forming a triangular configuration.

LOCATION MAP (SCALE 1"=200)



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NASHVILLE, TENNESSEE

RADFORD ARMY AMMUNITION PLANT
HERCULES INCORPORATED
RADFORD, VIRGINIA

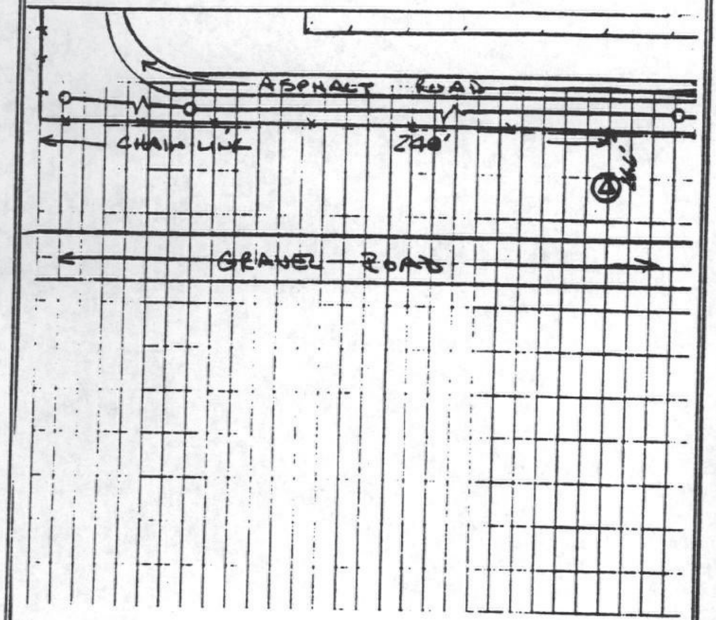
1991 GEODETIC GROUND CONTROL NETWORK MONUMENT SURVEY

REFERENCE AND RECOVERY DATA SHEET

VIRGINIA COORDINATE SYSTEM OF 1983 - SOUTH ZONE			
STATION	UNITS	NORTHING (Y)	EASTING (X)
Elroy	METERS	1095391.1480	3317058.9906
	U.S. SURVEY FT.	3593795.791	10882717.705
LATITUDE		LONGITUDE	
37-10-29.723548		80-33-36.865315	

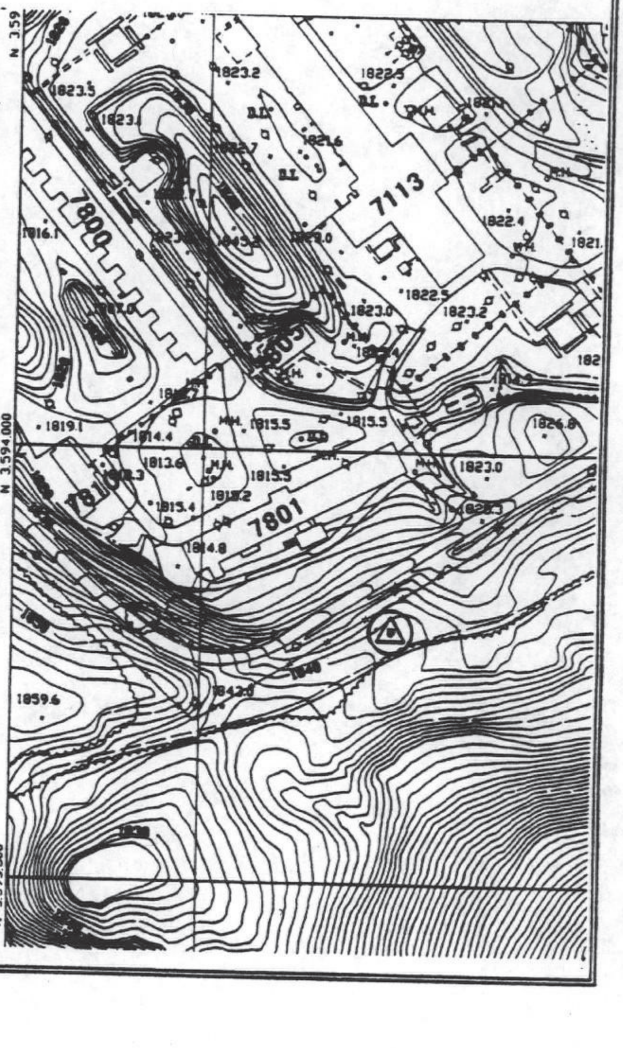
VERTICAL DATA	
ELEVATIONS REFER TO UNITED STATES GEODETIC SURVEY VERTICAL DATUM (1988)	
ELEVATION OF STATION IN FEET = 1838.856	
STATION Elroy	FIELD BOOK 6452.03R V.C. 1 of 2 pg. 69
COUNTY/STATE Montgomery County, VA	USGS QUADRANGLE Radford North

LOCATION SKETCH (NOT TO SCALE)



A 3" disk set in concrete flush with ground, surrounded by three metal fence posts forming a triangular configuration.

LOCATION MAP (SCALE 1'=200)



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NASHVILLE, TENNESSEE

ATTACHMENT 1

Appendix G

PERSONNEL AND TRAINING

Attachment 1

Appendix G

PERSONNEL AND TRAINING

Appendix G.1	**Outline of Training Program**
Appendix G.2	**Job Description Summary**
Appendix G.3	**Personal Training Summary**

ATTACHMENT 1
APPENDIX G
PERSONNEL AND TRAINING

A. Appropriate training shall be completed by all persons at RAAP and/or their consultants who are or may be involved in a task associated with a hazardous waste post-closure care activity. The Permittee shall insure that those individuals responsible for groundwater monitoring, inspections, and repair are appropriately trained. New employees who have as part of their job responsibility tasks which are associated or may be associated with a post-closure care activity shall not work unsupervised until the training requirements in accordance with this permit are completed. Such new employees shall complete required training within six months of their employment date.

B. All training of personnel shall be documented at the time of each completed session and such documentation shall be maintained in the facility files in the operating log for at least three years from the date on which the training was completed. Such documentation shall include the name of each trainee and trainer, date of instruction, and a summary or outline of the training session.

C. All training under this permit shall be reviewed at least annually and updated as necessary. All personnel who are subject to the training requirements under this permit shall be required to review their training at least annually.

D. In general, all personnel who are actively associated or may be associated with the proper inspection and maintenance of the monitoring wells and the proper operation of the monitoring wells are required to read the Permittees' Post-closure Plan and/or Sampling and Analysis Procedures as appropriate. The personnel shall be trained to properly perform their assigned duties including, but not limited to, conducting inspections required by Permit Attachment H, obtaining samples from groundwater monitoring wells and maintaining documentation in accordance with the requirement of this permit.

E. The personnel noted above shall be required under this permit to fully understand the techniques of proper maintenance and operation and maintain appropriate documentation required under this permit. Supervisory staff shall be trained to review and to provide appropriate guidance and/or liaison with the Permittees' management. The Permittee shall provide sufficient opportunity for personnel to acquire a full understanding of maintenance and operation techniques by providing sufficient instruction and/or sponsoring sufficient instruction by professionals who are qualified to provide such instruction.

F. All personnel who are or may be exposed to the hazards associated with the post-closure care activity shall receive the appropriate training and shall utilize the appropriate personnel training as specified by the Occupational Safety and Health Act (OSHA) requirements in 29 CFR 1910.120.

G. The personnel involved in the actual post-closure care activity, specifically the groundwater monitoring wells, within the scope of this permit will be trained in the proper procedures for spent monitoring well sample effluent (i.e., purge water, decontamination fluids) and the Sampling and Analysis Plan and Groundwater Monitoring Program required by **Permit Modules IV, V,** and **VI**. These procedures will ensure continued safe operation and maintenance and compliance with applicable environmental regulations.

H. The facility contact will be responsible for the overall training program, scheduling and documentation of such training and shall serve as the post-closure care Training Director. He/she shall ensure that all sub-contractors are trained in accordance with OSHA 1910.120(3)(2).

I. All personnel required under this permit to receive training shall at minimum shall be instructed in the following areas:

I.1 Area specific management practices regarding post-closure care activities.

I.2. Security and safety.

I.3. General and area specific inspections and record keeping.

I.4. Regulatory updates which affect operations and activities.

I.5. Job function and procedural descriptions of each employees respective role in post-closure care.

J. **Appendix 1** of this Attachment provides a summary of the position descriptions and specific training requirements for personnel who have or may be given tasks associated with post-closure care activity.

ATTACHMENT 1

Appendix G.1

OUTLINE OF TRAINING PROGRAM

Training Outline

1. Personnel Training

The purpose of the introductory and continuing hazardous waste training program is to educate the employees who are responsible for handling hazardous wastes and any post closure care permit related tasks. The program makes known to the employee the hazards of those wastes and the proper procedures to follow in the event of an emergency. The employee training has been and will be completed through formal classes and through on-the-job training given by Permittee.

2. Outline of the Training Program

The permittees have an established section of personnel responsible for the employee training program. The training program at the facility consists of a general orientation, instruction for area-specific procedures, on-the-job training, and a general and continuing training program.

3. Job Title/Job Description

Job titles, job descriptions, and the names of those individuals involved with hazardous wastes at the permitted treatment and storage area are summarized in the table in Appendix G.3. Those job titles and the name of the individual filling it are maintained and kept on file at the facility.

4. Training Content, Frequency, and Techniques

Introductory training for all facility employees consists of general orientation which is provided by the facility training department. Training in operating procedures is given on-the-job by the area foreman. The operating procedures cover subjects such as cleaning equipment and materials, operating equipment and materials, safety rules and precautions, and a step-by-step description of the designated task.

Facility personnel have or will successfully complete the required training program within six (6) months after the effective date of their employment or assignment to the permitted treatment and storage area, or to a new position at the permitted treatment and storage area, whichever is later. Employees will not work in unsupervised positions until they have completed the training requirements described in this section. Facility personnel will also participate in an annual review of the introductory training program.

All personnel who are or may be exposed to the hazards associated with the post-closure care activity shall receive the appropriate training and shall utilize the appropriate personnel training as specified by the Occupational Safety and Health Act (OSHA) requirements in 29 CFR 1910.120.

5. Training Director

The overall responsibility for facility training is the Permittee.

Permittee conducts or oversees all hazardous waste management training and maintenance of personnel training records. The responsibilities for this position include compiling the hazardous waste annual report, notifying health, safety, security, operations, and fire departments of changes in facility status, and reviewing operating procedures. Appropriate changes in facility operating procedures are implemented as a result of training.

Operating personnel receive on-the-job training based on these operating procedures. In this way, the training of the operating personnel in facility procedures is accomplished. The training department manager maintains the records of all training at RFAAP.

6. Relevance of Training to Job Description

All employees receive general plant orientation and training in area specific procedures. Employees then receive on-the-job training which specifically pertains to their area of involvement. If the monitoring is outsourced, the contractor employees will be trained to comply with the requirements of the permit.

Training records are maintained for all facility employees. Training records of all employees involved with hazardous waste management will be reviewed annually in order to ensure that employee training is current and that appropriate and relevant training is coordinated with employee job functions.

Contractor employees training records will be maintained by the contractor and supplied to ATK on an annual basis for recordkeeping.

7. Training for Emergency Response

The training program at RFAAP includes on-the-job training to cover effective response to emergencies.

Due to the reactive wastes at the facility, it is imperative that adequate fire prevention and protection is provided by the facility's fire department. The Fire Prevention and Protection Training Program includes drills, exercises, and hands-on training sessions. Each fireman receives minimum of four hours training each week. A training schedule is prepared and a training record is maintained on each fireman and retained in the fire station. New firemen receive formal and on-the-job training and respond with the fire company to all fires. The basic training period usually covers at least 18 months depending on prior qualification and experience of the new fireman. Training of other employees is conducted during drills and safety meetings. Fire department personnel are available to other people on request to conduct classes, demonstrations and drills.

8. Implementation of the Training Program

There exists at RFAAP, an extensive system and computer program to ensure that required on-the-job training has been conducted with each employee. Based on the job title/description, each employee is assigned two sets of training programs and procedures. The first set is a general plant training set that each new employee gets and the second set of training is an area and job specific set. These training sets have a deadline that they have to be completed by and if they are reaching the deadline or miss it, the employee and/or employee's supervisor will receive notification to that effect. On-the-job training and area specific procedure training is usually preformed by the forman/supervisor to the employees and when complete they will verify the training by signing a sign-off sheet.

Training records and the computer training program is maintained by the training department. The system notifies supervision when training is required.

Current training records of employees involved with hazardous waste management will be kept until closure of the hazardous waste facilities. Training records on former employees will be kept for at least three years from the date the employee last worked at the facility.

APPENDIX G.2
JOB DESCRIPTION SUMMARY

A. **Facility Coordinator:**
Oversees the monitoring wells, unit cap, security fence safety, and inspection and maintenance programs. Has record keeping responsibilities, retains Hazardous Waste Management Facility Permit, inspection checklists and/or logs, and assures that all inspection and maintenance schedules are in accordance with **Permit Attachment 1 Appendix F.**

B. **Monitoring Well Samplers:**
Follows sampling protocol as described in **Permit Attachment 1 Appendix H.** Collects samples and decontaminates equipment. Stabilizes samples and provides transport to appropriate laboratory facility for analysis. Transports and disposes of purge or decontamination water at the on-site water treatment facility. Checks wells for structural integrity and security. Redevelops monitoring wells when necessary. Maintains accurate and detailed records/logs of observations and remediation if required in accordance with **Permit Attachment 1 Appendix H.**

C. **Hazardous Waste Management Unit Inspectors**:
Follows inspection requirements as outlined in Attachment 1, Appendix F. Inspects the HWMU's following the inspection schedule, record keeping requirements, and training. Maintains accurate and detailed inspection forms noting any issues and corrective/preventive actions taken.

Appendix G.3

PERSONNEL TRAINING SUMMARY

APPENDIX G.3

PERSONNEL TRAINING SUMMARY

TITLE	RESPONSIBILITY AND TRAINING REQUIREMENTS	
RCRA Coordinator	Responsible for overall administration of hazardous waste management program as directed by the Army under the terms of the operating contract for the installations. Trained in all aspects of hazardous waste management. Involved in pollution abatement and hazardous waste management. Responsible for Waste Analysis Plan.	
Training Coordinator	Conduct general and continuing training program.	
Plant Protection Manager	Overall monitoring of radio transmissions and HWMU security. Trained in all aspects of hazardous waste emergency response.	
Fire Department Coordinator	Assist in preparation and presentation of training program, maintain pre-fire plan for SWMU's, responds to fire alarms. Trained in hazardous waste emergency procedures.	
Medical Director	Responds to all health emergencies. Responsible for all aspects of hazardous waste emergency health responses.	
Sub-contract Groundwater Samplers	Responsible to have trained personnel to properly collect groundwater samples. Trained to collect groundwater samples.	
Inspector	Responsible for performing the required inspections and trained to inspect the closed units according to the permit.	
Firemen	Respond to hazardous waste emergencies. Trained in all aspects of hazardous waste emergency response. Training conducted with regular fire training and not hazardous waste program.	
Environmental Manager	Functions as alternate to RCRA Coordinator. Responsible for overall plant environmental management. Trained in all	

	aspects of manufacturing and hazardous waste disposal operations.	
VP Operations	Functions as alternate to RCRA Coordinator. Responsible for overall plant management. Trained in all aspects of manufacturing operations.	

NOTE: Names of responsible personnel associated with Permit compliance will be maintained in the facility record at Radford AAP in accordance with 40 CFR § 264.16.d.

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 1

APPENDIX H

GROUNDWATER COMPLIANCE MONITORING PROGRAM – EXAMPLE OF SAMPLING AND ANALYSIS PLAN

FOR ALL POST-CLOSURE CARE UNITS

ATTACHMENT 1

Appendix H

GROUNDWATER COMPLIANCE MONITORING PROGRAM SAMPLING AND ANALYSIS PLAN

TABLE OF CONTENTS

I. INTRODUCTION

The groundwater beneath the closed waste management area (WMA) will be monitored with an upgradient monitoring well, downgradient point of compliance monitoring wells, and compliance monitoring wells. The wells are located as specified on the map presented in **Appendix A.1** to **Permit Attachment 2 and 3** for Units 5 and 16, respectively.

The **Groundwater Sampling and Analysis Plan (SAP)** is an essential part of the Compliance Monitoring Program in that it stipulates the field sampling, laboratory analysis and annual reporting methods to be utilized throughout the post-closure period. The SAP addresses the Compliance Monitoring Program requirements prescribed in the 40 CFR 264.99 and as described in the **Post-closure Care Permit.**

II. PRE-FIELD OFFICE ACTIVITIES

II.A. Summary of Tasks to Be Performed

Quality control is of foremost concern in conducting groundwater monitoring. The first step toward proper quality control is thorough preparation and pre-planning. This is undertaken prior to initiating field sampling and involves review of plans and scheduling to ensure the program is successfully implemented. The following discusses planning activities to be conducted prior to initiating field sampling.

II.B. Office Activities

The following provides a description of the discrete tasks associated with the office activities. These tasks identify the responsibilities of the individual or laboratory and outline procedures to ensure successful completion of each task.

II.B.1 Notification of the Analytical Laboratory(ies)

Prior to each event the analytical laboratory(ies) is informed in writing of the sampling schedule. The laboratory will be informed in ample time of any deviations in the tentative schedule. This task is handled by the Project Manager.

II B 2. Review the SAP and the Health and Safety Plan

Each field team member is required to review the SAP and Health and Safety Plan prior to initiating the sampling event. This initial step will ensure that the objectives of the groundwater monitoring program are attained in a safe and timely manner.

II.B.3 Quality Assurance/Quality Control

Field Quality Assurance/Quality Control (QA/QC) samples are an integral part of a groundwater sampling event. The site-specific **Quality Assurance Project Plan (QAPP) (Appendix 6)** of this SAP provides a detailed description of the QA/QC program.

II B.4. Sample Shipment Containers

Parameters listed in **Appendix I** to **Permit Attachment 1 (Appendix IX to 40 CFR 264),** and **Appendix E** to **Permit Attachment 2 and 3** for Units 5 and 16, respectively, (as appropriate) will be used by the off-site laboratory to develop a bottle list and prepare bottles utilizing the appropriate bottle preparation techniques. Specific bottle preparation procedures are discussed further in **Section VIII**. Bottle and preservative requirements, are listed in this SAP **Appendix 4.**

II B 5. Field Sampling Equipment Requirements

The appropriate quantity and type of sampling equipment will be determined from the SAP. The equipment will be prepared and checked. Equipment cleaning and/or decontamination will be performed following the procedures outlined in **Section IV**.

The calibration of meters will be performed prior to use in the field. Once in the field, the meters will be checked and calibrated as required. **Section IV**. contains specific information regarding the calibration procedures.

III. DOCUMENTATION REQUIREMENTS

III.A. Previous Field Data Sheets

The previous field data sheet should be reviewed and accompany the field team members during the sampling activities. The previous field data sheet is a quick reference document which will identify previous well and site conditions.

III.B. Field Log Book

A site-specific field log book will be utilized while in the field to document all activities. The field log book should, at a minimum, include the following:

a. Plant location and identifying number;

b. Names of field personnel present at the site;

c. Weather information (general);

d. Wells of consideration;

e. Time of sampling and date;

f. Diameter of wells;

g. Total depth of wells;

h. Distance to water in each well;

i. Amount of water in each well;

j. Detection/Amount of any product in each well;

k. Total volume of groundwater to be purged -- purge amount will be based on removing 3 to 5 well borehole volumes until the pH, specific conductance and temperature are stabilized;

l. Groundwater quality measurements (field);
   - pH
   - Specific conductance
   - Temperature
   - Dissolved oxygen (DO)
   - Oxydation/reduction potential (ORP/Eh)

m. Observations for each well;
   - Special procedures to purge/sample
   - Visual observations of the purge/sample water
   - Observations of well integrity (i.e., conditions of casing, lid, pad, or lock)

n. Collection of field Quality Assurance samples, (trip and equipment blanks); and

o. Regulatory agency personnel observing sampling, as appropriate.

III.C. Chain of Custody Forms

Have an appropriate number available for use in the field to accompany all samples collected (this SAP **Appendix 3**.).

III.D. Field Data Sheets

Have an appropriate number available in the field to accompany all samples collected (this SAP **Appendix** 1).

III.E. Notification of Designated Plant Personnel

Prior to the sampling event, the Plant Manager (or appropriate person) will be notified of the proposed sampling date. This should preclude any scheduling problems in regards to sampling and plant operations.

IV. ON-SITE ACTIVITIES

The methods and procedures to be implemented in the field to gather true and representative samples and test data are presented in the following sections. Field procedures are presented in their general order of implementation. Equipment requirements are presented in each section, and quality assurance and record keeping requirements are presented in the latter sections. Strict attention to these procedures is required. Field Quality Assurance/Quality Control procedures are described in this SAP **Appendix 6**.

Procedures for conducting groundwater sampling shall be conducted as described in this section. In summary, the following tasks are discussed:

- Meter calibration;
- Water level measurement procedures;
- Well purging procedures;
- Groundwater sampling procedures;
- Filtering procedures;
- Decontamination procedures;
- Documentation; and
- Safety precautions.

IV.A. Calibration of Meters

The calibration of the pH, temperature, and conductivity meter will be completed at the beginning of each day of sampling and at the end of each day of sampling according to manufacturers' specifications and consistent with *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), 3rd Edition, 1986* (as updated).

IV.B. Measurement of Static Water Level Elevations

Preceding the purging of each well, both the static water level (S.W.L.) and the depth to the bottom of the well shall be measured to +/– 0.01 foot (groundwater elevation mean sea level), referenced to a pre-established, surveyed measurement point clearly marked on the interior wall of the casing. Upgradient wells and wells where constituents have not historically been noted will be measured first, followed by wells where constituents have been noted. Measurements will be taken using an electronic water level tape or interface probe. All measurements for each well will be recorded in the Groundwater Log. Measurements which do not correlate with the previous trends will be verified in the field with different measurement technology, if necessary.

IV.C. Equipment

The static water level measuring device will be constructed of inert materials and will be thoroughly decontaminated in accordance with **Section VIII**. All sampling members will wear clean gloves during sampling and shall change gloves between sampling each well at a minimum. Either an interface probe that is capable of detecting non-aqueous phase liquids (NAPL) as well as water levels or an electric tape will be used to collect water level data. Each is discussed separately below.

IV.C.1. Interface Probe.

Oil/water interface probes are commonly used to detect the presence of floating or sinking NAPL layers. However, the probe can also be used to detect the water level. Procedures for using an interface probe are:

a. The probe should be lowered slowly inside each well. When water is detected, an intermittent tone will sound signifying water has been encountered. When the intermittent tone is heard, the water level measurement is read directly from the calibrated tape.

b. When a floating layer is encountered, a steady tone is heard. Continue lowering the probe (observe and record the calibrated tape) until the steady tone stops. The measurement on the tape between when the steady tone began and when it stopped will determine the thickness of the NAPL layer. This procedure can also be used to determine the presence (and thickness) of floating or sinking NAPL layers.

c. All measurements will be recorded to the nearest one hundredth of a foot (0.01).

d. Decontamination of the probe will be by performing a distilled water rinse and wiping the probe with a clean cloth, followed by a methanol then distilled water rinse.

IV C.2 Electric Probe Method

The electric probe method for measuring water levels is as follows:

a. Slowly lower the probe into the well casing. When the probe contacts water a steady tone will be emitted. Observe and record this reading from the calibrated tone.

b. All measurements will be recorded to the nearest one hundredth of a foot (0.01).

c. The probe will be decontaminated by performing a distilled water rinse and wiping the probe with a clean cloth, followed by a methanol rinse then distilled water.

V. CALCULATION OF STATIC WATER/PURGE VOLUME:

The static water level and total depth will be used to calculate the volume of stagnant water in the well and provide a check on the integrity of the well (e.g., identify siltation problems), as well as characterize changes in hydraulic conditions that occur over time.

V.A. Purge Volume

The volume of stagnant water to be purged shall be calculated according to the formulae presented in Appendix 2 of this SAP. Purge volume calculations will be recorded in the Groundwater Log and included in the monitoring report. At least three borehole volumes (assuming 30% porosity in the filterpack) will be purged from the monitoring well prior to sampling.

V.A 1 If the wells prove to be low yield, wells will be evacuated to dryness once and will be purged at a rate which will not cause recharge water to be excessively agitated. Dry and low recharge rates will be noted in the field observations.

V.A.2. If a well is either purged dry, or, to a dense NAPL layer, sufficient time must be allowed for recovery prior to sample collection.

V.A 3 All purge water and decontamination fluids will be containerized and disposed of in an on-site wastewater treatment system if available or a publicly owned treatment facility with approval.

V.B. Micro (or Low Flow)-purging

If micropurging or low-flow purging techniques or low-flow are utilized, EPA Region III guidance shall be followed. This guidance is included as this SAP **Appendix 8**.

This section specifies the low-flow purging equipment, the low-flow purging procedures, and the purging observations that be followed prior to the actual collection of any ground water samples.

V.B.1 Introduction and Overview

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. The stagnant water within the casing is not representative of the in-situ groundwater quality and should be removed so that formation water can be sampled.

V B 2 Purging Equipment

A dedicated bladder pump has been installed in each monitoring well. Flow rates on the order of 0.1 - 0.5 l/min will be used; however, this is dependent on site specific hydrogeology. Water quality indicator parameters are used to determine purging needs. After the field parameters (pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and temperature) have stabilized purging is considered complete. In-line flow cells will be used to continuously measure the above parameters. All equipment used during low-flow purging operations, shall be properly decontaminated using the procedures specified above.

V.B.3 Low-flow Purging Procedures

a. The bladder pump intake will be lowered to the top of, or just below, the top of the screen (refer to completion diagrams). During pump start-up, drawdown may exceed the 0.3 feet target and then recover; therefore, the stabilized drawdown value will be recorded, not the initial drawdown. The water level will not be allowed to fall to the intake level (if the static water level is above the well screen, the water level will not lowered to the screen).

b. To remove the stagnant formation water, the dedicated, bladder pump will be started at the lowest speed setting and slowly increased until discharge occurs. The water level will then be checked. The pump speed will be adjusted until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceed 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Water level and pumping rates will be monitored and recorded every three minutes during purging. Any pumping rate adjustments (both time and flow rate) will be recorded in the field logbook. Pumping rates will, as needed, be reduced to the minimum capabilities of the bladder pump (for example, 0.1 ± 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments will be made in the first fifteen minutes of pumping in order to help minimize purging time.

c. The final purge volume will be greater than the stabilized drawdown volume plus the extracted tubing volume. This volume will be calculated by the following equation:

$$V_{total} = V_{tubing} + V_{drawdown}$$

$$V_{tubing} = (h_{tubing})(\pi r_{tubing}^2)$$

$$V_{drawdown} = (h_{water} * \pi r_{well}^2) - (h_{purged} * \pi r_{well}^2)$$

d. Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates. If the recharge rate of the well is lower then extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well will be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (the intake will not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

V B.4 Monitoring Indicator Field Parameters

During well purging, indicator field parameters (temperature, specific conductance, pH, Eh, DO) will be monitored every three minutes (or less frequently, if appropriate). Purging will be considered complete and sampling may begin when all above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three-minute intervals, are within the following limits:

CONSTITUENT	VARIABILITY
DO	10%
Specific conductance	3%
Temperature	3%
PH	± 0.1 unit
ORP/Eh	± 10 millivolts

All measurements will be obtained using a transparent flow-through-cell, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, the cell will be disconnected while the pump remains running. The cell will be cleaned and reconnected and monitoring activities will continue.

The flow-through-cell will be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off, water in the cell must not drain out. Monitoring probes will remain submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe will come first (this parameter is most susceptible to error if air leaks into the system).

V.B.5 Purging Observations

Water level, extraction rate, and drawdown information will be recorded in a field logbook. The extraction rate (final pump dial setting) will be duplicated in future sampling efforts.

Collect the purge water in a clean 5 gallon bucket in order to estimate the rate of flow and to check temperature and specific conductance. Examine purge water for the presence of immiscible layer.

VI. WELL EVACUATION

All monitoring wells will be purged prior to sample collection to assure collection of representative groundwater samples. Wells will be purged until, at a minimum, three borehole volumes of water are removed from each well and until pH, conductivity and temperature of the purged water has stabilized prior to sampling. If pH, conductivity and temperature are not stabilized after removing three borehole volumes, a maximum of five borehole volumes will be removed.

VI.A. NAPL Layers

If NAPL layers are detected in the well, a peristaltic pump is the preferred method for well purging. This technique should reduce mixing of the NAPL within the water column. If a peristaltic pump is not feasible for well purging, then hand bailing will be utilized.

VI.B. pH and Specific Conductance

Prior to and after sampling, two measurements of pH, specific conductance and temperature will be determined for each well.

VI.C. Equipment

Well purging is completed either by bailing or pumping techniques. Pumps are typically used for purging and removing NAPL layers. The following summarizes the procedures of some pumps commonly used for groundwater purging and sampling. Pumps that can be employed include, but are not limited to, peristaltic pumps, centrifugal pumps, submersible pumps, and air bladder pumps.

VI C.1 Bailing:

The following outlines well purging techniques using hand bailers.

a. Place plastic sheeting (or garbage bags) around the well casing to create a clean surface for the placement of the sampling cord and equipment.

b. Use a clean stainless steel bailer on each well to be purged. Bailers are decontaminated using procedures outlined in **Section VIII**.

c. New surgical or nitrile gloves will be used for each well.

d. Remove the aluminum foil to expose the bailer's "eye." Thread new nylon cord through the bailer's "eye" and tie securely to prevent loosening. Remove the remainder of the protective foil from around the bailer and slowly lower the bailer to the well bottom if NAPL is not present. If LNAPL is present, remove the NAPL (if possible) using procedures outlined in **Section VIII**. before lowering the bailer in the well. If only a sinking NAPL layer is present, lower the bailer to a level that does not cause mixing of NAPL. Once the depth of the bailer has been determined, remove an additional length of cord and tie it securely to the well head to serve as a safety line for the bailer.

e. Begin purging by raising the bailer cord and collecting the cord on the plastic sheeting.

f. Purged water will be handled following the procedures outlined in **Section V.A.3**.

VI.C.2. Peristaltic Pump

Peristaltic pumps are operated above ground next to the well. Peristaltic pumps are generally used in wells where the water levels are less than 20 to 25 feet below grade. The following outlines the procedures for using a peristaltic pump:

a. A new nalgene suction line is used on each well being purged. New medical grade silicon pump head tubing will also be used if the pump is utilized for sampling.

b. If a peristaltic pump is used to collect a sample (e.g., the well casing is bent preventing the passage of a bailer), the choice of tubing used to collect the sample will be contingent on the parameters of interest. For example:

c. If conventional or metal parameters are being analyzed, standard nalgene tubing is sufficient for sample collection; or

d. If volatile or semi-volatile parameters are the constituents of interest, Teflon tubing is used for sample collection.

e. The suction line should be lowered to a depth in the water column that assures continual pumping, should drawdown of the water column occur. Additionally, the location of the suction line should be placed to avoid disturbing any NAPL layer. If a "floating" NAPL layer is encountered, this layer should be either removed with a pump or a bailer during purging. If a "sinking" NAPL layer is encountered, the layer shall be removed in accordance with **Condition V.B** of this SAP. The suction line should be placed above the layer to avoid this layer regardless of well water drawdown if possible.

f. Monitor the pumping to ensure proper pump operation and assure continuous discharge. If drawdown occurs, lower the tubing deeper into the water column.

g. When the required amount of water is purged from each well, allow for sufficient recovery before sampling.

h. See **Section V.A.3**. for disposition of purge water.

i. The suction line can be dedicated to the well for reuse in subsequent sampling events.

VI.C 3 Bladder Pumps:

The bladder pump is a gas operated positive displacement submersible well pump that uses inert compressed gas, (e.g., nitrogen) to inflate an internal bladder which pumps water up the discharge line. These pumps are used when large volumes of water must be purged from monitoring wells. Usually these pumps are used on wells with diameters greater than two inches and depths up to 150 feet. The line assembly is dedicated for use on one well only. After use, the tubing is wrapped, marked, and stored for future use in the well to which it is dedicated. The following describes the operation and use of the bladder pump:

a. Connect the line assembly to the pump by first attaching the cable and then connecting the sample and gas lines.

b. Lower the pump down the well by unrolling the line off the spool, until the pump touches bottom (if sinking NAPL is not present). Raise the pump to the desired position inside the well, allowing sufficient room for drawdown of the water column. If NAPL layers are present, the same procedures discussed previously for NAPL removal should be followed for the air bladder pump.

c. Secure the cable to hold the pump at the desired depth.

d. Connect the gas line to the control box. The discharge line should be placed in a container (e.g., 55-gallon drum) to collect the purged water.

e. Connect the gas supply to the control box and adjust the pressure according to the manufacturer's manual.

f. Turn on the control box and adjust inflate delay to obtain the best pumping cycle.

g. The pumping rate should be calculated to determine the length of time the pump should run to purge the well based on purging criteria.

h. When a sufficient amount of water has been purged, the well should be sampled using a laboratory cleaned stainless steel bailer.

i. Tubing is used on one well only and after each sampling it is disposed of properly.

j. Purge water will be handled following one of the approved procedures outlined in Section V.A.3.

VI C 4 Submersible Pumps

Submersible pumps are used when depths to groundwater exceed 20 feet and large volumes of water are purged. Submersible pumps can either be portable or fixed depending on use. When possible, the submersible pump apparatus is removed to allow for sampling with a laboratory cleaned stainless steel bailer. If this is not feasible, the submersible pump will remain intact and will be used to collect the sample. When economically feasible, submersible pumps will be dedicated to each well. However, in some cases this is not economically feasible and the same pump must be used in several wells. Submersible pumps will be decontaminated between wells when reused. The following describes use of the submersible pump:

a. The submersible pump should be lowered to a depth in each well between the middle to bottom screened portion of each monitoring well. The safety line should be secured to the well casing.

b. Connect the power cord to the power source (generator) and turn on the pump.

c. Monitor the pumping rate and lower the pump if drawdown of the water column occurs. The pumping rate will provide a means to assess when three borehole volumes are removed. Water will be pumped into 55-gallon drums/containers. Pumping will continue until purge criteria are met.

d. If the well is pumped dry, allow sufficient time for the well to recover before sampling.

e. Purge water will be handled following one of the procedures outlined in **Section V.A.3**.

VI C.5 Purger Pump

The purger pump is used for purging wells up to 60 feet deep. The purger pumps (models ES40 and ES60) have an output of up to 3 gpm, are 1.5 inches in diameter and are less than 13 inches in length. The ES60 model will pump up to 60 feet of head using a 1/2 inch ID hose. The length of lead line supplied with the pump is 60 feet. On one end of the lead line is the battery clips and the other end is the pump. Directions for using the purger pump are as follows:

a. Connect the required length of tubing to the pump and completely submerge the pumping water.

b. There is no control box or on/off switch. The pump will begin pumping when the connection is made to the 12 volt battery.

c. To prevent air cavitation in the pump, start the pump and allow to run for four seconds then turn the pump off for four seconds. Repeat turning the pump on and off for two more rounds and the air should be removed from the pump.

d. The pumps have an outlet for a 3/8 inch hose but can be adapted for a 1/2 inch hose by using a 1/2 inch nipple adaptor.

e. After each use of the pump, draw clean water through the pump.

VII. MONITORING WELL SAMPLING

Groundwater samples shall be collected at wells specified in **Permit Module V**. at the specified frequency. Annually, samples for all constituents in **Appendix I to Permit Attachment 1 (Appendix IX to 40 CFR 264)** will be collected at specified downgradient point of compliance wells.

VII.A. Compliance Monitoring.

The wells specified in the Compliance Monitoring Program shall be sampled at the specified frequency for all constituents listed in **Appendix E to Permit Attachments 2 and 3** (“**Groundwater Compliance Monitoring List**”) for Units 5 and 16, respectively,. Samples shall be collected from each well and analysis shall be obtained using the analytical method specified in the Attachment.

VII.B. Annual Appendix IX to 40 CFR Part 264 Sampling

The list of the parameters, constituents, test methods, and detection limits required for the **Appendix IX to 40 CFR Part 264** analyses is located in **Appendix I to Permit Attachments 1**. The Permittee may resample for any newly detected **Appendix IX to 40 CFR Part 264** constituent within 30 days to confirm or refute the detection. All newly confirmed **Appendix IX to 40 CFR Part 264** constituents must be added to the Compliance list.

VII.C. Sampling Procedures

VII.C.1. Low Yield

Where wells prove to be of low yield, sampling will be performed as soon as recovery volume is sufficient to sample for each parameter/constituent.

VII C 2. Volatile/Gases

When collecting samples where volatile constituents or gases are of interest using a positive gas displacement bladder pump, pumping rates will not exceed 100 milliliters/minute.

VII C 3. Large Volume

Once the portions of the sample reserved for the analysis of volatile components have been collected, the Permittee may use a higher rate, particularly if a large sample volume must be collected.

VII C 4 Filtration

Groundwater samples for dissolved metals analysis will be prepared by field filtration using a 0.45 micron filter.

VII C.5 Sample Collection

All samples will be transferred directly into the container that has been specifically prepared for the preservation and storage of compatible parameters. The type of sample containers and sample handling and preservation procedures for the parameters of interest are listed in **Appendix 4** of this SAP.

a. Containers utilized for sampling will be new pre-cleaned containers or used containers that have been cleaned. Used containers will be cleaned based on the analyte of interest.

b. Used containers intended for metals analyses must be thoroughly washed with a non-phosphate detergent and tap water, and rinsed with either a (0.1 N) nitric acid or hydrochloric acid, followed by a rinse of tap water and finally a deionized water rinse.

c. Used containers intended for organic analysis will be thoroughly cleaned in accordance with laboratory specifications.

VII.C 6. Sample collection sequence

Temperature, pH, and specific conductance will be taken at the start and ending of sampling as a check on the stability of the water samples over time. Four (4) replicate measurements of pH and specific conductivity will be recorded in the Groundwater Log shown in **Appendix 1**. of this SAP for four (4) representative water samples.

Samples will be collected and containerized for each parameter and constituent in the order of volatilization sensitivity of the parameters as follows:

- Initial pH, Temperature, and Conductivity
- Volatile Organics
- Total Organic Halogens
- Total Organic Carbon
- Extractable Organics (Semi-Volatile Organics)
- Pesticides/Herbicides
- PCBs
- Total Metals
- Dissolved Metals
- Total Phenols
- Cyanide
- Sulfate, Fluoride, and Chloride
- Nitrate,
- Final pH, Temperature, and Conductivity

VII.D. Equipment:

Monitoring wells will be sampled using Teflon bladder pumps with dedicated Teflon-coated tubing, bailers, or other appropriate equipment. If dedicated equipment is used, then no decontamination will be required; however, non-dedicated equipment will be disassembled and thoroughly decontaminated using the procedures in **Section VIII**.

VII.D.1. Bailing and Sample Collection

The following outlines well purging and sampling techniques using hand bailers.

a. Place plastic sheeting (or garbage bags) around the well casing to create a clean surface for the placement of the sampling cord and equipment.

b. Use a clean stainless steel bailer on each well to be sampled. Bailers are decontaminated using procedures outlined in Section VIII.

c. New surgical or nitrile gloves will be used for each well.

d. A separate, cleaned stainless steel bailer is used to collect samples from each monitoring well. Samples are collected after the well recharges and collected according to the volatilization order.

e. VOC samples will be collected with a bottom-filling stainless-steel bailer to prevent VOC degassification.

f. Samples are collected and preserved in accordance with the analytical method.

g. Preserved samples are placed in a container and cooled to a temperature of 4 + 2°C.

h. Before the shipping container is sealed, a chain-of-custody form is completed for each cooler containing samples.
i. Each cooler is sealed and shipped overnight or hand delivered to the analytical laboratory.

VII.D.2. Peristaltic Pump

Peristaltic pumps are operated above ground next to the well. Peristaltic pumps are generally used in wells where the water levels are less than 20 to 25 feet below grade and volatilization of samples is not an issue. The following outlines the procedures for using a peristaltic pump:

a. A new medical grade silicon pump head tubing will be used for sampling. Teflon tubing shall be used for sampling.

b. The suction line should be lowered to a depth in the water column that assures continual pumping, should drawdown of the water column occur. Additionally, the location of the suction line should be placed to avoid disturbing any NAPL layer. If a "floating" NAPL layer is encountered, this layer should be either removed with a pump or a bailer during purging. If a "sinking" NAPL layer is encountered, the suction line should be placed above the layer to avoid this layer regardless of well water drawdown.

c. Monitor the pumping to ensure proper pump operation and assure continuous discharge. If drawdown occurs, lower the tubing deeper into the water column.

d. The suction line can be dedicated to the well for reuse in subsequent sampling events.

VII D 3 Bladder Pumps

The bladder pump is a gas operated positive displacement submersible well pump that uses inert compressed gas, (e.g., nitrogen) to inflate an internal bladder which pumps water up the discharge line.

These pumps are used when large volumes of water must be purged from monitoring wells. Usually these pumps are used on wells with diameters greater than two inches and depths up to 150 feet. The line assembly is dedicated for use on one well only. After use, the tubing is wrapped, marked, and stored for future use in the well to which it is dedicated. The following describes the operation and use of the bladder pump:

a. Connect the line assembly to the pump by first attaching the cable and then connecting the sample and gas lines.

b. Lower the pump down the well by unrolling the line off the spool, until the pump touches bottom (if sinking NAPL is not present). Raise the pump to the desired position inside the well, allowing sufficient room for drawdown of the water column. If NAPL layers are present, the same procedures discussed previously for NAPL removal should be followed for the air bladder pump.

c. Secure the cable to hold the pump at the desired depth.

d. Connect the gas line to the control box. The discharge line should be placed in a container (e.g., 55-gallon drum) to collect the purged water.

e. Connect the gas supply to the control box and adjust the pressure according to the manufacturer's manual.

f. Turn on the control box and adjust the inflate delay to obtain the best pumping cycle.

g. When a sufficient amount of water has been purged, the well should be sampled using a laboratory cleaned stainless steel bailer.

h. Tubing is used on one well only and after each sampling it is disposed of properly.

VII D.4. Submersible Pumps.

Submersible pumps are used when depths to groundwater exceed 20 feet and large volumes of water are purged. Submersible pumps can either be portable or fixed depending on use. When possible, the submersible pump apparatus is removed to allow for sampling with a laboratory cleaned stainless steel bailer. If this is not feasible, the submersible pump will remain intact and will be used to collect the sample.

When economically feasible, submersible pumps will be dedicated to each well. However, in some cases this is not economically feasible and the same pump must be used in several wells. Submersible pumps will be decontaminated between wells when reused.
The following describes use of the submersible pump:

a. The submersible pump should be lowered to a depth in each well between the middle to bottom screened portion of each monitoring well. The safety line should be secured to the well casing.

b. Connect the power cord to the power source (generator) and turn on the pump.

c. Monitor the pumping rate and lower the pump if drawdown of the water column occurs.

d. If the well is pumped dry, allow sufficient time for the well to recover before sampling.

VIII. DECONTAMINATION PROCEDURES

VIII.A. Lab Cleaning

The following describes the laboratory cleaning procedures. NOTE: A methanol or ethanol rinse may be required initially if NAPL is noted on sampling equipment and all gross material should be removed from all equipment while at the job site.

a. Remove gross material from the sampling equipment by brushing and rinsing with tap water;

b. Wash with non-phosphate detergent and water;

c. Using a brush, wash equipment thoroughly with laboratory detergent and hot water to remove any particulate matter or surface film.

d. Rinse equipment thoroughly with hot tap water.

e. Place equipment in a ten percent nitric bath rinse followed by distilled water rinse.

f. Rinse equipment thoroughly with deionized water.

g. Rinse equipment twice with ethanol or methanol.

h. Rinse equipment twice with deionized water and air dry in an oven for two to three hours at 400°C.

i. Wrap equipment in one layer of aluminum foil. Roll edges of foil into a "tab" to allow for easy removal.

j. Rinse the stainless steel or metal sampling equipment thoroughly with tap water in the field as soon as possible after use.

VIII.B. Field Cleaning

The following describes the field cleaning procedures:

a. Remove gross material from the sampling equipment by brushing and rinsing with tap water;

b. Wash with non-phosphate detergent and water;

c. Using a brush, wash equipment thoroughly with laboratory detergent and hot water to remove any particulate matter or surface film.

d. Rinse equipment thoroughly with hot tap water.

e. Rinse with distilled water;

f. Rinse with a 10% nitric acid solution if metals are a constituent;

g. Rinse with ethanol or methanol and distilled water; and

h. Allow to air dry or dry with chemical-free paper towels.

IX. QA/QC Program

IX.A. Field QA/QC

Field Quality Assurance/Quality Control requires the routine collection and analysis of trip blanks to verify that the sample collection and handling process has not affected the quality of the samples. A complete description of required activities is contained in Appendix 6.

IX A 1 Trip Blank

One set of trip blanks for all volatile organics will be prepared prior to leaving the laboratory to ensure that the sample containers or handling process has not affected the quality of the samples. Blank containers, preservatives, handling and transport will be identical to those used for water samples.

IX.A 2. Equipment Blank.

The equipment blank is collected by passing laboratory-demonstrated analyte-free water through or over clean sample equipment, and then placing the water in an empty sample container for analysis. The equipment should have been decontaminated prior to sampling using the procedures described in **Section VIII.** The transfer should occur in the field location with the highest potential for contamination. One set of equipment blanks for all required analyses will be collected and containers, preservatives, handling and transport will be identical to those used for water samples.

IX.A.3 Duplicate samples

Duplicate samples shall be collected at an average frequency of ten percent to assess the sample collection and handling procedures. During the course of analysis, quality control data and sample data shall be reviewed to identify questionable data.

IX A 4. Sample Transport and Handling

Sample transport and handling will be strictly controlled to prevent sample contamination. Chain-of-Custody control for all samples shall be conducted as described in this SAP **Appendix 3.**

IX.A 5 Field Logbook.

The field technician will keep an up-to-date field logbook documenting information pertaining to the technician's field activities. **Appendix 1** of this SAP provides an example of a Groundwater Log that must be completed for each sampled well.

IX.B. LABORATORY QA/QC CONTROL OBJECTIVES

The laboratory QA/QC objectives include, but are not limited to: precision, accuracy, sample custody, method detection limits, instrument calibration, analytical procedures, and laboratory audits. These QA/QC objectives are documented in the Quality Assurance Project Plan (**Appendix 6** of this SAP) or the Example Laboratory Quality Assurance Manual, provided as **Appendix 7** of this SAP. QA/QC procedures will be used at all times. The laboratory shall assure the accuracy and precision of all analytical determinations.

IX B.1. Laboratory Analysis

The parameters and constituents to be analyzed include organic and inorganic constituents which have been used at the facility or have been detected in the facility's waste and/or groundwater (**Appendix E to Permit Attachments 2 and 3 for Units 5 and 16**, respectively, "**Groundwater Compliance Monitoring List**"). **Appendix E to Permit Attachments 2 and 3 for Units 5 and 16, respectively,**. lists analytical methods and detection limits that must be used in analysis.

Samples for all the constituents on Appendix IX to 40 CFR Part 264 shall be collected at least annually. **Appendix I to Permit Attachments 1**. lists the parameters, constituents, test methods, and detection limits required for the Appendix IX analyses. All newly confirmed Appendix IX to 40 CFR Part 264 constituents must be added to the Groundwater Compliance Monitoring list (**Appendix E to Permit Attachments 2 and 3 for Units 5 and 16, respectively,**) and be analyzed at least quarterly.

IX.B.2. Internal quality control

Internal quality control checks shall be undertaken regularly to assess the precision and accuracy of analytical procedures. Internal quality control checks shall include use of calibration standards, standard references, duplicates and spiked/fortified samples.

IX B.3 Calibration

Calibration standards shall be verified against standard reference from an outside source. Calibration curves shall be comprised of a minimum of one blank and three standards. Samples shall be diluted if necessary to ensure analytical measurements fall on the linear portion of the calibration curve.

IX.B 4. Duplicate samples.

Duplicate samples shall be processed at an average frequency of ten percent to assess the precision of testing methods, and standard references shall be processed monthly to assess accuracy of analytical procedures. Spiked/fortified samples shall be carried through all stages of sample preparation and measurement to validate the analytical accuracy. During the course of analysis, quality control data and sample data shall be reviewed to identify questionable data.

IX B 5 Sequential Dilutions.

In the event that sequential dilutions are required to ensure that the target analyte concentration is within the linear range of the instrument, results of all runs will be reported. Elevated detection limits due to dilution shall be avoided. The results from each run shall be reported.

X. RECORD KEEPING AND REPORTING

X.A. Documentation

Certain documents should be completed before, during, and after each sampling event. These documents include site data sheets, chain-of-custody sheets, field data sheets, and project notes sheets.

X A 1 Chain-of-Custody Sheets

When the field team sends samples to the appropriate analytical laboratories, each sample shuttle containing samples must be accompanied by a chain-of-custody form. The Permittee shall ensure that Chain of Custody requirements in Appendix 6 are adhered to by samplers.

X A.2 Field Data Sheets

The field data sheets in Appendix 1 serve as an example field logbook for information pertaining to each specific project. The basic project information such as the name of the project, the date of sampling, and the names of the technicians collecting the samples is contained on these forms. These forms are specifically designed for the collection of samples from groundwater monitoring wells. Information pertaining to the wells being sampled is recorded on these forms. Observations are made on the integrity of the wells being sampled and the physical characteristics of the water in the wells. The original copy of the field sheets is stored in the field team's project files and a copy shall be included in the monitoring report.

X A 3 Site Data Sheet

The site data sheet (**Appendix 1**.of this SAP) contains information specific to the sampling program. The following information is provided on the site data sheet: site name, location, sampling frequency, wells to be sampled, site constituents, and pertinent site notes. The Project Manager is responsible for revising and submitting the site data sheets to the field team members and the analytical laboratory.

X.B. Reporting Requirements

X.B.1 Groundwater Monitoring Results

The Permittee shall report concentrations or values of the parameters and constituents listed in **Appendix E to Permit Attachments 2 and 3 ("Groundwater Compliance Monitoring List"**) for Units 5 and 16, respectively, and **Appendix I to Permit Attachment 1 ("Annual Appendix IX to 40 CFR Part 264 Sampling"**) for each required groundwater monitoring well as required by **Permit Module V**.

X.B.2. Annual Report:

The Permittee shall submit an Annual Groundwater Monitoring Report by March 1st of the following year for the year beginning January 1st and ending December 31st as specified by **Permit Module V**.

APPENDIX H.1.

GROUNDWATER LOG EXAMPLE

Appendix H. 1
GROUNDWATER LOG EXAMPLE

SAMPLING EVENT ____________________________________.

LOCATION ____________________________________.

WELL NO. ____________ Date____________________________.

WEATHER ____________________________________.

TEMPERATURE____________________________________.

MEASUREMENT TEAM____________________________________.

TIME WELL CASING UNLOCKED ____________________________.

DEPTH TO WATER FROM TOP OF (INNER/OUTER) CASING________________FT

DEPT OF WELL FROM TOP (INNER/OUTER) CASING ________________ FT

STATIC WASTER LEVEL ________________________________ FT

MEASUREMENT TECHNIQUE: [ ]WATER LEVEL INDICATOR

[ ]OTHER/EXPLAIN ________________.

<u>FORMULAS FOR DETERMINING PURGE VOLUME</u>

Water Level above Sand Pack:

$$3 \times [(\pi r_b^2 h_s - \pi r_c^2 h_s) \times 0.3 + (\pi r_c^2 h_w)]$$

Water Level below Sand Pack:

$$3 \times [\pi r_b^2 h_w - \pi r_c^2 h_w) \times 0.3 + (\pi r_c^2 h_w)]$$

where:

r_b = radius of boring = ________________.

r_c = radius of casing = ________________.

h_s = height of sand = ________________.

h_w = height of water = ________________.

IMMISCIBLE LAYERS: [ ]YES [ ]NO

DETECTION METHOD : [ ]VISUAL [ ]OTHER________________.

COLLECTION METHOD: [ ]BEAKER [ ]OTHER________________.

Appendix H. 1 (cont'd)

SAMPLE IDENTIFICATION________________________________.

PURGE TEAM ________________________________.

PURGE PROCEDURE/EQUIPMENT: [ ]TEFLON BAILER [ ]WELL PUMP

URGE TIME____________ PURGE VOLUME____________________.

PURGE APPEARANCE________________________________.

COMMENTS________________________________.

SAMPLING EVENT________________________________

WELL NO.__________________ DATE ______________________

SAMPLING TEAM________________________________

SAMPLING PROCEDURE/EQUIPMENT: [ ]TEFLON BAILER [ ]WELLPUMP

SAMPLING TIME

pH METER CALIBRATED WITH BUFFERS: [ ]4 [ ]7 [ ]10

pH METER CALIBRATED BY________________________________

CONDUCTIVITY METER CALIBRATED WITH STANDARD SOLUTION OF

____________________UMHOS/CM BY____________________

pH(S.U.) ____________, ____________, ______________, ______________.

TEMPERATURE(°C) ____________, ______________, __________, __________.

CONDUCTIVITY (UMHOS/CM) ________, __________, ___________, __________.

SAMPLE COLLECTION TIME:CONTAINER*/PRESERVATIVE

(1)___________VOC(G/NONE) (2)_________TOX(A/HNO_3)

(3)___________TOC(a/H_2SO_4) (4)_________COD(A/H_2SO_4)

(5)___________O&G/TPH(A/HCL) (6)_________PHEN(A/H_2SO_4)

(7)___________N(/) (8)__________PHOS(A/H_2SO_2)

(9)___________SO(/) (10)________TMET(P/HNO_3)

(11)__________DMET(P/NONE) (12)________pH,COND(P/NONE)

(13)__________CHLORIDE(P/NONE) (14)________SMLL TST(P/NONE)

(15)______________ (/) (16)________(/)

Appendix H. 1 (cont'd)

FINAL pH(S.U.) ____________ FINAL TEMPERATURE(°C) __________________.

FINAL CONDUCTIVITY(UMHOS/CM) __________________________________

LOCKED WELL AT ____

COMMENTS ____

____

____

____

G=GLASS, A=AMBER GLASS BOTTLE, P=PLASTIC(POLYETHYLENE)

APPENDIX H. 2

EXAMPLE PURGE VOLUME CALCULATIONS

Appendix H. 2

CALCULATIONS OF PURGE VOLUME

Determine purge volume as follows:

Water Level above sand pack:

$3 \text{ x } [(\pi r_b^2 h_s - \pi r_c^2 h_s) \text{ x } 0.3 + (\pi r_c^2 h_w)]$

Water Level below sand pack

$3 \text{ x } [(\pi r_b^2 h_w - \pi r_c^2 h_w) \text{ x } 0.3 + (\pi r_c^2 h_w)]$

where:

r_b = radius of boring
r_c = radius of casing
h_s = height of sand
h_w = height of water

This calculation must be based upon 30% filter pack volume. Once the volume to be purged is known, purging can begin. The purge water will be collected, containerized and disposed of in accordance with local, state and federal regulations and laws.

Appendix H. 3

EXAMPLE CHAIN OF CUSTODY FORM

ATTACHMENT 1

APPENDIX H.3

EXAMPLE CHAIN OF CUSTODY FORM

Typical Field Custody Seal

NAME AND ADDRESS OF ORGANIZATION COLLECTING SAMPLES

Person Collecting Sample ______________________ Sample No. __________
(signature)

Date Collected ______________________ Time Collected __________

Place Collected ____

REF: SW-846, 3rd Edition

Part I: Field Section

Collector ____________ Date Sampled ________ Time ______ Hours

Affiliation of Sampler ____________

Address ________________________
number street city state zip

Telephone ( ) ________ Company Contact ____________

LABORATORY SAMPLE NUMBER	COLLECTOR'S SAMPLE NO.	TYPE OF SAMPLE*	FIELD INFORMATION**

Analysis Requested ____________

Special Handling and/or Storage ____________

PART II: LABORATORY SECTION**

Received by ____________ Title ________ Date ______

Analysis Required ____________

* Indicate whether sample is soil, sludge, etc.
**Use back of page for additional information relative to sample location.

REF: SW-846; 3rd Edition

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL

MANUFACTURER

PROJECT NAME

PROJECT NUMBER

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

..EIC

REI Consultants, Inc.
225 Industrial Park Rd.
P.O. Box 286, Beaver, WV 25813
Phone: 304-255-2500 or 800-999-0105
FAX: 304-255-2572

CHAIN OF CUSTODY RECORD

NO. 71470

CLIENT: ____________________
ADDRESS: ____________________
CITY/STATE/ZIP: ____________________
BILL TO: ____________________
CITY/STATE/ZIP: ____________________

CONTACT PERSON ____________________
TELEPHONE/FAX ____________________
SITE ID & STATE: ____________________
PROJECT ID: ____________________
SAMPLER: ____________________

SAMPLE LOG AND ANALYSIS REQUEST

TURNAROUND TIME REQUIREMENTS
REGULAR. ___
*RUSH: ___ 5-Day
___ 3-Day
___ 2-Day
___ 1-Day

*Rush work needs prior Laboratory approval and will include surcharges

PRESERVATIVES
- 0 No Preservative
- 1 Hydrochloric Acid
- 2 Nitric Acid
- 3 Sulfuric Acid
- 4 Sodium Thiosulfate
- 5 Sodium Hydroxide
- 6 Zinc Acetate
- 7 EDTA

NOTE PRESERVATIVES → PRESERVATIVE CODES

ANALYSIS REQUESTED & METHOD

SAMPLE ID	NO. & TYPE OF CONTAINERS	SAMPLING DATE / TIME	MATRIX	SAMPLE COMP / GRAB															COMMENTS

Relinquished by (Signature)	Date/Time	Received by (Signature)	Date/Time	Relinquished by (Signature)	Date/Time	Received by (Signature)	Date/Time

Special Requests

Sample Condition Good? Y N

Temperature Upon Arrival °C

Shipment: Hand Del Courier UPS FedEx

Shipment Date

FAX Results Y N

GROUND WATER SAMPLING FIELD LOGSHEET Site #____________

RADFORD ARMY AMMUNITION PLANT Well ID: ____________

WATER LEVEL MEASUREMENTS:

Date: __________ Time: ________ METHOD: ____________

Depth of water from reference point: ______ feet
Height of reference point above ground surface: ______ feet
Depth to water from ground surface (a less b): ______ feet

PURGING

Date: __________ Time: ________ Volume Purged ________ gallons

SAMPLING

Date: __________ Time: ________

Samples

____ TOC
____ TOX
____ Volatiles
____ Semi-Volatiles
____ MetalsClorides
____ Hardness
____ Sulfates
____ NO_2-NO_3
____ Ammonia
____ Conductivity
____ OCL PEST
____ PCB
____ pH
____ Phosphate
____ TDS
____ TKN
____ Fecal Coliform
____ Fluoride
____ Total Cyanide
____ Other
____ Other

FIELD MEASUREMENTS

DO ____ ____ ____ ____

Conductivity ____ ____ ____ ____

Temperature ____ ____ ____ ____

pH ____ ____ ____ ____

ORP/Eh ____ ____ ____ ____

SAMPLE PREPARATION

Date ________ Time ____

Required Preservation Completed Yes No

Sampled Packed on Ice Yes No

OBSERVATIONS:

GROUNDWATER SAMPLE LOG SHEET

Page ___ of ___

Project Site Name ______________________
Project No ______________________

☐ Domestic Well Data
☐ Monitoring Well Data
☐ Other Well Type ______________________
☐ QA Sample Type ______________________

Sample ID No ______________
Sample Location ______________
Sampled By ______________
C O C No ______________
Type of Sample
☐ Low Concentration
☐ High Concentration

SAMPLING DATA:

Date	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Method								

PURGE DATA.

Date	Volume	pH	S.C.	Temp (C)	Turbidity	DO	Salinity	Other
Method	Initial							
Monitor Reading (ppm)	1							
Well Casing Diameter & Material	2							
Type	3							
Total Well Depth (TD)								
Static Water Level (WL)								
One Casing Volume(gal/L)								
Start Purge (hrs)								
End Purge (hrs)								
Total Purge Time (min)								
Total Vol Purged (gal/L)								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No	Signature(s)

Appendix H. 4

RECOMMENDED SAMPLE CONTAINERS AND PRESERVATIVES

Appendix H. 4

Recommended Sample Containers and Preservatives

PARAMETER	ANALYTICAL METHOD	CONTAINER/ VOLUME REQUIRED	PRESERVATIVE	MAXIMUM HOLDING TIME
INORGANICS ANALYSES				
Metals (total) except Mercury	6010/6020	P - 1L	HNO_3 to pH<2	6 months
Mercury (total)	7470	P - 300 ml	HNO_3 to pH<2	28 days
Cyanide	9010	P, G - 500 ml	Cool to ≤6°C, NaOH to pH>12, 0 6 g ascorbic acid.	14 days
ORGANICS ANALYSES				
Acrolein and acrylonitrile	8260	2 - 40 ml VOA w/ G, Teflon-lined septum	Cool to ≤6°C HCL to pH 4-5	14 days
Purgeable Volatile Compounds	8260	2 – 40 ml VOA G, Teflon-lined septum	Cool to ≤6°C HCL to pH 4-5	14 days
Benzidines	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction, 40 days after extraction
[illegible]loethers	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction; 40 days after extraction
Phthalate esters	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction, 40 days after extraction
Nitrosamines	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction
Nitroaromatics and cyclic ketones	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction; 40 days after extraction
Phenol	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction
Polynuclear aromatic hydrocarbons	8270-SIM	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction

NOTES:

Reference: *Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (current edition).*

Container Types:

P = Plastic (polyethylene)
G = Glass

Appendix H. 5

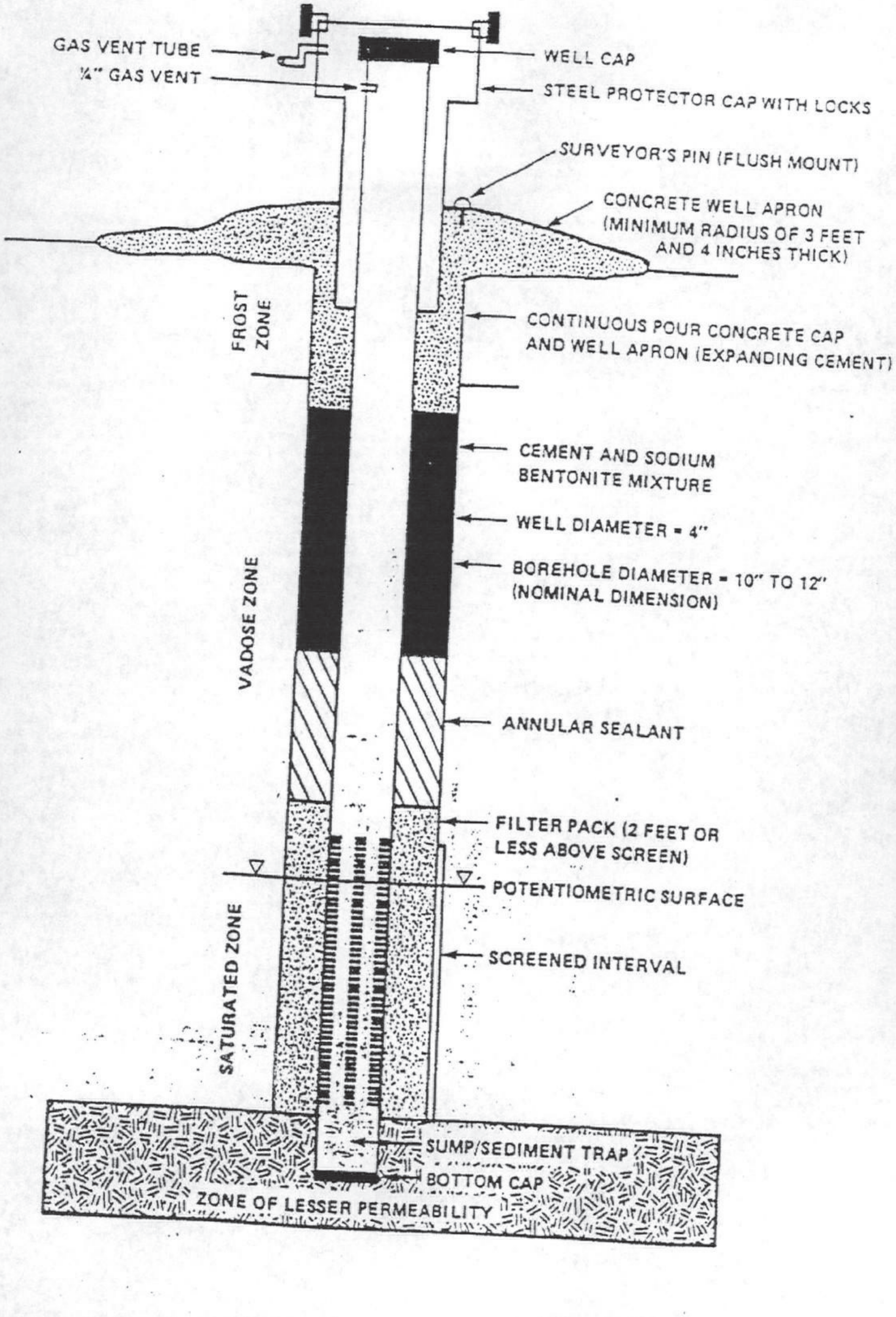
Groundwater Monitoring Well Construction Diagram

(from *EPA Technical Enforcement Guidance Document, 1986*)

ATTACHMENT 1

APPENDIX H.5

GROUNDWATER MONITORING WELL CONSTRUCTION DIAGRAM



GENERAL MONITORING WELL – CROSS SECTION

Appendix H. 6

QUALITY ASSURANCE PROJECT PLAN: AN EXAMPLE

Appendix H. 6
QUALITY ASSURANCE PROJECT PLAN

1.0. INTRODUCTION

The purpose of the **Quality Assurance Project Plan (QAPP)** is to define and document the specifications and methods to be employed, and to ensure the highest possible degree of technical accuracy and precision, statistical validity, and documentary compliance of data generated as required by this permit. The format of this document is in accordance with the *EPA Technical Guidelines for Quality Assurance Project Plans* (July 1988). Additional sources of information used for this QAPP originated from the *U S EPA RCRA Ground Water Monitoring Technical Enforcement Guidance Document (9/96), SW-846 Test Methods for Evaluating Solid Wastes, Standard Methods for the Examination of Water and Wastewater*, 1989, and the *Annual Book of ASTM Standards*, 1992.

2.0. PROJECT DESCRIPTION

2.1. Introduction

The Post-closure Care activities required by this permit are comprised of, but are not limited to: groundwater monitoring, cap maintenance and repair, and data evaluation.

2.2. Target Compounds

Analyses which will be completed during the Post-closure period are specified by **Permit Conditions I.I.1 and 2**, or **Permit Conditions V.F.1.c and 2.c,** for Units 5 and 16, respectively. Groundwater samples will be collected for all constituents listed in **Appendix E to Permit Attachments 2 and 3** for Units 5 and 16, respectively, at the frequency specified in **Permit Module V**. In addition, samples for Appendix IX to 40 CFR Part 264 constituents shall be collected annually at the point of compliance monitoring wells specified in the Compliance Monitoring Program (**Permit Conditions V.D.1.a and 2.a** for Units 5 and 16, respectively).

2.3. Data Use

Monitoring under the permit is designed to be consistent with the objectives of RCRA. During the remaining portion of the 30-year post-closure period which began in August 1993, groundwater data will be collected to establish a database to assess the groundwater quality. The monitoring program has been developed to determine compliance with the **Groundwater Protection Standards (GPS)** specified in **Appendix G** to **Permit Attachment 2 and 3** for Units 5 and 16, respectively, and to be protective of human health and the environment.

2.4. Sampling Locations

The locations of the monitoring wells from which the groundwater samples will be collected were determined by historical groundwater quality data and groundwater flow directions obtained from previous investigations. These locations are specified in **Permit Module V.**

2.5. Schedule

Groundwater monitoring shall be conducted at the frequency specified in **Permit Module V**. Sample analyses will be completed within approximately five (5) weeks of receipt of the final sample. Analytical results will be made available to the DEQ approximately 45 days from the date the analytical data is available from the laboratory.

3.0. QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

The Quality Assurance (QA) objectives for the project are listed below. The QA objectives for measurement data are provided below.

3.1. Precision

Precision is the degree of reproducibility of a measured quantity. Precision will be evaluated in the field at the point of measurement. Laboratory precision will be verified by the laboratory in accordance to the Laboratory Quality Assurance Manual (QAM).

a. Temperature and pH:
Two measurements of temperature and pH will be made before and after sampling at each well. The second measurement will be a duplicate measurement and must agree to within plus or minus the sensitivity of the instrument. These measurements will also be used to determine stability of groundwater for sampling.

b. Specific Conductivity:
Two measurements of specific conductivity will be made before and after sampling at each well location. The second measurement will be considered a duplicate measurement and must agree to within plus or minus the sensitivity of the instrument. These measurements will also be used to determine stability for groundwater sampling.

4.0. LABORATORY ANALYTICAL MEASUREMENTS

Precision objectives for all laboratory analytical measurements are defined in the QAM, provided as **Appendix 7** of this SAP.

4.1. Accuracy

Accuracy is the degree of conformity of a generated value to the true value. The accuracy of field measurements is generally limited to the sensitivity of the instruments used. The accuracy of laboratory measurements will be evaluated through the data validation process (see Section 10.0).

a. Groundwater Level:
The accuracy of water level measurements is limited by the sensitivity of the measuring instrument. The electric tape to be used must have a sensitivity of ± 0.02 feet.

b. Temperature and pH:
The accuracy of these indicator measurements will be limited to the sensitivity of the measuring device as follows: temperature to ± 1.0°C and pH to ± 1.0 standard unit.

c. Conductivity:
The accuracy of this indicator measurement will be limited to the sensitivity of the measuring device and no less than ± 10.0 umhos.

d. Laboratory Analytical Measurements:
Accuracy objectives for all laboratory analytical measurements are defined in Section 4.0 of the laboratory's QAM (**Appendix 7**).

5.0. SAMPLING PROGRAM

All sampling locations were selected to monitor groundwater quality in the alluvium and in the dolomite bedrock underlying the facility and western portion of the Kroger property. The purpose of the monitoring is to provide a database to track groundwater quality over a 30-year period to assess groundwater quality changes with time and provide early detection of migration beyond present limits.

5.1. Field Measurements

Environmental field measurements will be conducted as required in the Sampling and Analysis Plan (SAP) (**Appendix H to Permit Attachment 1**) prior to sampling. Health and safety field measurements will be adhered to as specified in the applicable Health and Safety Plan.

5.2. Groundwater Samples

The location, sampling frequency, and analytical analyses for an upgradient well or wells, point of compliance wells, compliance monitoring wells, sentinel well(s), and local potable water supply wells are specified in the Compliance Monitoring Program (**Permit Module V**.).

The SAP (**Appendix H to Permit Attachment 1**) provides details on the sampling methodology to be used at the site.

5.3. Trip and Equipment Blank Collection

a. Trip Blank:
Trip blanks are collected and analyzed for all constituents in the sampling list. A trip blank consists of a set of sample bottles (one of each type of sample bottle used) filled at the laboratory with laboratory-demonstrated analyte-free water. This water must originate from a single source and physical location within the laboratory. Trip blanks will be preserved in the same manner as aqueous field samples, but will be preserved before leaving the laboratory rather than in the field. Trip blanks will be handled, transported, and analyzed in the same manner as the samples acquired that day, except that the sample containers themselves are not opened in the field (they just travel with the sample collector). Trip blanks must return to the laboratory with the same set of bottles they accompanied into the field.

The following procedures will be followed with trip blanks:

- Each separate laboratory shuttle arriving at the site with empty sample bottles for sampling will contain a trip blank filled at the laboratory with analyte-free water.
- Prior to shipping the samples to the off-site laboratory, the trip blank will be cooled with ice to 4°C ± 2°C.
- Trip blanks will be collected/shipped at a frequency of one trip blank per sample shipment of samples for VOA analysis.

b. Equipment Blank:
The equipment blank is collected by passing laboratory-demonstrated analyte-free water through or over clean sample equipment, and then placing the water in an empty sample container for analysis. The equipment should have been decontaminated prior to sampling using the procedures described in **Appendix H to Permit Attachment 1**. The transfer should occur in the field location with the highest potential for contamination.

If non-dedicated equipment is being used, the following procedures will be followed for equipment blanks:

- At least one equipment blank will be collected during the sampling event and will be analyzed for the same parameters as the environmental samples.

- The equipment blank will be cooled with ice to 4°C ± 2°C to preserve the blank.

5.4. Laboratory Replicate Samples

Laboratory replicates will be performed by the laboratory consistent with the attached laboratory QAM. The collection of additional sample volume may not be necessary.

5.5. Containers, Preservation and Holding Times

The containers to be used, the preservation techniques to be employed, and the applicable holding times for aqueous samples are presented in **Appendix 4** of this SAP.

5.6. Chain-of-Custody Procedures

Chain-of-custody procedures are presented in **Section 6.0.**

5.7. Sample Transportation and Storage

Sample containers will be shipped from the laboratory to the field. After filling, the containers will be packed in ice and shipped via overnight courier to the off-site laboratory. Precautions will be taken to minimize the possibility of breakage. Upon the arrival at the laboratory, the temperature of the water inside the shipping containers will be checked and noted on the chain of custody. The laboratory will be prepared to receive shipments of samples during weekends.

5.8 Prevention of Cross-Contamination

Cross-contamination of field samples will be prevented through the use of decontaminated equipment and dedicated materials. Decontamination procedures for bailers, pumps, etc. will follow that provided in the SAP. Bailers will be decontaminated in the laboratory and transported to the site. Field decontamination of pumps will be required when a pump is used for more than one well for purging or sampling. Materials, such as nylon rope, will be dedicated to each sampling point.

5.9 Documentation of Sampling Activities

Proper documentation of all activities at the facility will be made by field staff. Water-resistant field log books will be maintained to record pertinent information at each sample location. Information recorded in the field logs will include name and location of site, date and time of arrival and departure, name of person keeping the log, names of all on-site personnel, purpose of visit, location of sampling points, field instrument calibration information, number of samples collected, matrix of sample and volume of samples taken, method of sample collection and any factors that may affect the quality of the data collected, sample identification numbers using unique sample labels, weather conditions and any other observations deemed pertinent.

6.0. SAMPLE CUSTODY

6.1. Field Custody

The Chain-of-Custody will begin with the shipment of sample containers from the laboratory to the site. For all sampling, appropriately prepared containers and blank water will be shipped in custody-sealed containers with a Chain-of-Custody Form. When overnight couriers are utilized, the air bill will become part of the Chain-of-Custody record, if available. The receiver will verify that all chain-of-custody seals are intact. Any shipping containers that show evidence of tampering will be addressed with the Project Manager. Any deviations from the original shipment documents will be noted on the Chain-of-Custody Form and the receiver will accept custody for all or part of the shipment by an exchange of signatures with the delivering agent.

When a sample has been taken in the field, the sampling technician will complete the Chain-of-Custody Form. The sample will be secured in a shipping container by the sampler and must remain in his or her possession until it is secured in an approved location accessible only to authorized personnel or until custody is transferred by an exchange of signatures to another person.

Each sample container will be clearly identified using standard container labels. It is imperative that information on the Chain-of-Custody Form and the container label matches in every respect. The label is printed in waterproof, self-adhesive stock. All labels in a set have the same identification number. Labels with the same identification number will be used on the various bottles that usually constitute a single sample.

Following are definitions for some of the terms on the labels:

a. *Identification Number*: This field consists of a four to seven character alphanumeric code and the date. All labels in a set have the same identification number. The label set will be applied to each bottle within one sample and to the corresponding forms or notebooks. The purpose of the identification number is to provide a single, unique identifier to distinguish the sample from all others and to simplify data management.

b. *Site*: The site is the name of the overall area from which the sample was taken. It is the largest area of concern in a project (i.e., it is the name used for the area of the entire project). A single name or abbreviation will be used by samplers.

6.2. Laboratory Custody

Transfer of custody to the analytical laboratory, and sample custody within the laboratory, are addressed in Section 6.0 of the laboratory's QAM (**Appendix 7**). Upon completion of analysis, samples will be maintained at the laboratory under chain-of-custody for a period of six months. Thereafter, all remaining samples will be released for proper disposal.

7.0. CALIBRATION PROCEDURES AND FREQUENCY

7.1. Field Instruments

A calibration program will be implemented to ensure that routine calibration is performed on all field instruments. Field team members familiar with the field calibration and operations of the equipment will maintain proficiency and perform the prescribed calibration procedures outlined in the manufactures' instructions accompanying the respective instruments. Calibration records for each field instrument used on the project will be maintained in the field.

Three field instruments will be used during sampling that will require calibration and include specific conductivity meter, pH meter, and a thermometer. Calibration procedures for these instruments is provided in the SAP.

7.2. Laboratory Instruments

Laboratory calibration procedures are addressed in detail in the laboratory QAM provided as **Appendix 7**. All calibration procedures will be consistent with the method used for analysis.

8.0. ANALYTICAL PROCEDURES

8.1. Field

On-site procedures for analysis of temperature, pH, and specific conductance are addressed in the SAP.

8.2. Laboratory

Laboratory analytical procedures will be in accordance with EPA's *SW-846, Test Methods for Evaluating Solid Waste,* August 1, 2000. Web site: http://www.epa.gov/epaoswer/hazwaste/test/main.htm, as updated. Specific analytical methods for constituents in aqueous samples are listed in **Appendix E to Permit Attachments 2 and 3** for Units 5 and 16, respectively, and **Appendix I to Permit Attachment 1**. The laboratory will maintain, and have available for the appropriate operators, SOPs relating to sample preparation and analysis according to the methods stipulated in the tables referenced above. Specific laboratory procedures are addressed in the Laboratory QAM provided as **Appendix 7**.

9.0. INTERNAL QUALITY CONTROL (QC) CHECKS

9.1. Field QC Checks

a *Calibration*

Field measurements of temperature, pH, and specific conductance will be obtained for groundwater samples. Calibration of the instruments used to obtain these measurements is discussed in Section 7.0 of this QAPP. Calibration records for each field instrument used on this project will be maintained in the field notebook.

b. *Trip Blanks.*

The primary purpose of this type of blank is to detect any potential additional source of contamination that could potentially influence contaminant values reported in actual samples, both quantitatively and qualitatively. Trip blanks serve as a mechanism of control for sample bottle preparation, blank water quality and sample handling. The trip blank travels to the site with the empty sample bottles and returns from the site with the collected samples in an effort to simulate sample handling conditions. Contaminated trip blanks may indicate inadequate bottle cleaning or blank water of questionable quality. The following have been identified as potential sources of contamination:

- Laboratory reagent water,
- Sample container,
- Cross-contamination during shipment,
- Ambient air or contact with analytical instrumentation during preparation and analysis at the laboratory, and
- Laboratory reagents used in analytical procedures.

Issues affecting the use and integrity of trip blanks include the following:

- Handling - The trip blank must be shipped back to the laboratory with the same sample bottles they accompanied into the field regardless of whether all the sample bottles were used. The temperature of the trip blanks must be maintained at $4^{\circ} \pm 2^{\circ}C$ during shipment
- Holding Time - The holding-time for volatile organics begin at the time of sample collection of the oldest sample in the shuttle.

c *Equipment Blanks*

The equipment blank provides a check on possible sources of contamination such as ambient air and sampling instruments. The reason for performing equipment blanks in the most impacted area is to attempt to simulate a worst-case scenario regarding contributions from ambient air or from improperly cleaned sampling equipment to sample contamination.

Equipment blanks should be handled, transported, and analyzed in the same manner as the samples with which they are associated.

Issues affecting the use and integrity of equipment blanks include the following:

- Handling - The temperature of the blank water must be maintained at 4° ± 2°C during shipment.
- Holding Time - Holding times for individual parameters are dictated by the specific analytical method being used. The holding-time clock begins at the time of sample collection of the equipment blank.

d. *Laboratory Replicate Samples:*
Laboratory replicates will be performed by the laboratory consistent with the laboratory QAM. Laboratory replicate samples may or may not necessitate the collection of additional sample volume in the field. The contracted laboratory will include additional sample containers if they require additional sample volume.

9.2. Sample Collection

Groundwater samples will be collected according to the following order of volatilization (TEGD, 1986):

- Volatile Organic Compounds - no headspace or air bubbles
- Semi-volatile Organic Compounds
- Metals (dissolved and total)

In the event additional sample volume is required for laboratory replicates, the additional laboratory replicate sample will be collected by alternately filling sample containers from the sampling device for each parameter. Samples for volatile organics analysis should be filled from the same bailer full of water whenever possible and be the first set of containers filled.

9.3. Laboratory QC Checks

Internal QC checks are documented in the laboratory QAM provided as **Appendix 7**. All laboratory internal QC checks will conform to those required by the methodologies noted in the tables provided in Section 8.0 of this QAPP.

10. DATA REPORTING

10.1. Field Data Reduction

Data reduction will occur for the field measurements at the point of sampling. At the point of sampling, the data, as measured by the field instrument, will be reported in the field notebooks as well as on any forms required for the project.

10.2. Office Data Reduction

Upon the return of the analytical results from the laboratory, and after data evaluation, the data will be further reduced to data tables, graphs and images. The data tables will contain the following information:

- The date and number of the most current revision;
- Information identifying exactly the samples represented on the tables (e.g. sample location, matrix, depth, etc.);
- The compounds for which the samples were tested;
- The results for each compound; and
- The data flags as applied by the laboratory and the data validators.

10.3. Data Reduction

Data reduction in the laboratory is covered in detail in the laboratory QAM provided as **Appendix 7**.

a. *Identifying Outliers in Field Data.*
Outliers are isolated, anomalous analytical results. Outliers in the field measurements will be determined through comparison of historical data to current measurements. The Principle Investigator responsible for field activities will conduct the comparison and order any suspicious measurement data re-measured.

b *Identifying Outliers in Lab Data:*
Detailed procedures for the laboratory identifying outliers are found in the laboratory's QAM provided as **Appendix 7**. The laboratory's results, including their identification of outliers, will be verified through the data validation process.

10.4. Data Reporting

Any proposed equivalent forms required below must be justified by the laboratory and approved in advance by the Permittee or its designated representative.
Appendix 7

Appendix H. 7

EXAMPLE LABORATORY QUALITY ASSURANCE MANUAL

Appendix H. 7
EXAMPLE LABORATORY QUALITY ASSURANCE MANUAL

NOTE: This document is provided as an example of the minimum acceptable standard for Quality Assurance Manuals.

ATTACHMENT 1

APPENDIX H.7

EXAMPLE LABORATORY QUALITY ASSURANCE MANUAL

Appendix H. 7
EXAMPLE LABORATORY QUALITY ASSURANCE MANUAL

NOTE: This document is provided as an example of the minimum acceptable standard for Quality Assurance Manuals.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

CHESTER LabNet is committed to excellence in analysis. All data generated by CHESTER LabNet must be technically sound, properly documented, legally defensible, and supported by defined and verified confidence limits. The program therefore, whenever possible, employs analytical methods derived from EPA, ASTM, AOAC, or Standard Methods.

This document is designed to serve as a guideline to CHESTER LabNet as a whole. Specifically, it defines the laboratory objectives, organization, functional activities, and QA/QC programs that routinely apply to each laboratory. This document is also supplemented by sets of Standard Operating Procedures. The standard practices within CHESTER LabNet are set forth; however, for specific projects, addenda will be prepared corresponding to project needs.

2.0 OBJECTIVES

The Quality Assurance Program at CHESTER LabNet is principally aimed at producing results of verifiable high quality. Towards this goal, the Program addresses several areas:

1. Detection of problems through statistical measures of acceptability and confidence.
2. Implementation of corrective action.
3. Documentation procedures designed to produce legally defensible results.
4. Establishment of training programs to assure that each person is thoroughly familiar with the methods, procedures, and documentation of his area of activity.
5. Development of a review and validation process to verify that all data produced by the Lab are within the guidelines defined in this Manual, and the associated Standard Operating Procedures.

3.0 ORGANIZATION AND RESPONSIBILITY

The laboratories of Chester LabNet are placed within the organizational structure as described in this section.

3.1 CHESTER LabNet

CHESTER LabNet-Pittsburgh is an integral part of a larger organization, CHESTER LabNet, whose organizational scheme is illustrated in Figure 3-1. The LabNet Operations Manager is responsible for assuring that the Laboratory Directors are thoroughly familiar with the Quality Assurance Manual and good laboratory practices. The role of the Laboratory Directors will be discussed in the next section.

3.2 Laboratory

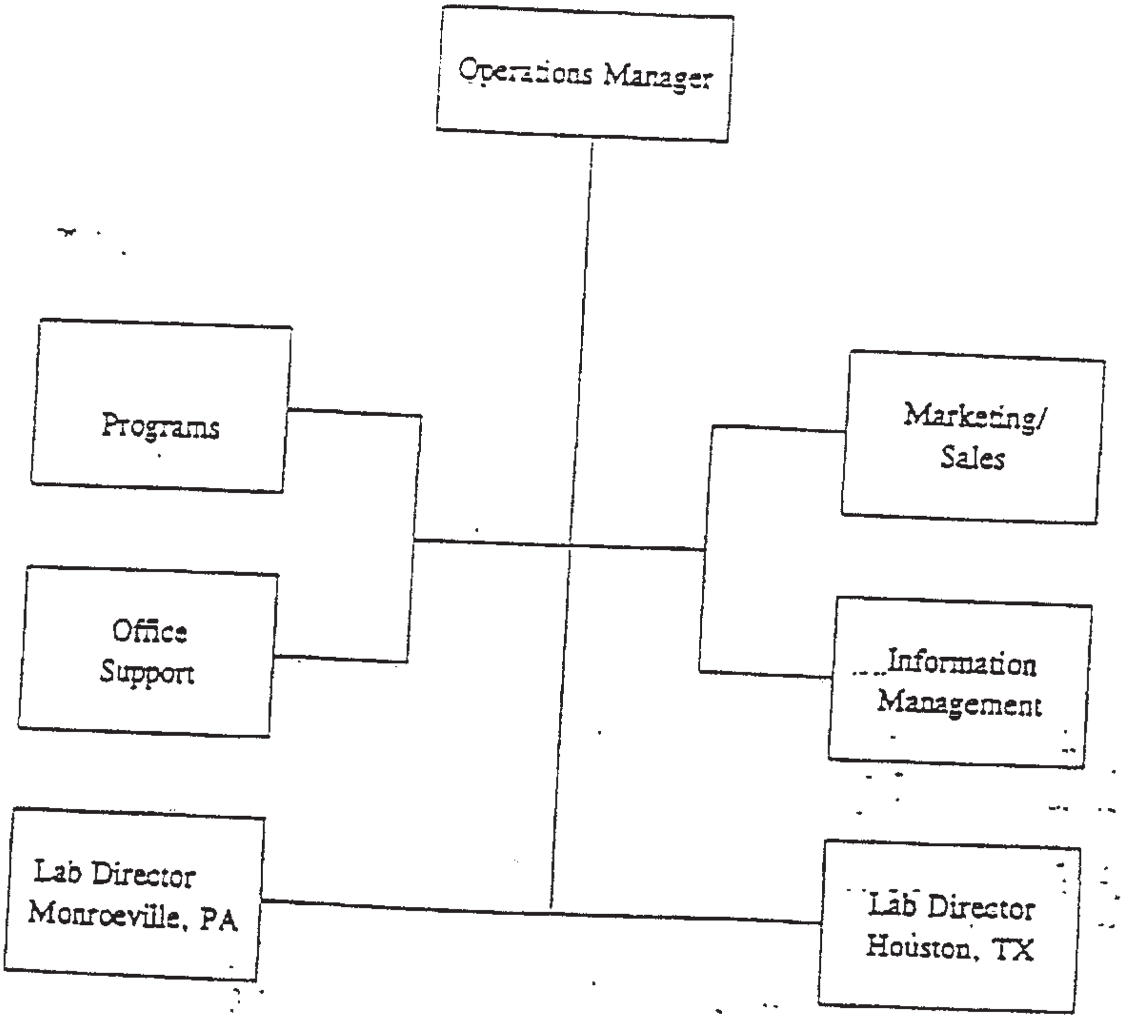
3.2.1 Organization

Figure 3-2 illustrates generically the organization of each Laboratory.

3.2.2 Responsibility

The Laboratory Director is responsible for assuring that all Section Managers and Group Leaders are thoroughly familiar with the Quality Assurance Manual and good laboratory practices and that all laboratory personnel meet the requisite qualifications for their positions within the laboratory. The Laboratory Director, or his designee, must review and approve all outgoing reports. The Laboratory Director is also responsible for effective daily management of the laboratory and its staff, and for communication and liaison with the client.

FIGURE 3-1
CHESTER LABNET ORGANIZATION CHART



CHESTER LabNet-PITTSBURGH LABORATORY ORGANIZATION

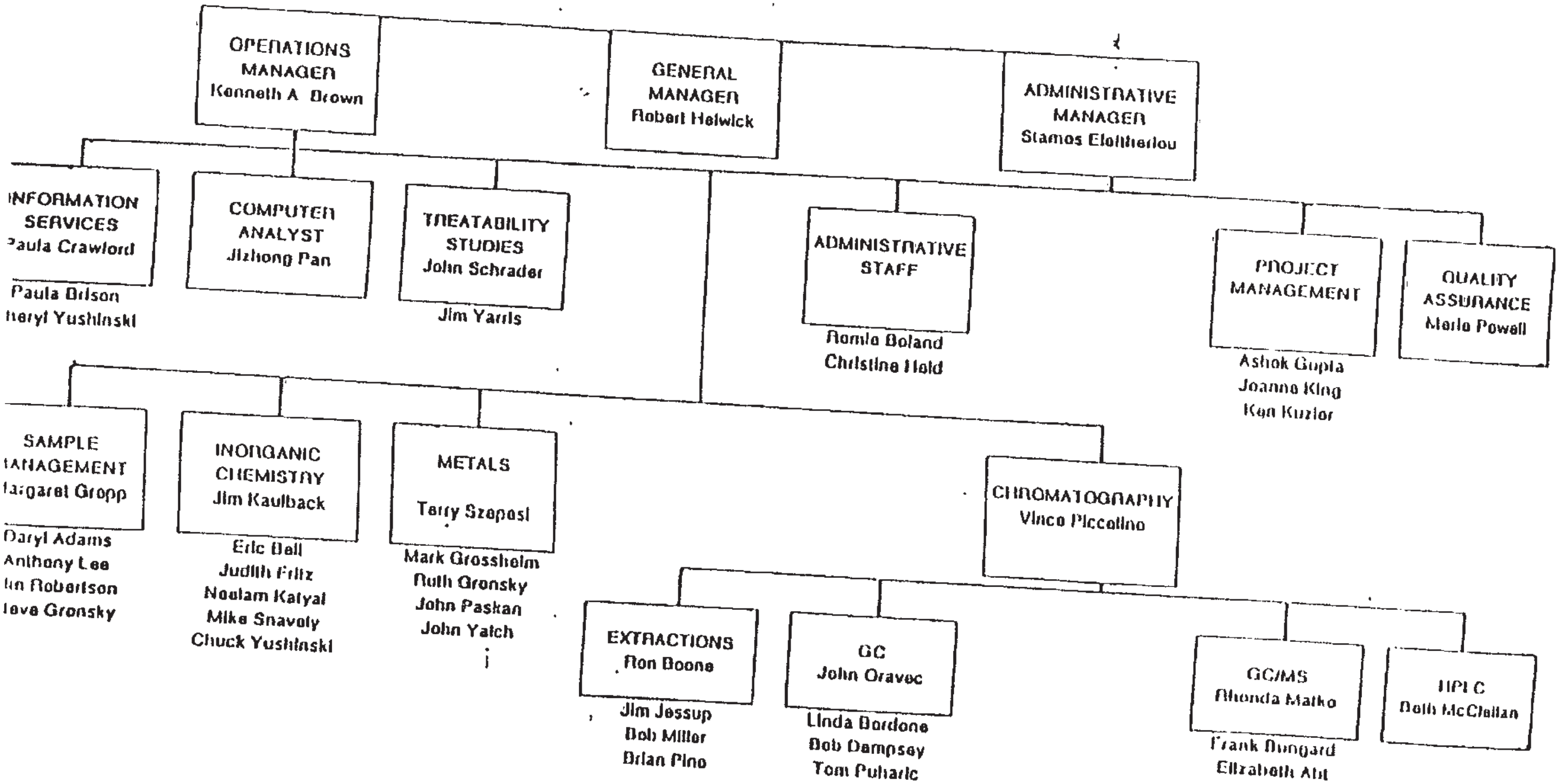


Figure 3-2

The Group Leader is responsible for the production of quality results within the group. To achieve this, the Group Leader must be thoroughly familiar with the Quality Assurance Manual and Standard Operating Procedures used by the group. He is also responsible for familiarizing personnel with the Quality Assurance Manual and Standard Operating Procedures, seeing that required protocols are followed, reviewing the results, and approving release of the data to the Information Services Section. The Group Leader, in coordination with Sample Receiving, Information Services, and the Project Manager is responsible for scheduling work and conforming to required holding times. The Group Leader, in conjunction with the Quality Assurance Manager, is responsible for providing the necessary training to laboratory personnel.

The Analysts are responsible for performing all analyses as required and noting the required QC analyses demanded by the analytical method or technique. In order to provide proper analysis, they must be familiar with the Quality Assurance Manual and the associated Standard Operating Procedures. They are also responsible for initiating system or method corrective action should they become aware of a malfunction. Initiation of corrective action requires appropriate notification, as discussed later in this manual.

The Manager of Sample Receiving is responsible for the following functions: sample receipt, storage, distribution of the information through the laboratory, sample custody, and sample disposal. It is his responsibility to notify the Group Leaders and Project Managers should there be any discrepancies or irregularities in the shipment of samples.

The Manager of Information Services is responsible for maintaining the status of the work within the Laboratory, coordinating the compilation of the data, and preparation of reports for review and approval.

The Quality Assurance Manager is responsible for assuring that the QA/QC requirements of the Quality Assurance Manual and its associated Standard Operating Procedures and addenda are strictly followed. He is responsible for reviewing data validation procedures, alerting the sections and groups should the need for corrective action exist, performing internal audits, introduction of performance evaluation samples on a periodic basis, and maintenance of the QC records. He is also responsible for preparing project-specific QA/QC plans.

The QA/QC Manger functions independently of the laboratory staff. In order to achieve independence from the pressures of daily production in the laboratory and maintain the necessary objectivity, the QA/QC Manager reports both to the Laboratory Director and the Operations Manager.

The Project Manager is a position assigned by the Laboratory Director for specific projects. Projects may require a specifically assigned manager because of the unusual nature of the project, complexity of the analytical techniques or reporting requirements, or the need for coordination of activities in several laboratories. The responsibility of the Project Manager to the specific project transcends that of the Laboratory Director. The Project Manager will alert the Group Leaders if problems arise in meeting schedules or sample holding times. It is also the Project Manager's responsibility to assure that work on the project is performed in accordance with project specified protocols, following project specific QC requirements. Acceptance of results on analyses for the project is subject to approval by the Project Manager.

4.0 SAMPLE CUSTODY

To provide for legal defensibility of all work performed at a given site, it is essential to be able to provide documentation tracing the samples from collection, to the laboratory, and through the analytical procedures. CHESTER Environmental performs both sampling functions and analytical functions: however, the laboratory can guarantee that this Manual is followed from the point of origin only for samples that are both collected and analyzed by CHESTER Environmental.

Maintaining sample custody consists of two distinct aspects: maintenance of the samples in the field, and maintenance of the samples from the time of receipt in the laboratory. These two aspects are discussed separately in the following sections. Inasmuch as sampling is not necessarily performed by our personnel, the custody and documentation in the field are included here as a recommendation.

4.1 Custody and Documentation in the Field

The field sample custodian, which, depending upon the project, may be the sampler or another person in the same sampling group is considered to have custody of the samples at all times during the field operations, until the samples are shipped to storage or to the laboratory. Upon collection of a sample in the field, the sampler tags the sample with its site and type (water, soil, sludge, etc.) identification. The sampler also indicates on the tag the date and time of sampling. After cleaning the exterior of the sample container, the field sampler transfers the container with the tag to the field sample custodian.

Throughout this document, the term sample is used to indicate a quantity of one type of material collected at one time, at a single location. Thus, a water sample may be shipped to the laboratory in several containers, depending upon the required testing and sample preservation dictated by the project. Each container is identified as a sub-sample, but it is not classified as a unique sample.

The field sample custodian compares the identification of the individual sample with the sampling plan, and enters all pertinent information on the chain-of-custody document and on the label of the sub-sample container. The information that must be included consists of the following:

Project identification

Sample identification (such as station number and location)

Date of sampling

Time of sampling

Name of sampler

Parameters for which the sample is to be analyzed

Number of containers

Sample matrix (groundwater, surface water, wastewater, soil, sediment, sludge, unknown waste, etc.)

Added preservatives in each sample container

Ice chest number

Chain of custody number

A sample field chain-of-custody is shown in Figure 4-1.

NDWATER
NOLOGY®

CHAIN OF CUSTODY RECORD

PLANT CODE

PROJECT NAME

SAMPLERS
(Signature)

STA NO	DATE	TIME	COMP	GRAB	WELL	STATION LOCATION	NUMBER OF CONTAINERS									CONDUCTIVITY	pH	REMARKS OR OBSERVATIONS

Relinquished by (Signature)	Date	Time	Received by. (Signature)	Relinquished by: (Signature)	Date	Time	Received by (Signature)
Relinquished by (Signature)	Date	Time	Received by. (Signature)	Relinquished by. (Signature)	Date	Time	Received by (Signature)
Relinquished by (Signature)	Date	Time	Received for Laboratory by (Signature)	Date	Time		

Ice Chest Temp	Ice Chest	Chain of Custody
°C	#	Tag #

DISTRIBUTION: Original accompanies shipment, Copy to Coordinator Field Files.

PAGE ___ OF ___

The field sample custodian is then responsible for packaging the sample(s) for shipping, adding ice if the samples require chilling, signing and dating the chain of custody document, placing the chain of custody document in a waterproof envelope and attaching the envelope to the inside of the ice chest lid.

If the samples are to be shipped by a common carrier, then the field sample custodian must also place custody seal on the ice chest.

Simultaneously with filling out the chain of custody document, the field sample custodian also records the information in the field logbook. In filing the chain of custody document and the field logbook, any corrections that need to be made must be done so that the original incorrect entry is legible. Hence, the incorrect entry is lined out, and the change is initialed and dated by the field sample custodian.

Table 4-1 lists the required types of containers, preservatives, and holding times for each type of analyte. It is the responsibility of the field sample custodian to assure that each sample or sub-sample are packaged correctly. The samples are considered formally to be in the custody of the field sample custodian until they are officially transferred to the carrier, and the transfer is documented on shipping records, or until the samples are transferred to the laboratory in person.

4.2 Sample Custody in the Laboratory

The laboratory operation, as it pertains to the sample custody, consists of several functions. Specifically, these are: sample receipt, inspection of the samples, reconciliation of the information on the sample label and the chain-of-custody, alerting the project manager of any inconsistencies in the shipment, logging in of the samples, placing the samples in appropriate storage areas, distribution of the information to the laboratory analytical sections, transferring of the custody of the samples to the analysts, and recovery of the samples at the completion of the analysis.

TABLE 4-1
CONTAINERS, PRESERVATIVES, AND HOLDING TIMES

ANALYSIS	CONTAINER	PRESERVATIVE	HOLDING TIME
Volatile organics	G	HCl, Cool to 4°C	14 d
Semivolatile organics	G	Cool to 4°C	7 d to extraction, 40 d for extract.
Organochlorine pesticides	G	Cool to 4°C	7 d to extraction, 40 d for extract.
Herbicides	G	Cool to 4°C	7 d to extraction, 40 d for extract.
Organophosphorus pesticides	G	Cool to 4°C	7 d to extraction, 40 d for extract.
Metals (except mercury)	P	HNO_3	6 m
Mercury	P	HNO_3	28 d
Hexavalent chromium	P	Cool to 4°C	24 h
Acidity, Alkalinity	P,G	Cool to 4°C	14 d
Ammonia, COD, total Phosphorus, Nitrate-Nitrite	P,G	H_2SO_4, Cool to 4°C	28 d
BOD	P,G	Cool to 4°C	48 h
Chloride, Fluoride	P	None	28 d
Color	P,G	Cool to 4°C	48 h
Cyanide	P,G	NaOH, Cool to 4°C	14 d
Hardness	P	HNO_3	6 m
pH	P,G	None	Immediately
Nitrogen, Kjeldahl and Total organic, Phenols	G	H_2SO_4, Cool to 4°C	28 d

TABLE 4-1
CONTAINERS, PRESERVATIVES, AND HOLDING TIMES
(continued)

ANALYSIS	CONTAINER	PRESERVATIVE	HOLDING TIME
Nitrate & Nitrite	P,G	Cool to 4°C	48 h
Oil and Grease	G	H_2SO_4, Cool to 4°C	28 d
Ortho-phosphate	P,G	Cool to 4°C	48 h
Dissolved oxygen	G	None	Immediately
Residue, Total, Filterable, Nonfilterable, Volatile	P,G	Cool to 4°C	7 d
Residue, Settleable	P,G	Cool to 4°C	48 h
Silica	P	Cool to 4°C	28 d
Sulfate, Specific Conductance	P,G	Cool to 4°C	28 d
Sulfide	P,G	Zinc acetate + NaOH. Cool to 4°C	7d
Sulfite	P,G	None	Immediately
Surfactants, Turbidity	P,G	Cool to 4°C	48 h
Temperature	P,G	None	Immediately
TOC	G	H_2SO_4 Cool to 4°C	28 d
TOX	G	H_2SO_4 Cool to 4°C	8 d

NOTES:

P = Polyethylene
G = Glass
h = hours
d = days
m = months

These operations are the responsibility of Sample Receiving. The individual steps are itemized below:

4.2.1 Sample Receipt in the Laboratory

Samples will be received in the laboratory either by commercial carrier, the postal service, or hand-carried. Personnel in Sample Receiving sign for the receipt of each shipment of samples and retain a copy of the shipping documents. The individual receiving the sample shipment will open a sample shipment checklist (see Figure 4-2) at the time of receiving the shipment.

If, for any reason, the shipping container is not expected to be opened immediately, then the seals on the container must remain intact.

4.2.2 Shipment Inspection

It is expected that a shipment received in the laboratory will be opened and inspected immediately upon receipt. Prior to opening the shipping container, the custody seals will be inspected to assure that no tampering has been done with the sample containers. The state of the custody seals will be noted on the sample shipment checklist by the person inspecting the shipment.

After the seals are inspected, the ice chest is opened. The temperature of the interior of the ice chest is measured and recorded. To measure the temperature, the lid is quickly opened and a thermometer is inserted into the ice chest, and the lid is closed again for five minutes. At the end of five minutes, the lid is quickly opened and the temperature read rapidly. The temperature is recorded on the sample shipment checklist.

The ice chest is opened, the chain-of-custody document is removed from the inside of the lid, and the individual sample containers are removed from the ice chest. The sample or sub-sample containers are counted and reconciled with the number of

CHESTER LABNET-PITTSBURGH
SAMPLE SHIPMENT CHECKLIST

Customer: ______________________

No(s) ______________________

____

Date Shipped: ______________________

Date Received: ______________________

Shipped Via. ______________________

Air Bill No ______________________

Lab Project Manager: ______________________

Data Package Required: _____Yes _____No

Please Check One of The Following
If The TAT Is Less Than 2 Weeks.

_____ 24 Hours

_____ 48 Hours

_____ 3 – 5 Days

_____ 1 Week

_____ 10 Days

Number of Shipping Containers (Coolers, Boxes, Etc.): __________

Cooler/ Container I.D.	Custody Tape		Temp. (C)	pH of Preserved Samples Checked (Y/N)	Chain-of-Custody	
	Present? (Y/N)	Intact? (Y/N)			Present/ Absent	Agree With Samples

rregularities: _____ No _____ Yes (If yes, please explain)

Sample I.D.	Irregularity

ab Representative Contacted: ______________________ Date __________ Time: __________

ec: ______________________

____

____

Signature

such containers indicated on the chain-of-custody. If the number of retrieved sample containers is less than that indicated on the chain-of-custody, the packing materials inside the ice chest are further checked to make sure that no sample container has been accidently left in the ice chest.

Each individual sample or sub-sample container is visually inspected to determine that no breakage, cracking, external corrosion, or leakage has occurred. If none have occurred, the individual sample containers may be removed from the fume hood and placed on a workbench to complete the inspection. If, on the other hand, there is indication that breakage, cracking, corrosion, or leakage has occurred, the inspection of the sample containers will be completed while the containers are kept in the fume hood.

The integrity of the individual sample or sub-sample containers is recorded on the sample shipment checklist.

4.2.3 Reconciliation with Chain-of-Custody Document

Once the integrity of the sample containers has been determined, the sample containers are reconciled against the records on the chain-of-custody. This is done by checking the sample identification on the chain-of-custody and on the sample container label. In addition, the analyte identifications are checked to ensure that they are correct.

Any discrepancy is noted on the chain-of-custody, signed, and dated. The discrepancies are also entered on the sample shipment checklist. At this point, the sample shipment inspection is complete. The sample shipment checklist is signed and dated by the person performing the inspection. If there are no discrepancies, and the shipment is complete as evidenced by the inspection, the shipment of samples is ready to be logged in. If there are discrepancies or inconsistencies, the sample shipment checklist is submitted to the Project Manager and the logging in process is delayed until the discrepancies are resolved.

4.2.4 Resolution of Shipment Irregularities

If any irregularities are noted during the sample shipment inspection, they are recorded on the sample shipment checklist, and the checklist is submitted to the Project Manager. The Project Manager will contact the client's representative to determine the fate of the sample shipment. The records of the conversation with the client's representative are entered on the sample shipment checklist, including name of contact, time and date of the conversation and the resolution of the irregularities.

There are several possibilities for the resolution of the irregularities. These are:

a. Return the sample shipment to sender.

b. Destroy the entire shipment of samples.

c. Log in and process those samples that are intact.

The sample shipment checklist containing comments regarding resolution of any irregularities is returned to Information Services, the personnel of which will act according to the annotated agreement with the client.

To maintain the custody of the samples, the entire sample shipment during this period is either locked up in a secure area or is in view of Sample Receiving personnel.

4.2.5 Sample Log In

Once the sample shipment has been inspected and any irregularities resolved, the sample shipment is ready to be logged in. For laboratory purposes, a single sample shipment from a specific client constitutes a single job. The shipment may contain one or many samples and may have arrived in a single shipping container or in many shipping containers.

For the log-in process, Sample Receiving staff performing the logging-in will use the field chain-of-custody and the sample shipment checklist both with whatever corrections were required to be made during the inspection and resolution steps. The log-in process consists of the four steps described below:

4.2.5.1 Entry in Master Log

The Master Log is a hardbound book in which all jobs received in the laboratory are chronologically recorded. The following information is entered in the Master Log:

(a) Job Number

(b) Date of Receipt

(c) Date of Logging-in

(d) Name of Client

(e) Number of Samples (not sub-samples)

(f) Due Date

(g) Sample Matrix

The job number consists of a letter followed by a seven digit number. The initial letter code identifies the laboratory (M - Pittsburgh, H - Houston). The four digits following the letter identify the year and the month of the sample shipment logging-in, and the last three digits are chronological within the month. Thus, M9402005 is a job number issued by the Pittsburgh Laboratory for the fifth job logged in during February 1994.

A sample page of the Master Log is shown in Figure 4-3. At the time of entering the job in the Master Log, the job number is manually written on the Field Chain-of-Custody and on the Sample Shipment Checklist. The job number remains the identification of the job in the laboratory and on the job records.

4.2.5.2 Job Traveller

In addition to opening an entry in the Master Log, a Job Traveller is issued for every job in the laboratory. The Job Traveller is a computer generated document that gives all the pertinent details regarding the individual samples in the job.

For each sample in the job, a unique number is assigned. The unique number consists of the job number followed by three digits, which are sequential within the job. This number is entered on the traveller, as well as the original sample identification from the field chain-of-custody, the date of sampling, the sample matrix, and the parameters for which the sample or sub-sample is to be analyzed. In addition, the traveller heading contains information such as client identification, project contacts, date of collection, date of logging in, and due date.

A sample of a Job Traveller is shown in Figure 4-4.

4.2.5.3 Sample Labeling

When the logging-in process is complete, the operator entering the information proofs the input and verifies that all the information is correct. The complete laboratory sample or sub-sample identifications are entered on labels. The operator then places the correct label on each container of each sample, and verifies once more that the information has been correctly recorded.

The labelled sample containers are then placed in a secure storage area for preservation at the appropriate temperatures.

Chester ot-Pittsburgh
3000 Tech Center Drive
Monroeville, PA 15146

GURE 4-3
SA E MASTER LOG

Logbook # Assigned ____________

Project Number	Date Received	Date Logged	Client	No. of Samp.	LIMS Sample Numbers	Due Date	Sample Matrix				
							Soil	Water	Sludge	Oil	Other

FIGURE 4—4

CHESTER LABNET-PITTSBURGH

Date: ____________________ Received By: ____________________

Project Number: ____________________ Date Received: ____________________

Customer ____________________ Time Received ____________________

P O Number: ____________________ Charge Number: ____________________

Description: ____________________ Priority: ____________________

Matrix: ____________________

Sample No.

SOURCE/ SAMPLE TAG NO								
DATE COLLECTED								
NO OF CONTAINERS								
PRESERVED CORRECTLY								

OMMENTS: ____

____

4.2.5.4 Information Distribution and Job Filing

The Job Traveller is the working document for each job. Sample Receiving personnel make a copy of each traveller for each group in the laboratory as well as for the relevant Project Manager and Information Services. The copies are distributed to the Group Leaders as required. The original traveller is used to open a file for the job in which the laboratory copy of the field chain-of-custody and the sample shipment checklist are placed. The file is identified by the job number. As the work on the job is completed, the file will be used to store all laboratory records regarding the job.

The file for the job is placed in the active laboratory central job filing system.

The sample log-in process is extremely critical for the proper functioning of the laboratory. It must be performed rapidly and accurately, so that holding times will be met, and so that the correct analyses will be performed on the appropriate samples.

4.2.6 Custody Transfer Within the Laboratory

Because the laboratory is considered a secure facility, samples will be considered as being in the custody of the laboratory from the time that sample receipt is recorded.

All samples will be maintained at secure locations under supervision of Sample Receiving staff until the group responsible for the sample preparation for analysis is ready to start work on the samples. The group representative will then obtain the samples from their designated storage area. The person retrieving the samples will fill in a transfer form, a sample of which is shown in Figure 4-5, and submit the form to the Sample Receiving Section.

Chester LabNet-Pittsburgh
Internal Transfer Form

JOB: ____________________

SIGNED OUT BY	DATE	SAMPLE NUMBERS	ANALYSES	RETURNED BY	DATE

When the sample preparation or analysis is completed and residual samples are returned to the original, secure storage location, the analyst will indicate on the Internal Transfer Form which samples, if any, have been completely used up. The Sample Receiving Section will maintain a record of these forms.

4.2.7 Sample Disposal

Sample Disposal is an issue requiring attention to the specific, and often changing, regulatory requirements. For these reasons, laboratory practices in this area are dealt with separately in an SOP written to address these concerns.

5.0 ANALYTICAL PROCEDURES

In order to produce meaningful results, both sampling and analytical procedures must be sound and complimentary to each other. While close coordination of activities between the laboratory and field services is highly advisable in order to produce a high quality product, laboratory services may involve analyses of samples collected through organizations other than CHESTER Environmental. Thus, the application of strict procedures regarding the transfer of samples from the field in some cases may involve conditions beyond the control of the laboratory.

5.1 Coordination of Activities

Analytical services are requested through several sources. The project manager acts as liaison between the client and the laboratory on all matters pertaining to the project. However, requests for analytical services may originate with the laboratory sales representatives or other key technical persons in the laboratory. The person receiving the request will enter a description of the requested work on an Analytical Request Form, shown in Figure 5-1, and the information will be entered into the Laboratory Information System as proposed work. When the proposed project becomes a definite task for the laboratory, the Laboratory Director will assign a Project Manager who will activate the project and distribute the information together with the anticipated schedule. In that way, the laboratory sections and groups that will be involved in the analysis are made aware of the upcoming work.

All further coordination and scheduling of the work will be through the assigned Project Manager.

5.2 Preparation of Sample Containers

For clients and projects that require the laboratory to supply containers for samples, the Manager of Sample Receiving will be responsible for preparing the containers, labeling them, and shipping them to the client. It is the responsibility of the Project Manager to inform the Manager of Sample Receiving of the need for containers.

FIGURE 5-1
ANALYTICAL REQUEST FORM

Client Contact: ____________________ Date: ____________________

Client: ____________________ Telephone: ____________________

Address: ____________________ Project Manager: ____________________

____

____

# SAMPLES	MATRIX	PARAMETERS	TURNAROUND

Instructions: ____

____

Such notification must be received by the Sample Receiving Section at least three working days prior to the time for which the sample containers are required.

For aqueous field samples, new pre-cleaned sample bottles with Teflon lined screw caps will be used. The containers will be prepared with the appropriate preservatives and will be labelled with information regarding the analytes that are to be determined on the sample.

For solid samples, a variety of containers may be used. For soils, glass containers with Teflon liners are employed. When the samples are to be collected in polyethylene, appropriate new and pre-cleaned containers will be used.

Table 4-1 lists the appropriate containers and preservatives for aqueous samples.

5.3 Instrument Maintenance

Maintenance of the instruments in the laboratory consists of two major aspects. The first is routine preventive maintenance and the second is repair due to malfunction. Acceptable procedures and specifications in either case confirm to those recommended by the manufacturer of the specific equipment as well as any criteria provided in the applicable approved methods. Written equipment maintenance documentation is part of the laboratory records for both types of maintenance as described below.

5.3.1 Preventive Maintenance

The manufacturer's recommended schedule of preventive maintenance will be followed to reduce occurrences of instrument failure and to help maintain the reliability of analytical results. If more frequent routine maintenance is necessary to assure proper operation, then these practices will be added to the maintenance scheduled, and will be performed and documented in laboratory records.

It is the responsibility of the Group Leader to provide the time required for preventive maintenance. Preventive maintenance records must be kept and include procedures performed by laboratory personnel and any preventive maintenance contracted for using outside repair technicians. The Group Leader will insure that preventive maintenance records are complete, accurate, and comply with the Standard Operating Procedures dealing with these laboratory records. Verification of instrument performance and recalibration as necessary must take place immediately after maintenance has been completed and before resuming sample analyses.

5.3.2 Repair After Instrument Failure

Unscheduled repairs which result from instrument malfunction are arranged for immediately after the failure is detected. Deteriorating equipment performance is detected both directly through observations during analyses and indirectly through the routine use of verification samples throughout the course of an analytical run. If instrument response and performance on verification samples is not within acceptable criteria, analyses are halted, preceding analytical results to the last acceptable verification sample of the run are marked "VOID", and repair is undertaken. The Group Leader will make the decision as to whether the scope of the repair is within the capability of laboratory personnel or whether a service call to a repair contractor is necessary.

Data from voided analyses will not be entered into the LIMS. Notice of invalid data will be given by the Group Leader to the Quality Assurance Department if data from the voided analyses have been released by the analytical section to the Information Services Group. A Corrective Action Notice Form, as shown in Figure 5-2, will be initiated by the Group Leader to track such data so that the appropriate action can be taken. Other laboratory documentation which results from instrument repairs are the equipment maintenance records that are described in the previous section on preventive maintenance. As indicated in the maintenance recordkeeping Standard Operating Procedures, repairs are documented in logbooks along with related information which will include the identification of any sample results which have been affected by the malfunction, and a subsequent verification of performance within acceptable criteria prior to resuming sample analyses.

FIGURE 5-2

CORRECTIVE ACTION NOTICE

Work Order: ______________________ Date Analyzed: ______________

Sample #(s): ____

Client: ______________________ Parameter: ______________

ORIGINATING DEPARTMENT

_______ GC/HPLC _______ Metals _______ Extractions

_______ GC/MS _______ Wet Chemistry _______ Other _______

Invalid data submitted to Data Management? YES ____ NO ____

ACTION

I. State the analysis and/or reporting problem recognized: Analyst or Manager _______ Date _______

____

____

____

II. State what action was taken to correct the problem:

____

____

____

Individual completing the necessary corrective action ______________ Date _______

APPROVALS

I. MANAGER OF ORIGINATING DEPARTMENT

The problem appears _______ laboratory (e.g. procedure, instrument) related. Signature _______

_______ sample (e.g. matrix, volume) related. Date _______

II. PROJECT MANAGER

The client _______ was contacted. Signature _______

_______ was not contacted. Date _______

III. QC MANAGER

Additional follow-up _______ is necessary. Signature _______

_______ is not necessary. Date _______

COMMENTS

____

____

____

____

____

OTES.

1. HOW TO USE: Use only one notification sheet to track and document one common problem related to samples associated with a single work order.
2. WHEN TO USE: Always initiate everytime invalid data is submitted to Data Management and any time a problem cannot be immediately isolated and corrected.
3. DISTRIBUTION:

5.4 Preparation of Standards

A calibration standard is made by the appropriate dilution of a pure substance, the purity of which is traceable to an approved (e.g., NIST or equivalent) standard. Because of the high sensitivity of many analytical instruments, the calibration standard is an extremely dilute version of the pure compound. Because of the high dilution required, in order to be within the linear range of the instrument, the preparation of the calibration standard is frequently made by serial dilution rather than in a single step. In order to provide standard solutions at sufficiently low concentration, a miniscule amount of the pure substance will be required, the measurement of which is subject to extreme error. Thus, it is preferable to deal with potential dilution errors, rather than with the large error associated with the measurement of a very small amount of the pure substance.

The initial pure standard is obtained either as a pure material or already in solution prepared as a certified solution of a given concentration of the pure compound or compounds. In preparing the stock solution of the calibration standard, great care must be exercised in measuring weights and volumes as accurately as possible since all the analyses following the calibration will be based on the accuracy of the calibration, and the accuracy of the ultimate data cannot be any better than that of the calibration curve. Table 5-1 summarizes the valid lifetime of primary and secondary standards used in many tests. These lifetimes should be taken as a guide only. It is the analyst's responsibility to assure that all standards used by him are within the standard solution holding time, and to prepare fresh standard solutions whenever necessary. In preparing working solutions, or using working solutions, the analyst must check for signs of deterioration, such as the formation of cloudiness, precipitation, or discoloration. The standard must also be periodically compared with previous runs of standards, and with independently prepared standards to assure that response factors fall within an historically accepted range.

TABLE 5-1

STANDARDS AND SOLUTIONS HOLDING TIMES

MATERIAL	HOLDING TIME PURE COMPOUND	 STOCK SOLUTION	 WORKING SOLUTION
Volatile organic compounds for GC or GC/MS analysis	1 Yr @ -10°C	2 Mo @ -10°C	1 Wk @ -10°C
Semivolatile organic compounds for GC or GC/MS analysis	1 Yr @ 4°C	1 Yr @ 4°C	6 Mo @ -10°C
Semivolatile organic compounds for HPLC analysis	1 Yr @ 4°C	1 Yr @ 4°C	6 Mo @ 4°C
Pesticides (Cl, P, N,) and herbicides	1 Yr @ 4°C	1 Yr @ 4°C	6 Mo @ -10°C
Polychlorinated dioxins and furans	1 Yr @ 4°C	1 Yr @ 4°C	6 Mo @ 4°C
Metals for ICP analysis	Indef @ RT	1 Yr @ RT	6 Mo @ RT
Metals for GFAA analysis	Indef @ RT	1 Yr @ RT	6 Mo @ RT
Mercury	Indef @ RT	6 Mo @ RT	1 D @ RT
Hexavalent chromium	Indef @ RT	1 Yr @ RT	1 Yr @ RT

For anions and other parameters, the holding times of standard solutions should be checked in the appropriate method.

All standards and standard solutions of organic compounds will be maintained in glass containers, protected from light, and stored under the conditions specified in the particular method. The position of the meniscus in each container will be marked after each time that the container is opened so that changes due to evaporation can be detected.

Metals working solutions and stock solutions will be kept in polyethylene containers at room temperature. The position of the meniscus will be marked each time a solution is used to insure that concentration changes due to evaporation are detected. Before using any standard solution, the analyst will examine it for signs of precipitation and changes in color. If precipitation has occurred, the solution will be discarded and a new standard prepared. Discoloration frequently is only a warning sign, but will not affect the results. If a solution is discolored, the analyst will compare the results with historically established response factors, to assure that the solution is still within the operating range of the method, and within experimental error of its original concentration.

The preparation of standards is very exacting. To facilitate the operation of preparing standards, a separate area is set in the laboratory equipped with a small hood and analytical balance. A freezer in the same room is used to store all primary standards and no other samples or extracts. In this fashion, the contamination of standards by samples, and vice versa, is minimized.

For each stock standard solution that is prepared, accurate records will be kept in a special logbook used only the maintenance of standards data. The following information will be entered in the logbook at the time of stock standard preparation:

a. Date of preparation and expiration date

b. Application for which the standard is being prepared (i.e., identification of the method)

c. For each compound, the supplier of the primary standard, the batch number, and the amount taken

d. The solvent identification (compound, supplier, batch number)

e. The final volume of the stock standard

f. The identification number assigned to the stock standard preparation

g. The name of the analyst preparing the standard

A sample logbook page is shown in Figure 5-3, however, Group Leaders may use another format as long as the listed information is recorded.

In preparing the diluted working standards, it is the analyst's responsibility to make sure that the stock standard is of valid vintage. The preparation of all working standards is also recorded in the logbook. The following information is recorded in the logbook:

a. Date of preparation and expiration date

b. Identification number of the stock standard solution

c. Volume of stock standard solution taken

d. Final volume of the diluted standard solution

e. Concentration of each parameter in the diluted standard

f. Identification number for the diluted standard

g. Name of the analyst preparing the diluted standards

All stock and working standard solutions will be labelled with ID number, composition and concentration, date of preparation, initials of the responsible individual, and expiration date. The ID number assigned in the logbook is used for labelling. It consists of: logbook number, page number, and item or line number identifier (e.g., 1 - 2 - 3 is the ID number assigned to the solution found in logbook 1 on page 2 as item 3).

Solution I.D No	Prep.		Stock Identification					Compound	Quantity Taken					Fin. Vol ml	Final Conc. ug/ml
	Date	By	Number	Pure Comp.	Stock Sol'n	Conc. Stock Sol'N, ug/ml	Exp. Date		Amount	g	mg	ul	ml		

FIGURE 5-3

STANDARD PREPARATION LOG

The working standards for organic analysis will be stored in a freezer in the work area. No other samples or extracts will be stored in the same freezer. The working standards for metals will be stored in the work area in a cabinet or shelf designated for standards only. These do not need to be refrigerated. For other parameters, the working standards will be maintained in either a refrigerator or at room temperature in the work area on specifically designated cabinets or shelves where no other materials are being stored.

5.5 Determination of Detection and Quantitation Limits

For many projects, knowledge of detection limits is essential in order to be able to bracket analytical results that are obtained. Several such limits exist, and different experts define these limits differently. For this reason the definition and determination used by CHESTER LabNet is given below.

5.5.1 *Instrument Detection Limit*

In simple terms, the instrument detection limit is the smallest quantity of material that the instrument can detect. It has been defined in the past as a certain value of the signal-to-noise ratio. Many modern instruments, however, are designed to self compensate for noise, so that the measurement of the signal-to-noise ratio is not a simple matter.

For the purpose of work at CHESTER LabNet, the instrument detection limit is defined as three times the standard deviation from the mean of seven replicate measurements of a low concentration standard that produces a definite, measurable signal. The signal may be an area count, a peak height, an absorbance reading, or electric measures (such as voltage, current, resistance). The nature of the signal is dictated by the instrument and detector that are used. The instrument detection limit is calculated from the following equation.

$$IDL = \frac{3S}{RF}$$

Where: IDL = Instrument detection limit, in weight units (ng, mg) for those parameters where the signal depends on an absolute quantity (such as chromatographic methods), and in concentration units for those parameters that are concentration dependent

S = Standard deviation of the seven replicate readings, in units of the reading (i.e., area count, peak height, etc.)

RF = Response factor, in units of signal reading/unit weight, or concentration, depending upon the units used for IDL (see Section 5.6).

In order for the results to be useful, the standard chosen to obtain the detection limit should be such that the mean of its readings is slightly greater than 3S. This may require some trial and error initially when a new instrument is installed.

Records of the instrument detection limit determination will be kept in the instrument log, and the values of the instrument detection limit will be updated in the working SOP's at each time that the instrument detection limits are determined.

5.5.2 Method Detection Limit

The method detection limit is obtained in a manner very similar to that of the instrument detection limit. The principal difference is that in determining the method detection limit (MDL), the analytes are subjected to the entire analytical protocol for the specific method that is being employed. Ideally, the method detection limit should be determined for every matrix that is being analyzed. Unfortunately, obtaining reproducible, well characterized matrices for media other than water is not yet feasible. Hence, method detection limits will be determined for water only.

To determine the method detection limit, seven replicates of laboratory pure water are each spiked with a known amount of the analyte. The amount that is being added is the same for all seven replicates, and should be 2 - 3 times greater than the previously determined instrument detection limit. The seven replicates are subjected to the same analytical procedures as a sample would be, and the concentrations of the analytes of interest are measured. The method detection limit, as was the instrument detection limit, is defined as three times the standard deviation of the seven readings. The calculation of the method detection limit should be done in units of weight of the analyte. In this fashion, such variables as injection volume in chromatographic techniques or pathlength in spectrophotometric techniques are eliminated.

The equations that apply to the calculations of method detection limits are identical to those used for the instrument detection limit.

$$MDL = \frac{3s_m}{RF}$$

Where:

MDL = Method detection limit, in units of weight (ng,ug) for those methods that depend upon an absolute quantity, and in concentration units for those methods that depend upon concentration.

s_m = The standard deviation of the seven readings from the mean, in units of signal size (area, height, etc.)

RF = The response factor of the instrument to the analyte, in units of signal size/unit weight or concentration, depending upon the MDL units.

The method detection limit will be determined for all analytes associated with the method on an annual basis.

A method detection limit study will also be performed whenever the instrument undergoes major repair or modification, if the measurement of the instrument detection limit shows a significant departure from the previously determined instrument detection limit. If the instrument detection limit has remained substantially unchanged after the repair or the modification, there is no need to run the method detection limit again.

Additionally, a method detection limit study must be performed whenever the sample preparation mode is modified.

5.5.3 Quantitation Limits

The quantitation limit is determined at the same time as the method detection limit and from the same runs. The quantitation limit (QL) is defined as five times the standard deviation that has been measured in determining the method detection limit. Thus:

$$QL = \frac{5s_m}{RF}$$

where the symbols have the same meaning as above.

5.5.4 Conversion of Detection Limits to Minimum Detectable Concentration

The conversion of the detection limit (MDL and QL) to a minimum detectable concentration in a sample is done as follows:

$$DLS = \frac{DL}{V_i} \times \frac{V_j}{S}$$

Where: DLS = Detection limit in sample in units of weight per unit weight or per unit volume.

DL = Either the MDL or the QL as defined in the preceding sections.

V_i = Volume of prepared sample taken for analysis (such as the volume of extract injected into a GC), in mL.

V_j = The volume of the prepared sample (such as the final volume of an extract), in mL.

S = The sample size that was taken to produce the prepared sample of volume V_j. Sample size is normally measured in liters for aqueous samples and in grams, dry weight, for solid samples.

5.5.5 Documentation of Detection Limits

Whenever instrument detection limits, method detection limits, and quantitation limits are determined, the results will be copied to the QA/QC Section. The results must identify the type of detection limits and include both the value in terms of weight (absolute quantity) and concentration. In reporting the concentration units, standard sample sizes and aliquots will be reported.

5.5.6 Application of Limits in Data Reporting

In reporting data, the following rules pertaining to detection limits shall apply:

a. Results which are equal to or greater than the value of DLS that has been calculated on the basis of QL will be reported with the concentrations found, without any qualifiers.

b. Results below the value of DLS, calculated on the basis of the MDL, will be reported as not detected at the DLS value.

Exceptions to these rules will be applied only for contracts and projects which specify their detection limits, and whose detection limits exceed the value of QL. Also, exceptions will be applied when a prepared sample requires very high dilution in order to have the analyte of the highest concentration within the linear range of the method.

5.6 Instrument and Equipment Calibration

Instrument and equipment calibration must be rigorously and routinely performed in order to provide reasonable assurance that the data generated are valid and acceptable.

Two principal types of calibration are performed. The first is an initial calibration, which consist of determining the linear range of the instrument and its response factor. The second is a verification calibration, which serves, during the course of running samples, to ascertain that the instrument calibration has not drifted unacceptably. The frequencies of performing the different types of calibrations are shown in Table 5-2.

5.6.1 Initial Calibration

All instrumental methods of analysis are subjected to an initial calibration, consisting of the measurements of responses to various concentration levels of the analytes of interest. The standard solution of the lowest concentration should have a concentration of the analytes of interest approximately 2-5 times the concentration that corresponds to the Instrument Detection Limit; and the standard solution of the highest concentration should have a concentration of the analytes of interest at or near the upper end of the linear range of the method.

In performing the analyses of the standards to determine the response factor and the linear range, the standard solution is prepared as discussed in Section 5.4, and surrogates and internal standards are added as required. The identification of the working standard solution and the date of performing the calibration are entered on the records of the run by the analyst.

When the calibration is completed, the responses are fitted to a straight line of the form:

$$y = ax + b$$

Where: y = The measured response

x = The known amount of the analyte

a = The response factor

b = The y-intercept

In addition to determining the values of a and b, the correlation coefficient is determined. The latter is a measure of how closely the five points were to the straight line. In order for the calibration curve to be valid, the correlation coefficient must be 0.995 or higher, and the ratio b/a must be no greater than the method detection limit (MDL). If the correlation coefficient is not met, it usually implies that either the lowest or the highest concentration of standard is outside the linear range. To correct for this, the analyst should rerun the highest standard, and also run a high standard somewhat more dilute than the initially used highest concentration. Similarly, the analyst should examine the effect of increasing slightly the concentration of the lowest standard.

If the ratio b/a criterion is not met, the problem may be with contamination in the system or change in the noise level of the instrument. To correct for this, the instrument detection limit should be first checked. If it has in fact changed, the ratio should be compared to the newly determined noise level, in order to see if the criterion is met.

While, as much as possible, certified standards are used in the preparation of solutions for calibration, it is always possible that the manufacturer has made a mistake. To circumvent the possibility of error due to a mistake in the manufactured primary standard, a calibration check sample will be analyzed whenever an initial calibration curve is constructed. The calibration check sample will consist of a solution of the analytes of interest, and at known concentration, but obtained and prepared by a different source than the manufacturer of the calibration standards. When the analyte concentrations in the check sample are calculated, they should differ by no more than 15% from the known concentration.

If the discrepancy is greater than 15%, a determination of the source of inaccuracy will be performed.

Once the initial calibration curve has been determined and verified, a table is prepared with the response factors for all the analytes. The table also includes the identification of all the standards used in generating the data, and the date of running the initial calibration. A copy of the calibration curve is maintained in the work area for ready reference on a daily basis and is available for review by the QA/QC Section. Another copy will be submitted with the sample data to the Information Services Section.

5.6.2 Continuing Calibration

Continuing calibrations, sometimes also called verification calibrations, serve to insure that the instrument, during the course of running samples, is remaining sufficiently stable so that the response factor calculated in the initial calibration remains valid.

In performing a continuing calibration, the analyst analyzes a midrange standard containing all the analytes of interest and internal standards and surrogate compounds if applicable. The response factor is determined for each analyte by dividing the signal by the known concentration of the analyte. If the response factor is sufficiently representative of the originally determined response factor as specified by the acceptance criteria for the relevant method, then the instrument is considered to be within calibration. Analysis may continue without performing the initial calibration procedure again. If the response factor is determined to be outside the acceptance range, then the instrument will be recalibrated using the initial calibration process. Samples that have been analyzed since the last acceptable calibration will also require reanalysis after the instrument has been recalibrated.

In recording the information on continuing calibrations, the analyst will enter the identification of the initial calibration to which the continuing calibration relates.

Copy or copies will be submitted to the Information Services Section for inclusion in the file of the project from which samples have been analyzed.

At no time should the response factor be corrected on the basis of the continuing calibration. Until such time as it is necessary to reestablish the initial calibration, the response factors determined in the initial calibration will be adhered to.

5.6.3 Calibration Frequency

Instruments have widely variable stabilities, requiring variable frequencies of calibration. Table 5-2 summarizes the frequencies of such calibrations. It should be emphasized that these frequencies are based on instruments that are performing normally. It is obvious that after change in instrument parameters or after repair the initial calibration must be repeated and the cycle started over again. Thus, the frequencies included in the table are minimum requirements.

TABLE 5-2
CALIBRATIONS FREQUENCIES

INSTRUMENT	APPLICATION	INITIAL CALIBRATION	CONTINUING CALIBRATION
GC/MS	Volatiles	As Needed	Every twelve hours and at the end of a sample sequence, if the instrument is about to be idle.
GC/MS	Semi-Volatiles	As Needed	Every twelve hours and at the end of a sample sequence, if the instrument is about to be idle.
GC	Volatiles by Purge-and-Trap	Every Three Weeks	After every ten samples, and at the end of a sample sequence.
GC	Extracts	Every Three Weeks	After every ten samples, and at the end of a sample sequence.
HPLC	Extracts	Every Four Weeks	After every ten samples, and at the end of a sample sequence.
IC	Solutions	Every Three Days	After every ten samples, and at the end of a sample sequence.
Autoanalyzer	Solutions	Daily	After every ten samples, and at the end of a sample sequence.

TABLE 5-2
CALIBRATIONS FREQUENCIES
(CONTINUED)

INSTRUMENT	APPLICATION	INITIAL CALIBRATION	CONTINUING CALIBRATION
ICP	Digests	Daily	After every ten samples, and at the end of a sample sequence.
AA	Digests	Daily	After every ten samples, and at the end of a sample sequence.
Mercury Analyzer	Digests	Daily	After every ten samples, and at the end of a sample sequence.
TOC Analyzer	Solutions	Daily	After every ten samples, and at the end of a sample sequence.
TOX Analyzer	Solutions	Daily	After every ten samples, and at the end of a sample sequence.
IR	Solutions for O&G or TPH	Daily	Every ten samples, and at the end of a sample sequence.
UV/Vis Spectrophotometer	Solutions	Monthly	Every ten samples, and at the end of a sample sequence.
pH Meter	Aqueous Solutions	Daily[1]	Every ten samples, and at the end of a sample sequence.
Analytical Balance	Solids	Annual[2]	Daily[2]
Thermometers	Temperature	Semi-Annual[3]	Not Applicable

1) pH calibration will require the use of three standards.

2) Analytical balances are calibrated and serviced annually by a contractor. Calibration is checked daily using Class S weights. Deviations from the true weight are recorded and applied to weighings when appropriate.

3) Thermometers are calibrated semiannually against an NIST certified thermometer and any required corrections are applied to measurements.

5.7 Monitoring Laboratory Reagent Water

Multipurpose high purity water is prepared on-site. The laboratory measures the specific conductance and pH of this water on a daily basis. The records are kept in chronological sequence in a bound laboratory notebook with the date of each analysis and responsible analyst. The filters and ion beds of the system are changed as required to assure that high quality water is constantly available.

5.8 Analysis of Quality Control Samples

Routine quality control samples are analyzed to assure that the operation is within control as established for the laboratory on the basis of historical data. The routine quality control consists of blanks, spiked blanks, spiked samples, duplicate samples and external check samples analyses. These are discussed separately in the following sections.

5.8.1 Blanks

Four types of blanks may be associated with any batch of samples. These are: reagent blank, method blank, trip blank, and field blank. The latter two types are treated by the laboratory as ordinary samples and are not part of the internal laboratory QC, although they are very much part of the program QC. Thus, trip and field blanks will not be discussed here.

5.8.1.1 Reagent Blank

Reagent blanks are set aside whenever the reagents are used for preparation of samples. The reagent blank is taken from the reagent or group of reagents that is normally used for sample preparation and that does not go through any of the preparation steps. This reagent blank is normally not analyzed unless the method blank, discussed in Section 5.8.1.2, shows the presence of contamination which may have arisen from the reagents. The reagent blank will be labelled with the QC batch identification, followed by the letter R. It will be set aside until all the samples of the QC batch have been analyzed. At that point, if the method blank was acceptable, the reagent blank may be discarded.

5.8.1.2 Method Blank

The method blank is a preparation carried through all preparatory steps, except that the reagents do not come in contact with a sample. Rather, laboratory reagent water is used in lieu of a real sample. Ideally, the method blank would be prepared using a matrix that is similar to the matrix of the samples that are being prepared. Since a reference matrix is not available for matrices other than water, water is the only matrix used as a method blank.

In preparing the method blank, water is spiked with surrogates and internal standards, if appropriate for the method, and the water sample is carried through the entire analytical procedure. The method blank is prepared with every batch of samples that is being prepared at the same time, provided the batch is no greater than twenty samples. For batches of greater than twenty samples, a method blank will be prepared for every sub-batch of twenty samples or part thereof. The preparation lot will then indicate which samples are associated with the new lot number of reagents.

The method blank is analyzed before any samples are analyzed, and the data of the analysis are reviewed. If no analytes are found above the quantitation limit, analyses of the prepared samples may be undertaken.

If analyte concentrations are found above the quantitation limit, analyses of the associated samples will not be undertaken until the contamination source is identified and isolated. At this stage the reagent blank will be analyzed. If it is found that the reagent blank shows the contamination, the samples will be reprepared using a new lot of reagents.

5.8.2 Spiked Blank

The spiked blank, or laboratory control sample, serves as a measure of accuracy of the analytical procedure in the laboratory. The spiked blank is prepared by adding prescribed amounts of specific analytes to laboratory reagent water prior to preparation of the water for analysis. For inorganic parameters, a spiked blank is prepared for each batch of twenty or fewer samples that are prepared at the same time. Water is spiked for certain analytes of interest for the inorganic parameters.

For organic parameters, a spiked blank is prepared for every batch of 20 samples that is subjected to sample preparation. The spike contains only selected analytes which are specified in the pertinent methods of analysis in the Standard Operating Procedures.

Preparation of the spiking mixture is done in the same manner as the preparation of standard solutions for calibration. The spiking mixture is also assigned an identifying code, which is recorded at the time of preparing the spiked blank.

The spiked blank is carried through the entire analytical procedure, and the concentrations of the spiked analytes determined. These values are accumulated by the QA/QC Section to update acceptance criteria and to validate data. The spiked blank forms the backbone of the determination of the reproducibility of data in the laboratory, since it is based on a well-characterized matrix (water) and is designed to be essentially free of matrix effects. If the spiked blank does not meet established acceptance criteria, the requirements of the analytical method will be relied upon to determine whether the sample failing the acceptance criteria will be reprepared and reanalyzed.

5.8.3 Spiked Sample

Spiked samples serve to confirm that the sample matrix is causing certain effects which preclude the ability to recover analytes using the prescribed method. Thus, the spiked sample is used only to determine matrix effects.

One sample per batch of twenty or fewer samples, of the same apparent matrix, will be spiked with a spiking solution in the same manner as the spiked blank. The spiked sample will be processed through the entire analytical scheme, and the recovery of the spiked analytes will be determined.

In utilizing spiked sample information, great care should be taken because deviations from acceptability may be due either to procedure or to matrix effects. Generally, if the spiked blank associated with the batch exhibits acceptable recoveries, it can be assumed that the sample preparation and analysis have been performed correctly.

Since sample spiking is performed before the sample is initially analyzed, it is possible that for some parameters the analyte level in the sample is so high that the spiked amount is insignificant. Under those circumstances, the analyte spike recovery will be meaningless and need not be calculated.

In selecting a sample for spiking, every effort will be made to choose a field sample, and not one of the field or trip blanks. This can be accomplished only if the identity of the field and trip blanks is known in advance. If those samples are submitted entirely as blind samples, then the selection of the sample to be spiked will be random.

5.8.4 Sample Duplicate

Either sample or spiked sample duplicates are run to assess precision of the laboratory work. One in a batch of 20 or fewer samples of the same matrix will be prepared and analyzed as a sample or spiked sample duplicate.

The precision exhibited by the analyses of sample or spiked sample duplicates may vary due to the effect of the matrix on the analyses. If that is the case, the related batch samples will not be reanalyzed unless the approved method calls for such action.

As in the case of the spiked sample analysis, the choice of sample for sample or spiked sample duplicate analysis will be limited to actual field samples, excluding blanks, unless the identity of the blanks is not known. In that case, the selection will be random.

5.8.5 External Quality Control Audit

An external quality control audit will be performed periodically by submitting for analysis known standard materials from a source other than that from which the calibration standards are prepared. These quality control audit samples will be submitted for analysis by the QA/QC Section, and they will be analyzed by the same procedures as are used for the analyses of samples.

The external quality control audit will be performed on a quarterly basis. If there are projects in the laboratory which have these audit samples submitted by the project, and where the results are made known to the laboratory, then the QA/QC Section will not submit the external quality control audit samples for those parameters which are included in project audit samples.

5.8.6 Record Keeping on Analysis of QC Samples

The results of the analyses of the QC samples may pertain to more than one project, since the sample preparation area batches samples from potentially several sources to provide for efficient operation. Hence, the retrieval of the QC data may be necessary for several different projects. The QC data is identified by the batching identification provided upon the preparation of the samples. Hence, the retrieval of the data can be readily achieved by identification of the preparation batch.

For every batch of samples, the identification of the batch will be entered at the preparation stage on the appropriate forms. Sufficient number of copies of the forms will be made to file with every project associated with the batch. The results of the analysis of the QC samples will be filed sequentially by the QC batch number and will be retrieved through the batch number system whenever it is necessary to retrieve these data.

The QC approval of an analyzed batch will be based on the acceptance of the QC samples associated with the batch. Once the QC samples are determined to be within acceptable limits, the entire batch of samples will be released and the analytical data for each sample will be recorded with the appropriate project.

5.9 Use of Surrogates

The use of surrogates in organic analysis serves as an additional measure of the acceptability of the results. The significant advantage of the use of surrogates is in measuring recovery against a historically established acceptance range in the performance of each analysis. Thus, the data do not depend solely on the spiked blank to assess the quality of each run.

Surrogates are compounds that are expected to behave analytically in a manner similar to the target analytes. The surrogates are added into the sample before the preparation stage is initiated, and their recovery is a measure of the efficiency of the extraction. The following surrogates have been used at CHESTER LabNet and are recommended for use in the approved methodology.

TABLE 5-3

SURROGATE COMPOUNDS AND TYPICAL RECOVERIES

EPA METHOD	COMPOUND	RECOVERY RANGE
501/601/8010	Bromochloromethane	70 - 120
	2-Bromo-1-chloropropane	70 - 120
	1,4-Dichlorobutane	70 - 120
502/602/8020	Benzotrifluoride	80 - 120
604/8040	2-Fluorophenol	21 - 100
	2,4,6-Tribromophenol	10 - 123
605/8050	1-Naphthylamine	10 - 94
606/8060	Dibutylchlorendate	24 - 154
608/8080	Dibutylchlorendate	24 - 154
	2,4,5,6-Tetrachloro-m-xylene	25 - 125
609/8090	2-Fluorobiphenyl	43 -116
610/8310	Benzo(e)pyrene	15 - 113
	2-Fluorobiphenyl	40 - 116
611/8110	Isodrin	33 - 141
612/8120	Dibutylchlorendate	24 - 154
615/8150	2,4-DB	40 - 140

For GC/MS, standard EPA surrogate compounds will be used for all analyses.

5.10 Establishment of Acceptance Criteria

Establishment of acceptance criteria is necessary in order to be able to determine whether or not quantitative data generated by the laboratory are within the control limits. The principal criteria that are used to measure the quality of the data are accuracy and precision.

The initial determination of acceptance criteria hinges upon repetitive measurements of prepared spiked solutions and determination of spike recovery.

Twenty samples of laboratory reagent water are spiked with the analytes of interest at a concentration of approximately twice the quantitation limit. Where applicable, the water is also spiked with surrogates and internal standards. The samples are then prepared for analysis following the appropriate protocol, and the concentrations of the analytes are determined. From these values, the mean and the standard deviation for the recovery of each analyte are determined. The deviation of the mean from the known spiked amount is a measure of the accuracy of the method. The standard deviation of the series of measurements is a measure of the precision of the method.

The percent recovery is calculated as follows:

$$R = 100 \times \frac{C_m - C_1}{C_s}$$

Where:

R = Percent recovery of the analyte.

C_m = The measured concentration of the analyte

C_1 = The native concentration of the analyte in the sample ($C_1 = 0$ for blank spike).

C_s = The amount of analyte spiked into the sample.

The accepted recoveries of the analytes must be within three standard deviations of the mean. It should be emphasized that recoveries are dependent upon both the method of sample preparation and the sample matrix. Thus, recoveries from soil are not expected to be within the acceptance limits as determined for water. Similarly, extraction by sonication may not show the same recovery as would an extraction via a Soxhlet extractor. Thus, acceptance criteria must be determined matrix by matrix, and method by method.

Frequently, samples are spiked at the time of sample preparation, without knowing if the analytes that are being spiked into the sample are present or not, and without knowing if these analytes are at levels that would make the spike amount insignificant. The analyst is cautioned that recoveries of spikes should not be calculated if the amount in the sample is greater than 5 times the spike. For most applications, if the ratio C_1/C_S is equal to or greater than 5, the spike recovery should not be calculated, since the uncertainty in the native concentration is sufficient to cause greater uncertainties in the spike recovery.

The acceptable precision range is defined in a similar manner. The precision is a measure of the deviations from the mean of repetitive measurements. Thus, standard deviation can be used as a measure of precision. More frequently, the relative percent deviation will be used because, at best, measurements are performed in duplicate.

The relative percent deviation is determined by the equation:

$$\%RPD = 100 \times \frac{X_1 - X_2}{X_m}$$

Where: X_1 = High value for the analyte
X_2 = Low value for the analyte
X_m = mean value for the analyte $= \frac{X_1 + X_2}{2}$

The results of the determination of recoveries and relative percent deviations will be plotted, indicating the upper and lower limits of acceptance, and the upper and lower warning limits. Future data will be considered acceptable if recoveries of spikes and relative deviations of duplicates fall within the acceptance criteria. The control charts will be updated regularly, generally requiring 20 data points to obtain a valid control chart. The QC Section will maintain the control charts and update them regularly, when sufficient data are collected. Whenever the control charts are updated and the acceptance limits modified, the QC Section will issue the new limits to the analytical section of the laboratory in which the analyses are performed. It is the responsibility of the Group Leader to assure that data within their section are within the acceptance limits. If they are not, corrective action must be initiated immediately by the Group Leader of the appropriate section.

If five successive measurements, while falling within the control limits, appear on the same side of the mean, the analyst will stop to investigate if the trend indicates that a change in methodology has occurred. Such successive points may indicate a pattern, and it would be necessary to institute a return to preexisting conditions to avoid the possibility that out of control situations may arise.

It is not feasible, in organic analysis, to obtain control charts for every analyte. Thus, while initial control charts are constructed for all the parameters that are being analyzed, continuous verification of the control is obtained through the use of surrogate compounds and the spiked blank analysis. All other analytes in the organic analysis will be assumed to be within control if their relative response to the internal standards and surrogate have remained constant.

While accuracy and precision form the backbone of the acceptability of quantitative data, qualitative identification is more difficult to cast into quantitative measures. In organic analysis, the principal criterion for chromatographic analysis is the retention time, or relative retention time. Relative retention time is used with those methods employing internal standards. It is the more reliable measure because it is less dependent on such physical parameters as the length of the column. In all cases, the retention time for each analyte, or the relative retention time for the analyte, will be based on the data obtained from the nearest standard.

To determine the acceptance windows for retention times, the continuing calibration data will be employed. For each compound, the retention times obtained in performing the continuing calibrations during the period of one week will be averaged and their standard deviation determined. The acceptance window will consist of three standard deviations from the mean retention time for each compound. The retention time acceptance window will be redetermined whenever the chromatographic column is changed or the chromatographic conditions altered. It is the responsibility of the analyst to maintain the records for retention time criteria. Copies of the established acceptance windows will be available to the QC Section for reference in reviewing work. In mass spectrometric analysis, in addition to the retention time, the mass spectral match of the compound to the standard will be used to verify its identity.

5.11 Development of New or Modified Methods

There are occasions when it is necessary in the laboratory either to devise a new approach to analysis or modify an existing method. The former may be needed for analytes for which proven methods do not exist, or if they do, they are not applicable to the matrix being handled. The latter case is frequently the situation that arises because of unusual matrix interferences. It is not the intent of this manual to prescribe analytical approaches to analytes for which methods do not yet exist. However, in order that the laboratory may use the methods with any reliance on the data, the new method must be subjected to the repetitive analyses of a spiked matrix in order to ascertain method precision and accuracy. No method will be employed by the laboratory without the establishment of precision, accuracy, and detection limits.

When a method is being modified, or a new method is being devised and tested for analytes for which an existing approved method is available, a new or modified method will be subjected to equivalency testing. In performing the equivalency testing, the analytes will be subjected to seven replicate analyses in parallel by the existing method and the new method. To be acceptable, the new method must produce results that are statistically equivalent or are better than the old method. In addition, sufficient replicate analyses will be performed to assure that acceptance criteria may be established. The new or modified method will then be written, the method with the supporting data and documentation will be reviewed by the Section Manager for the section in which the analyses will be performed and by the QA/QC Manager. When approved, the method may become part of the repertoire of the laboratory for clients whose work does not require method approval by EPA or other regulatory agencies.

6.0 DATA HANDLING

The data produced by the various groups of the laboratory are ultimately the product which the laboratory offers. Hence, not only is it necessary to produce results with accuracy and precision but it is also necessary to be able to maintain the traceability of the data and the association of sets of data with each other. The responsibilities to the production of accurate and precise data are with the individual analysts. They are, after all, the producers of the data. No amount of supervision and validation can correct for mistakes or omissions occurring at the bench. At best, supervision and validation can cull the unsupported data. Traceability of the data, however, pertains to the manner in which the records are kept within the laboratory as a whole. Because of this, record keeping in the laboratory, will be addressed first. This will be followed by a brief discussion of data reduction, data validation, data review and release, and reporting.

6.1 Data Recording

The modes of maintaining data in the various groups will differ with the methods of analysis. Certain aspects of record keeping have been addressed in the section pertaining to the sample log in and distribution of the information through the laboratory. The traveller and the sample transfer forms constitute the first step in the generation of data for any set of samples. Samples in the laboratory, however, are analyzed in batches. On large jobs, a batch may constitute just a portion of the total number of samples in the job. For small job, a batch may consist of samples from several travellers handled together. Thus, the maintenance or records in the laboratory must also provide for cross-referencing batches and travellers.

6.1.1 Notebooks

Certain records are maintained in notebooks by the analysts. These records may pertain to methods that are entirely manual, such as many of the methods in wet chemistry, or they may be used to record unusual observations during the performance of preparation and analyses of instrumental techniques. These notebooks become a permanent record of laboratory work, and they must be traceable.

Bound hardcover notebooks, with prenumbered pages, will be numbered and issued by the QA/QC section. The QA/QC section will number the notebook, and record in its own notebook log the date of issuance and the laboratory section to which the notebook has been issued. When the notebook has been filled, it will be maintained in the analytical section for permanent archiving.

Users of the notebooks will maintain good laboratory practices in their use. No pages will be torn out of the notebook; corrections will be done by single line-out erasures, followed by initialling and dating the correction; and each page of the notebook will be signed and dated by the analyst at the time entries are made on the page. The use of correction tape, liquid paper, erasures, or other means to make corrections is not permitted.

6.1.2 Record Keeping in Sample Preparation

All records for routine sample preparation will be kept on standardized forms. The forms will be filled by the person preparing the samples. The forms will be filled in ink, with no erasures.

If an error occurs, the preparer will line out the erroneous entry once, and enter the correct entry. The preparer will then initial and date the correction.

The following information must be entered:

a. The analysis type for which the samples are prepared (usually the heading of the sheet)

b. The date of preparation, and the name of the preparer

c. The QC batch identification

d. A listing of the samples being prepared, using the laboratory's sample identification

e. For each sample listed, the quantity of sample taken, including the units of measurement (for solid samples, use the wet weight)

f. If the method calls for the addition of surrogates, then for each sample the surrogate mixture identification and the quantity, including units

g. For any sample that is spiked, the identification of the spiking mixture and the quantity, including units

h. The identification of the medium of the prepared sample (i.e., the solvent for organic extraction, the acid for metal preparation, etc.) and the lot numbers of the reagent media

i. The final volume of each prepared sample, including units

j. Any unusual observations. If these are recorded in a notebook, the notebook and page numbers must be entered on the form.

In addition to filling the form, the preparer must also label the prepared samples. As a minimum, the label will identify the sample and the QC batch in which the sample has been prepared.

When the preparation is complete, the form will be checked for completeness by the Group Leader and initialed and dated. The preparer will make as many copies of the filled form as there are different jobs in the batch. The original of the form will be maintained in the file of the preparing section. The preparer will then transfer the prepared samples with the accompanying copies of the preparation records to the section responsible for the analysis of the prepared samples.

Examples of standard forms for maintaining the records in the sample preparation areas are shown in Figures 6-1 and 6-2.

FIGURE 6-1

CONTINUOUS EXTRACTION BENCH SHEET

Extracted by: ____________________

pH Meter ____________________

Date Extraction Began ____________________ Date Completed ____________________

Length of Extraction ____________________

Solvent ______________ Lot # ____________________ Manufacturer ____________

Work Order	Sample Number	Sample Source	pH	Extract Volume	Surrogate Lot #	Matrix Spike Lot #
					Amount Added	Amount Adde

[illegible] ____________________ Date: ____________

wed by: ____________________ Date. ____________

FIGURE 6-2

AQUEOUS SAMPLE METALS DIGESTION

Page # ____________

Case Number (CLP only) ____________

SDG Number (CLP only) ____________

Date of Digestion ____________

Time of Digestion ____________

Technician ____________

Digestion for (ICP/GFAA) ____________

Work Order Number	Sample Number	Sample Source	Initial Vol. (mls)	Final Vol (mls)	Color Before	Color After	Clarity Before	Clarity After	Comments

6.1.3 Record Keeping for Instrument Analysis

Many instrument methods of analysis produce printed traces, charts, or tables. Some of the information specified below is entered through a data system before samples are analyzed. Clearly, those items of information need not be reentered manually.

For every technique, however, a run log must be maintained. The following information must be entered in the run log by the analyst.

a. Identification of the analysis (usually this will be the heading of the log)

b. Identification of the instrument

c. Date of analysis, and identification of the analyst

d. Identification of the QC batch

e. Sequential listing of samples (including tuning, initial calibration or continuing calibration, blanks, spiked blanks, samples, duplicate samples, spiked samples, etc). This listing must be accurate and sequential, and the run number (where applicable) must be included.

f. Aliquot of prepared sample that is taken for analysis, including units

g. Any unusual observations. If these are entered in a notebook, they need only be summarized on the form, and the notebook and page numbers entered for further identification of the comments.

Where printouts for each sample are obtained separately, the printout must include the identification of the method of analysis, date of analysis, identification of the analyst, identification of the run, identification of the QC batch, and the aliquot of sample that was used.

Before transferring the data further, the analyst must confirm that the results, as they appear on the printout, are correct. If the results are incorrect, the analyst will line them out once, enter the correct value manually, and initial and date the change. These corrections will be done in ink. When the analyst is finished with the batch of samples, including the review of the data, he will initial the run log and transfer the run log with the data to the Group Leader.

The Group Leader will review the run log to verify that the sample sequence has been properly followed as required by the specific method. Next, the Group Leader will check the QC data pertaining to the batch and verify that the instrument was performing within the required specifications. The Group Leader also reviews any dilutions to make sure that they are appropriate, assures that calculations are accurate, and verifies that reporting units are proper. The QA/QC Section will spot check data and provide guidance for data validation to the Group Leader.

When the Group Leader is satisfied that the data are valid (see Section 6.3, Data Validation), he will initial the run log and date it. He will have as many copies made of the run log as there are jobs represented in the batch that has been analyzed. He will then transfer the sample data to Information Services. Together with the data, the Group Leader will transfer the copies of the records from the preparation group to the Information Services Section. The original run log will be maintained in the files and records of the section responsible for the analysis.

For instrument methods which do not produce the identifying code of the run on the permanent records, for example, methods that employ a strip chart as the instrumental output, the individual traces will be identified manually by the run number, and the identification of the parameters associated with the run will be recorded manually on the run log.

6.1.4 Record Keeping in Noninstrument Analyses

Raw data from these analyses will be kept in permanently bound, sequentially paginated notebooks and will include all the information discussed above in reference to automated printouts. Copies of this data will be submitted to the Information Services Section, and the original data will remain in the laboratory notebooks.

6.2 Data Reduction

Reducing the raw data to a presentable form is the responsibility of the analyst performing the analysis. In reducing data, the analyst must take into account whether the sample is aqueous or solid, the sample size, and whether or not the data are to be presented in the form of wet weight or dry weight. All final values must be accompanied with the units of the value. The following equation applies to the calculation for concentration of an analyte in most analytical techniques employed in the laboratory.

$$C = \frac{I}{RF} \times \frac{1}{V_i} \times \frac{V_e}{A_s} \times DF$$

Where: C = Concentration of the analyte in the sample, in appropriate units [ng/L (ppt), ug/L (ppb), mg/L (ppm); ng/kg (ppt), ug/kg (ppb), mg/kg (ppm)]

I = Signal size, in units appropriate to the method

RF = The response factor, as defined in Section 5.6.1, in units of signal size per unit weight of the analyte. This response factor is essentially a mean response factor, determined through regression of the initial calibration data. If is not possible to use the mean response factor (usually because of instrumental software limitations), then the response factor from the run that corresponds to the midpoint of the linear range is used, as long as this response factor does not differ from the mean by more than 10%. The response factor to be used is always taken from the initial calibration.

V_i = The aliquot size (such as injection amount) of the prepared sample, taken for analysis, in units of mL

V_e = The total final volume of the prepared sample (extract volume, digest volume, etc.) in units of mL

A_s = The amount of sample taken for preparation. For liquid samples, use mL; for solid samples use the weight in kg. If the results are to be determined on the basis of dry weight, use the following to determine the sample size:

$$A_s\,(\text{dry}) = A_s\,(\text{wet}) \times \frac{\%\text{solids}}{100}$$

DF = Dilution factor. The dilution factor is 1 for samples that are prepared exactly as prescribed in the protocol. If the extract or digestate require dilution, then the dilution factor differ from unity. For example, if an extract is diluted from 1 mL to 100 mL the dilution factor becomes 100. If an extract is concentrated from 10 mL to 1 mL the dilution factor becomes 0.1.

In many methods, the data reduction is computerized, alleviating the need for extensive manual reduction of the results. However, the analyst must review the data, relating it back to the fundamental measurements on which the analyses are based. Thus, in chromatographic techniques, the analyst will compare area counts of peaks with those of the corresponding standard, and verify that the data were in fact correctly reduced. It is also the responsibility of the analyst to verify the identification of parameters.

6.3 Data Validation

Data validation within each analytical group has been discussed previously. It is not the responsibility of the QA/QC personnel to check and verify every value generated and reported by the laboratory; however, the QA/QC Section will function in a reviewing capacity to assure that the data validation process remains reliable and is performed according to laboratory policy.

These items must be verified during the data validation process:

a. Is the batch complete?

b. Have all the analyses been performed within holding times, and if not is there an acceptable explanation for deviations from the holding times?

c. Is there a valid continuing calibration associated with the runs for each parameter of the individual samples within the batch?

d. Is the sample sequence proper for the method (i.e., are there regular blanks run when necessary, are there standards run for methods requiring periodic standards, are there laboratory blank spikes, matrix spikes, and laboratory duplicates)?

e. If surrogates are required by the method, are recoveries within the control limits in the spiked blank?

f. Are surrogate recoveries within control limits in the samples?

g. Is the recovery of spiked compounds in the laboratory spiked blank acceptable?

h. Is the recovery of spiked compounds in the spiked sample acceptable?

i. Do duplicate analyses in the run sequence exhibit precision within the control limits?

j. Is the documentation in order?

If the answers to all the questions above are "yes", the data will be released and reported.

If the answer to any of the questions is negative, corrective action will be undertaken and reported to the QA/QC Section and the Project Manager. A Corrective Action Notice (Figure 5-2) will be generated and submitted to the QA/QC Section by the Group Leader, thus documenting the source of the problem and its resolution. Data Validation is a check of the batch for completeness, accuracy and precision. If all criteria are met, the batch is released. If some are not met, the batch may still be released, depending upon what criteria are not met and what is the explanation for not meeting the criteria. There are certain circumstances when the release of the data is not allowed regardless of the rationale for the lack of acceptability. These are:

a. Continuing calibration was either not performed as required.

b. Laboratory control standards (spiked blanks) were not run or did not meet acceptance criteria

c. Data sets are not complete

Corrective action for these situations will be discussed in Section 7.0.

If certain aspects of the data do not meet acceptance criteria, but consultation with the project manager or the Group Leader resulted in a decision to release the data, the Quality Assurance Manager will annotate on the Corrective Action (Figure 5-2) the shortcomings of the data, the decision to proceed with reporting the data, and the person with whom that decision had been reached. The QA Manager will then submit the form to the Information Services Section so that the final report can be prepared.

If the decision has been made not to release the data, the form will be marked "DO NOT RELEASE DATA" and submitted to the Information Services Section.

In addition to validating the data, it is also necessary to validate specific jobs before they are released. Specifically, releasing a job consists of insuring that all required parameters have been analyzed and are reported. The result for each parameter must have been acceptably validated through approval of the individual batches that make up all of the parameters associated with the job. It is the responsibility of the Information Services Section in conjunction with the Project Manager to assure that all data are validated and entered and that the documentation is complete before the final report is generated. The QA/QC Section will only spot check the final reports.

6.4 Data Compilation

Information Services personnel will review the job file to confirm that all the data are in the file and references are made to those items which are associated with the job but are present in other files.

The data will then be entered in standardized forms, and the report printed out.

6.5 Final Review

When the final report has been printed, the Project Manager will proof the report against the raw data in the file. If all the data are properly entered, the report will be reviewed by the Lab Director and approved before it is sent to the client. A copy of the report will be placed in the job file, and the file will be transferred to the central file storage for completed jobs.

7.0 CORRECTIVE ACTION

There are many areas of the laboratory functions which may require corrective action. The decision to undertake corrective action and the ensuing action must be documented so that traceability can be maintained. The point of originating the corrective action varies, depending upon the mode of detecting that such action is necessary. It is, however, frequently the role of the QA/QC Section to initiate such action simply because it is this section which is most exposed to the malfunctions of the laboratory as they reflect upon the data produced. Those actions that affect the quality of the data will be recorded and the record maintained by the QA/QC Section.

7.1 Identification of Potential Problem

Identification of sources of problems is not always an easy matter. It is not expected that the QA/QC Section will be able to trace the source of every problem identified. However, the QA/QC Section will be responsible for informing the Section Manager or Group Leader and the Laboratory Director when a problem exists in a particular analysis. In this case, data for that type of analysis will not be accepted until the problem is isolated and corrected. It will be the responsibility of the Group Leader to address the identification of the source of the problem, and the responsibility of the Laboratory Director to assure that the Group Leader is acting upon the need for corrective action.

In some situations, the need to correct an operation is apparent to the analyst. For example, instrument failures are detected by the analyst and the corrective action is taken in the form of repairing the instrument either through a service call or using laboratory personnel. Such action must be recorded in the instrument maintenance log and close scrutiny will be paid to the analyses just preceding the instrument failure. If these analyses meet the required acceptance criteria, no further action will be taken relative to that data.

In other situations, the time of data validation is the more logical time to isolate a potential problem. For example, if a systematic drift occurs due to chromatographic column contamination, it is easier to identify at the time of validating the data and comparing the results with historically available information.

7.2 Problems and Actions

7.2.1 Continuing Calibration Outside Acceptance Range

When the continuing calibration is outside the acceptance range, the problem should be identified by the analyst and corrected before further sample processing is undertaken. However, the acceptability of the continuing calibration is also subject to review at all later checks in the data validation process.

The data on all samples that have been analyzed following the last time that the calibration was within specification will be rejected. (If data have been released to Information Services, the QA/QC Section will be notified immediately using the Form shown in Figure 5-2.) The affected samples will be reanalyzed after the new initial calibration curve has been constructed.

7.2.2 Calibration Standards Exceeding the Permitted Holding Time

If calibrations standards have been continuously used beyond their permitted shelf-life, the group responsible for the analysis will be notified, and a Corrective Action Notice (Figure 5-2) will be generated. The group will then be responsible for preparing fresh calibration standards, and the instrument calibration will be checked against the new standards. If the previous runs, performed with the expired standards meet the acceptance criteria based on the new standard, the data generated will be considered valid, in spite of the use of an expired calibration standard.

If the calibrations performed with the expired standard do not meet the acceptance criteria when measured against the new standards, the samples that have been analyzed against the expired standard will be reanalyzed and quantified using the freshly prepared standards.

7.2.3 Laboratory Method Blanks Exceed Method Detection Limit but are Below Quantitation Limit

When laboratory blanks exhibit the presence of target analytes at a level exceeding the method detection limit, but still below the quantitation limit, the responsible group will be notified.

The responsible section will check the reagent blanks that have been retained at the time of use of the reagents in order to determine if contamination or interferences are due to impurities in the reagents. If this is the case, the reagent batch will be discarded, and new reagents will be used.

If the reagents appear to be sufficiently pure, the cleanliness in laboratory procedures will be reviewed to establish if the source of problems may have been contamination of the apparatus.

7.2.4 Laboratory Method Blank Exceeds the Quantitation Limit

When the laboratory method blank exceeds the quantitation limit, the Group responsible for the analysis will be notified. As discussed in Section 7.2.3, the analysts will check for potential contamination of reagents and apparatus. If the reagents are contaminated, the existing reagent batch will be discarded and a fresh batch from new containers will be prepared.

If the problem arose from the apparatus or glassware, the problem will be corrected within the analytical group, and the correction documented before any further analyses can be undertaken. Notification of the corrective action will be submitted by the Group Leader to the QA/QC Section.

The data associated with the failed method blank will not be accepted. The samples will be reanalyzed to produce acceptable data.

7.2.5 Laboratory Control Standard Exhibits Recoveries Outside the Acceptance Criteria

When the laboratory control standard (spiked blank) does not meet the acceptance criteria, the batch of samples associated with the laboratory control standard will be reanalyzed if determinative methods call for this as corrective action. Where, as in many organic methods, a check sample is analyzed only for failed spiked sample components, then reanalysis of the batch will also be necessary, but only for the failed components. In methods that require the use of a laboratory control standard at frequent intervals through the day, only those samples analyzed since the last acceptable laboratory control standard analysis will require repeating. Data originating from batch analyses preceding the failed QC check will be rejected.

Before repeating a whole set of preparations of samples, the calibration of the instrument or method shall be checked. If the instrument is within calibration, the samples will require repreparation. If the instrument calibration has drifted, the prepared samples from the initial preparation can be reanalyzed after the instrument has been recalibrated.

7.2.6 Surrogates and Sample Spikes Exhibit Recoveries Outside the Acceptance Limits

When recoveries from spiked samples are outside the acceptance limits, but the laboratory spiked blank is within the acceptance criteria, the poor recovery or enhanced apparent recovery may be due to matrix effect. One such sample from the batch will be reprepared and reanalyzed. If the same phenomenon is observed, it will be assumed that the failure to meet recovery criteria was, in fact, a matrix effect. This information will be included in the report to the client; however, the original data will be accepted.

7.2.7 Control Chart Exhibits a Regular Trend

By their very nature, the individual points that make-up the control chart for any analyte vary randomly about a mean value. The control chart is used to assess the acceptability of recovery data on the basis of historical data. The control chart is also used to warn the analyst that some consistent problem or deviation in the method may be occurring.

When five successive points on the control chart form a steady pattern, either regularly increasing or regularly decreasing, they imply that some change is occurring in the analytical scheme. Even if all the points are within the control limits, a warning will be issued by the QA/QC Section to the responsible group to investigate the cause of the pattern. If, in fact, a change has occurred in the method, and if the change indicates an improvement in recoveries (an improvement is defined as approaching complete recovery, not necessarily an upward trend), then a new control chart will be established, and subsequent data will be compared to the new control chart limits. If a change has occurred that worsens the recovery, it will be the responsibility of the Group Leader to assure that a return to the previously used technique is made in his section.

7.2.8 Internal and External Audits and Corrective Actions

Internal system audits are quarterly samples issued by the QA/QC Section, using known spiked solutions to determine the acceptability of performance in every group of the laboratory. External performance evaluation is either done through a contract required performance audit, or though voluntary participation in interlaboratory studies.

7.2.8.1 Evaluation of System Audits

When the achieved results on these audits fall below acceptable standards, as defined on the basis of historical recovery data, a thorough review of the system will be initiated. The QA/QC Section is responsible for the initiation of the process.

The first step will consist of complete review of the correctness of the documenting of the job and the calculations of the results. This process will be performed by the personnel of the QA/QC Section. When the results of the review are complete, a memo will be issued to the responsible group of the laboratory, itemizing the deficiencies that have been identified. If no deficiencies have been identified, the difficulty may be with the performance of the analyst, the analytical method, or incorrect preparation of the audit sample.

7.2.8.2 Corrective Action and Feedback

The group leaders will be responsible for investigating problem areas identified by the QA/QC Section. A written report of the findings and corrective action taken will be submitted to the QA/QC Section within one week of the beginning of the Group Leader's investigation into the problem. If the source of the problem has not been located at this point, the QA/QC Section will issue a repeat performance evaluation audit sample. It will be assumed that the problem was with the original audit sample itself if the repeat evaluation sample is successfully analyzed within acceptance limits. Otherwise, the process outlined above will continue until the manager of the QA/QC Section determines that the problem has been corrected and notifies the Group Leader of the successful resolution.

7.2.8.3 Documentation of Corrective Action

When the cause for failed internal or external audit samples has been identified and corrective action implemented, the QA/QC Section will document the resolution of the problem in a brief report to laboratory management. The QA/QC Section will also maintain a file of corrective actions which were necessary to remedy performance deficiencies which have arisen.

Appendix H. 8

EPA III MICRO-PURGING GUIDANCE

ATTACHMENT 1

APPENDIX H.8

EPA III MICRO-PURGING GUIDANCE

United States
Environmental Protection
Agency

Office of
Research and
Development

Office of Solid Waste
and Emergency
Response

EPA/540/S-95/504
April 1996

EPA Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls[1] and Michael J. Barcelona[2]

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

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I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic *units*. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

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Director

chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquitards or* low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at *hazardous waste sites to detect and monitor plume movement* over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987, McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990, McCarthy and Degueldre, 1993; Backhus et al., 1993, U. S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals, hydrous iron, aluminum, and manganese oxides, dissolved and particulate organic materials, and viruses and bacteria. These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total mobile* contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias naturally suspended particle concentrations.

Currently the most common ground water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;

2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and

3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

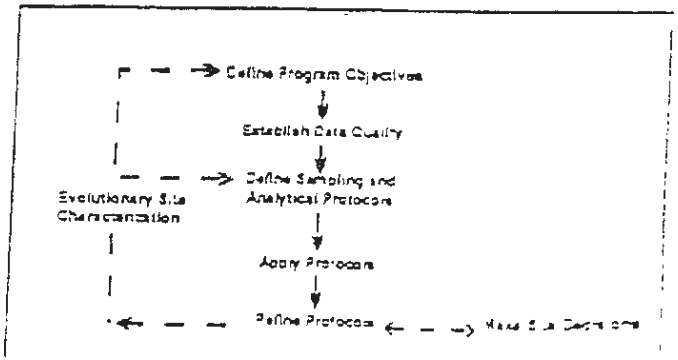

Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1.78 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the mobile load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control

- reduced stress on the formation (minimal drawdown),
- less mixing of stagnant casing water with formation water;
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time,
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986, Puls and Barcelona, 1989; Puls et. al. 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include: mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g., pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation

D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling

1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and *minimal* disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U. S. EPA (1992), Parker (1994) and Thurnblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over <u>any</u> other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 µm filters]) concentrations of major ions and trace metals, 0.1 µm filters are recommended although 0.45 µm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO_2 composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 µm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, ± 3% for conductivity, ± 10 mv for redox potential, and ± 10% for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe^{2+}, CH_4, H_2S/HS^-, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

(1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.

(2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.

(3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

A. *Low-Permeability Formations (<0.1 L/min recharge)*

1. Low-Flow Purging and Sampling with Pumps

a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.

b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2. Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

B. *Fractured Rock*

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop -- A Workshop Summary" (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

VII. Notice

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Figure 2. Ground Water Sampling Log

Project ______________ Site ______________ Well No. ______________ Date ______________

Well Depth ______________ Screen Length ______________ Well Diameter ______________ Casing Type ______________

Sampling Device ______________ Tubing type ______________ Water Level ______________

Measuring Point ______________ Other Infor ______________

Sampling Personnel ______________

Time	pH	Temp	Cond.	$Dis.O_2$	Turb.	[ ]Conc			Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3 \pi r^3$

Figure 3. Ground Water Sampling Log (with automatic data logging for most water quality parameters)

Project ______________ Site ______________ Well No. ____________ Date ______________

Well Depth ____________ Screen Length __________ Well Diameter _________ Casing Type __________

Sampling Device ______________ Tubing type ______________________ Water Level ____________

Measuring Point _________________ Other Infor ____

Sampling Personnel ____

Time	Pump Rate	Turbidity	Alkalinity	[ ] Conc	Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3 \pi r^3$

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUNDWATER SAMPLES FROM MONITORING WELLS

Quality Assurance Unit
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Revision Page

Date	Rev #	Summary of changes	Sections
7/30/96	2	Finalized	
01/19/10	3	Updated	All sections

TABLE OF CONTENTS

Page

USE OF TERMS

Equipment blank. The equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank needs only to include the pump in subsequent sampling rounds. If the pump and tubing are dedicated to the well, the equipment blank is collected prior to its placement in the well. If the pump and tubing will be used to sample multiple wells, the equipment blank is normally collected after sampling from contaminated wells and not after background wells.

Field duplicates: Field duplicates are collected to determine precision of the sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

Indicator field parameters: This SOP uses field measurements of turbidity, dissolved oxygen, specific conductance, temperature, pH, and oxidation/reduction potential (ORP) as indicators of when purging operations are sufficient and sample collection may begin.

Matrix Spike/Matrix Spike Duplicates: Used by the laboratory in its quality assurance program. Consult the laboratory for the sample volume to be collected.

Poteniometric Surface: The level to which water rises in a tightly cased well constructed in a confined aquifer. In an unconfined aquifer, the potentiometric surface is the water table.

QAPP: Quality Assurance Project Plan

SAP: Sampling and Analysis Plan

SOP: Standard operating procedure

Stabilization: A condition that is achieved when all indicator field parameter measurements are sufficiently stable (as described in the "Monitoring Indicator Field Parameters" section) to allow sample collection to begin.

Temperature blank: A temperature blank is added to each sample cooler. The blank is measured upon receipt at the laboratory to assess whether the samples were properly cooled during transit.

Trip blank (VOCs): Trip blank is a sample of analyte-free water taken to the sampling site and returned to the laboratory. The trip blanks (one pair) are added to each sample cooler that contains VOC samples.

SCOPE & APPLICATION

The goal of this groundwater sampling procedure is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations. This standard operating procedure (SOP) for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under certain low-flow conditions.

The SOP emphasizes the need to minimize hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns, and by using low pumping rates during purging and sampling operations. Indicator field parameters (e.g., dissolved oxygen, pH, etc.) are monitored during purging in order to determine when sample collection may begin. Samples properly collected using this SOP are suitable for analysis of groundwater contaminants (volatile and semi-volatile organic analytes, dissolved gases, pesticides, PCBs, metals and other inorganics), or naturally occurring analytes. This SOP is based on Puls, and Barcelona (1996).

This procedure is designed for monitoring wells with an inside diameter (1.5-inches or greater) that can accommodate a positive lift pump with a screen length or open interval ten feet or less and with a water level above the top of the screen or open interval (Hereafter, the "screen or open interval" will be referred to only as "screen interval"). This SOP is not applicable to other well-sampling conditions.

While the use of dedicated sampling equipment is not mandatory, dedicated pumps and tubing can reduce sampling costs significantly by streamlining sampling activities and thereby reducing the overall field costs.

The goal of this procedure is to emphasize the need for consistency in deploying and operating equipment while purging and sampling monitoring wells during each sampling event. This will help to minimize sampling variability

This procedure describes a general framework for groundwater sampling. Other site specific information (hydrogeological context, conceptual site model (CSM), DQOs, etc.) coupled with systematic planning must be added to the procedure in order to develop an appropriate site specific SAP/QAPP. In addition, the site specific SAP/QAPP must identify the specific equipment that will be used to collect the groundwater samples.

This procedure does not address the collection of water or free product samples from wells containing free phase LNAPLs and/or DNAPLs (light or dense non-aqueous phase liquids). For this type of situation, the reader may wish to check: Cohen, and Mercer (1993) or other pertinent documents.

This SOP is to be used when collecting groundwater samples from monitoring wells at all Superfund, Federal Facility and RCRA sites in Region 1 under the conditions described herein. Request for modification of this SOP, in order to better address specific situations at individual wells, must include adequate technical justification for proposed changes. <u>All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.</u>

BACKGROUND FOR IMPLEMENTATION

It is expected that the monitoring well screen has been properly located (both laterally and vertically) to intercept existing contaminant plume(s) or along flow paths of potential contaminant migration. Problems with inappropriate monitoring well placement or faulty/improper well installation cannot be overcome by even the best water sampling procedures. This SOP presumes that the analytes of interest are moving (or will potentially move) primarily through the more permeable zones intercepted by the screen interval.

Proper well construction, development, and operation and maintenance cannot be overemphasized. The use of installation techniques that are appropriate to the hydrogeologic setting of the site often prevent "problem well" situations from occurring. During well development, or redevelopment, tests should be conducted to determine the hydraulic characteristics of the monitoring well. The data can then be used to set the purging/sampling rate, and provide a baseline for evaluating changes in well performance and the potential need for well rehabilitation. Note: if this installation data or well history (construction and sampling) is not available or discoverable, for all wells to be sampled, efforts to build a sampling history should commence with the next sampling event.

The pump intake should be located within the screen interval and at a depth that will remain under water at all times. It is recommended that the intake depth and pumping rate remain the same for all sampling events. The mid-point or the lowest historical midpoint of the saturated screen length is often used as the location of the pump intake. For new wells, or for wells without pump intake depth information, the site's SAP/QAPP must provide clear reasons and instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected. If the depths to top and bottom of the well screen are not known, the SAP/QAPP will need to describe how the sampling depth will be determined and how the data can be used.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU, and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the indicator field parameter criteria in this procedure are met. If after 2 hours of purging indicator field parameters have not stabilized, one of three optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization), c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may reflect a sampling bias and therefore, the data may not meet the data quality objectives of the sampling event).

It is recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

HEALTH & SAFETY

When working on-site, comply with all applicable OSHA requirements and the site's health/safety procedures. All proper personal protection clothing and equipment are to be worn. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

CAUTIONS

The following cautions need to be considered when planning to collect groundwater samples when the below conditions occur.

If the groundwater degasses during purging of the monitoring well, dissolved gases and VOCs will be lost. When this happens, the groundwater data for dissolved gases (e.g., methane, ethene, ethane, dissolved oxygen, etc.) and VOCs will need to be qualified. Some conditions that can promote degassing are the use of a vacuum pump (e.g., peristaltic pumps), changes in aperture along the sampling tubing, and squeezing/pinching the pump's tubing which results in a pressure change.

When collecting the samples for dissolved gases and VOCs analyses, avoid aerating the groundwater in the pump's tubing. This can cause loss of the dissolved gases and VOCs in the groundwater. Having the pump's tubing completely filled prior to sampling will avoid this problem when using a centrifugal pump or peristaltic pump.

Direct sun light and hot ambient air temperatures may cause the groundwater in the tubing and flow-through-cell to heat up. This may cause the groundwater to degas which will result in loss of VOCs and dissolved gases. When sampling under these conditions, the sampler will need to shade the equipment from the sunlight (e.g., umbrella, tent, etc.). If possible, sampling on hot days, or during the hottest time of the day, should be avoided. The tubing exiting the monitoring well should be kept as short as possible to avoid the sun light or ambient air from heating up the groundwater.

Thermal currents in the monitoring well may cause vertical mixing of water in the well bore. When the air temperature is colder than the groundwater temperature, it can cool the top of the water column. Colder water which is denser than warm water sinks to the bottom of the well and the warmer water at the bottom of the well rises, setting up a convention cell. "During low-flow sampling, the pumped water may be a mixture of convecting water from within the well casing and aquifer water moving inward through the screen. This mixing of water during low-flow sampling can substantially increase equilibration times, can cause false stabilization of indicator parameters, can give false indication of redox state, and can provide biological data that are not representative of the aquifer conditions" (Vroblesky 2007).

Failure to calibrate or perform proper maintenance on the sampling equipment and measurement instruments (e.g., dissolved oxygen meter, etc.) can result in faulty data being collected.

Interferences may result from using contaminated equipment, cleaning materials, sample containers, or uncontrolled ambient/surrounding air conditions (e.g., truck/vehicle exhaust nearby).

Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment and/or proper planning to avoid ambient air interferences. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

Clean and decontaminate all sampling equipment prior to use. All sampling equipment needs to be routinely checked to be free from contaminants and equipment blanks collected to ensure that the equipment is free of contaminants. Check the previous equipment blank data for the site (if they exist) to determine if the previous cleaning procedure removed the contaminants. If contaminants were detected and they are a concern, then a more vigorous cleaning procedure will be needed.

PERSONNEL QUALIFICATIONS

All field samplers working at sites containing hazardous waste must meet the requirements of the OSHA regulations. OSHA regulations may require the sampler to take the 40 hour OSHA health and safety training course and a refresher course prior to engaging in any field activities, depending upon the site and field conditions.

The field samplers must be trained prior to the use of the sampling equipment, field instruments, and procedures. Training is to be conducted by an experienced sampler before initiating any sampling procedure.

The entire sampling team needs to read, and be familiar with, the site Health and Safety Plan, all relevant SOPs, and SAP/QAPP (and the most recent amendments) before going onsite for the sampling event. It is recommended that the field sampling leader attest to the understanding of these site documents and that it is recorded.

EQUIPMENT AND SUPPLIES

A. Informational materials for sampling event

A copy of the current Health and Safety Plan, SAP/QAPP, monitoring well construction data, location map(s), field data from last sampling event, manuals for sampling, and the monitoring instruments' operation, maintenance, and calibration manuals should be brought to the site.

B. Well keys.

C. Extraction device

Adjustable rate, submersible pumps (e.g., centrifugal, bladder, etc.) which are constructed of stainless steel or Teflon are preferred. Note: if extraction devices constructed of other materials are to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

If bladder pumps are selected for the collection of VOCs and dissolved gases, the pump setting should be set so that one pulse will deliver a water volume that is sufficient to fill a 40 mL VOC vial. This is not mandatory, but is considered a "best practice". For the proper operation, the bladder pump will need a minimum amount of water above the pump; consult the manufacturer for the recommended submergence. The pump's recommended submergence value should be determined during the planning stage, since it may influence well construction and placement of dedicated pumps where water-level fluctuations are significant.

Adjustable rate, peristaltic pumps (suction) are to be used with caution when collecting samples for VOCs and dissolved gases (e.g., methane, carbon dioxide, etc.) analyses. Additional information on the use of peristaltic pumps can be found in Appendix A. If peristaltic pumps are used, the inside diameter of the rotor head tubing needs to match the inside diameter of the tubing installed in the monitoring well.

Inertial pumping devices (motor driven or manual) are not recommended. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability, etc). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

D. Tubing

Teflon or Teflon-lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. Note: if tubing constructed of other materials is to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for metal and other inorganics analyses.

The use of 1/4 inch or 3/8 inch (inside diameter) tubing is recommended. This will help ensure that the tubing remains liquid filled when operating at very low pumping rates when using centrifugal and peristaltic pumps.

Silastic tubing should be used for the section around the rotor head of a peristaltic pump. It should be less than a foot in length. The inside diameter of the tubing used at the pump rotor head must be the same as the inside diameter of tubing placed in the well. A tubing connector is used to connect the pump rotor head tubing to the well tubing. Alternatively, the two pieces of tubing can be connected to each other by placing the one end of the tubing inside the end of the other tubing. The tubing must not be reused

E. The water level measuring device

Electronic "tape", pressure transducer, water level sounder/level indicator, etc. should be capable of measuring to 0.01 foot accuracy. Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each sampling event.

F. Flow measurement supplies

Graduated cylinder (size according to flow rate) and stopwatch usually will suffice.

Large graduated bucket used to record total water purged from the well.

G. Interface probe

To be used to check on the presence of free phase liquids (LNAPL, or DNAPL) before purging begins (as needed).

H. Power source (generator, nitrogen tank, battery, etc.)

When a gasoline generator is used, locate it downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate samples.

I. Indicator field parameter monitoring instruments

Use of a multi-parameter instrument capable of measuring pH, oxidation/reduction potential (ORP), dissolved oxygen (DO), specific conductance, temperature, and coupled with a flow-through-cell is required when measuring all indicator field parameters, except turbidity. Turbidity is collected using a separate instrument. Record equipment/instrument identification (manufacturer, and model number).

Transparent, small volume flow-through-cells (e.g., 250 mLs or less) are preferred. This allows observation of air bubbles and sediment buildup in the cell, which can interfere with the operation of the monitoring instrument probes, to be easily detected. A small volume cell facilitates rapid turnover of water in the cell between measurements of the indicator field parameters.

It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.

Turbidity samples are collected before the flow-through-cell. A "T" connector coupled with a valve is connected between the pump's tubing and flow-through-cell. When a turbidity measurement is required, the valve is opened to allow the groundwater to flow into a container. The valve is closed and the container sample is then placed in the turbidimeter.

Standards are necessary to perform field calibration of instruments. A minimum of two standards are needed to bracket the instrument measurement range for all parameters except ORP which use a Zobell solution as a standard. For dissolved oxygen, a wet sponge used for the 100% saturation and a zero dissolved oxygen solution are used for the calibration.

Barometer (used in the calibration of the Dissolved Oxygen probe) and the conversion formula to convert the barometric pressure into the units of measure used by the Dissolved Oxygen meter are needed.

J. Decontamination supplies

Includes (for example) non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.

K. Record keeping supplies

Logbook(s), well purging forms, chain-of-custody forms, field instrument calibration forms, etc.

L. Sample bottles

M. Sample preservation supplies (as required by the analytical methods)

N. Sample tags or labels

O. PID or FID instrument

If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

P. Miscellaneous Equipment

Equipment to keep the sampling apparatus shaded in the summer (e.g., umbrella) and from freezing in the winter. If the pump's tubing is allowed to heat up in the warm weather, the cold groundwater may degas as it is warmed in the tubing.

EQUIPMENT/INSTRUMENT CALIBRATION

Prior to the sampling event, perform maintenance checks on the equipment and instruments according to the manufacturer's manual and/or applicable SOP. This will ensure that the equipment/instruments are working properly before they are used in the field.

Prior to sampling, the monitoring instruments must be calibrated and the calibration documented. The instruments are calibrated using U.S Environmental Protection Agency Region 1 *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity),* January 19, 2010, or latest version or from one of the methods listed in 40CFR136, 40CFR141 and SW-846.

The instruments shall be calibrated at the beginning of each day. If the field measurement falls outside the calibration range, the instrument must be re-calibrated so that all measurements fall within the calibration range. At the end of each day, a calibration check is performed to verify that instruments remained in calibration throughout the day. This check is performed while the instrument is in measurement mode, not calibration mode. If the field instruments are being used to monitor the natural attenuation parameters, then a calibration check at mid-day is highly recommended to ensure that the instruments did not drift out of calibration. Note: during the day if the instrument reads zero or a negative number for dissolved oxygen, pH, specific conductance, or turbidity (negative value only), this indicates that the instrument drifted out of calibration or the instrument is malfunctioning. If this situation occurs the data from this instrument will need to be qualified or rejected.

PRELIMINARY SITE ACTIVITIES (as applicable)

Check the well for security (damage, evidence of tampering, missing lock, etc.) and record pertinent observations (include photograph as warranted).

If needed lay out sheet of clean polyethylene for monitoring and sampling equipment, unless equipment is elevated above the ground (e.g., on a table, etc.).

Remove well cap and if appropriate measure VOCs at the rim of the well with a PID or FID instrument and record reading in field logbook or on the well purge form.

If the well casing does not have an established reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook (consider a photographic record as well). All water level measurements must be recorded relative to this reference point (and the altitude of this point should be determined using techniques that are appropriate to site's DQOs.

If water-table or potentiometric surface map(s) are to be constructed for the sampling event, perform synoptic water level measurement round (in the shortest possible time) before any purging and sampling activities begin. If possible, measure water level depth (to 0.01 ft.) and total well depth (to 0 1 ft.) the day before sampling begins, in order to allow for re-settlement of any particulates in the water column. This is especially important for those wells that have not been recently sampled because sediment buildup in the well may require the well to be redeveloped. If measurement of total well depth is not made the day before, it should be measured after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe may not be necessary unless analytical data or field analysis signal a worsening situation. This SOP cannot be used in the presence of LNAPLs or DNAPLs. If NAPLs are present, the project team must decide upon an alternate sampling method. All project modifications must be approved and documented prior to implementation.

If available check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). If changes are made in the intake depth or extraction rate(s) used during previous sampling event(s), for either portable or dedicated extraction devices, record new values, and explain reasons for the changes in the field logbook.

PURGING AND SAMPLING PROCEDURE

Purging and sampling wells in order of increasing chemical concentrations (known or anticipated) are preferred.

The use of dedicated pumps is recommended to minimize artificial mobilization and entrainment of particulates each time the well is sampled. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

A. Initial Water Level

Measure the water level in the well before installing the pump if a non-dedicated pump is being used. The initial water level is recorded on the purge form or in the field logbook.

B. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the appropriate depth (may not be the mid-point of the screen/open interval). The Sampling and Analysis Plan/Quality Assurance Project Plan should specify the sampling depth (used previously), or provide criteria for selection of intake depth for each new well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well.

Pump tubing lengths, above the top of well casing should be kept as short as possible to minimize heating the groundwater in the tubing by exposure to sun light and ambient air temperatures. Heating may cause the groundwater to degas, which is unacceptable for the collection of samples for VOC and dissolved gases analyses.

C. Measure Water Level

Before starting pump, measure water level. Install recording pressure transducer, if used to track drawdowns, to initialize starting condition.

D. Purge Well

From the time the pump starts purging and until the time the samples are collected, the purged water is discharged into a graduated bucket to determine the total volume of groundwater purged. This information is recorded on the purge form or in the field logbook.

Start the pump at low speed and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and if present fix or replace the affected equipment. Try to match pumping rate used during previous sampling event(s). Otherwise, adjust pump speed until there is little or no water level drawdown. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

Monitor and record the water level and pumping rate every five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. If the initial water level is above the top of the screen do not allow the water level to fall into the well screen. The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

Avoid the use of constriction devices on the tubing to decrease the flow rate because the constrictor will cause a pressure difference in the water column. This will cause the groundwater to degas and result in a loss of VOCs and dissolved gasses in the groundwater samples.

Note: the flow rate used to achieve a stable pumping level should remain constant while monitoring the indicator parameters for stabilization and while collecting the samples.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (e.g., bladder, peristaltic), and/or the use of dedicated equipment. For new monitoring wells, or wells where the following situation has not occurred before, if the recovery rate to the well is less than 50 mL/min., or the well is being essentially dewatered during purging, the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site's DQOs, or have a new well installed.

E. Monitor Indicator Field Parameters

After the water level has stabilized, connect the "T" connector with a valve and the flow-through-cell to monitor the indicator field parameters. If excessive turbidity is anticipated or encountered with the pump startup, the well may be purged for a while without connecting up the flow-through-cell, in order to minimize particulate buildup in the cell (This is a judgment call made by the sampler). Water level drawdown measurements should be made as usual. If possible, the pump may be installed the day before purging to allow particulates that were disturbed during pump insertion to settle.

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, ORP, DO) at a frequency of five minute intervals or greater. The pump's flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (for a 250 mL flow-through-cell with a flow rate of 50 mLs/min , the monitoring frequency would be every five minutes; for a 500 mL flow-through-cell it would be every ten minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly. Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments followed by stabilization of indicator parameters. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings are within the following limits:

Turbidity (10% for values greater than 5 NTU; if three Turbidity values are less than 5 NTU, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (± 10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Samples for turbidity measurements are obtained before water enters the flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities.

The flow-through-cell must be designed in a way that prevents gas bubble entrapment in the cell. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help remove bubbles from the flow-through-cell (see Appendix B Low-Flow Setup Diagram). All during the measurement process, the flow-through-cell must remain free of any gas bubbles. Otherwise, the monitoring probes may act erratically. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

F. Collect Water Samples

When samples are collected for laboratory analyses, the pump's tubing is disconnected from the "T" connector with a valve and the flow-through-cell. The samples are collected directly from the pump's tubing. Samples must not be collected from the flow-through-cell or from the "T" connector with a valve.

VOC samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the pump's flow rate is too high to collect the VOC/dissolved gases samples, collect the other samples first. Lower the pump's flow rate to a reasonable rate and collect the VOC/dissolved gases samples and record the new flow rate.

During purging and sampling, the centrifugal/peristaltic pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use the following procedure to collect samples: collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing, collect the VOC/dissolved gases samples, and record new drawdown depth and flow rate.

For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL VOC vial.

Use pre-preserved sample containers or add preservative, as required by analytical methods, to the samples immediately after they are collected. Check the analytical methods (e.g. EPA SW-846, 40 CFR 136, water supply, etc.) for additional information on preservation.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter (transparent housing preferred) is required, and the filter size (0.45 μm is commonly used) should be based on the sampling objective. Pre-rinse the filter with groundwater prior to sample collection. Make sure the filter is free of air bubbles before samples are collected. Preserve the filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health or ecological risk calculations.

Label each sample as collected. Samples requiring cooling will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

G. Post Sampling Activities

If a recording pressure transducer is used to track drawdown, re-measure water level with tape.

After collection of samples, the pump tubing may be dedicated to the well for re-sampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth annually is usually sufficient after the initial low stress sampling event However, a greater frequency may be needed if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and then following sampling of each well. Pumps should not be removed between purging and sampling operations. The pump, tubing, support cable and electrical wires which were in contact with the well should be decontaminated by one of the procedures listed below.

The use of dedicated pumps and tubing will reduce the amount of time spent on decontamination of the equipment. If dedicated pumps and tubing are used, only the initial sampling event will require decontamination of the pump and tubing.

Note if the previous equipment blank data showed that contaminant(s) were present after using the below procedure or the one described in the SAP/QAPP, a more vigorous procedure may be needed.

Procedure 1

Decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump and tubing. The pump may be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Optional - flush with isopropyl alcohol (pesticide grade; must be free of ketones {e.g., acetone}) or with methanol. This step may be required if the well is highly contaminated or if the equipment blank data from the previous sampling event show that the level of contaminants is significant.

Flush with distilled/deionized water. This step must remove all traces of alcohol (if used) from the equipment. The final water rinse must not be recycled.

Procedure 2

Steam clean the outside of the submersible pump

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the groundwater samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. Quality control samples include field duplicates, equipment blanks, matrix spike/matrix spike duplicates, trip blanks (VOCs), and temperature blanks.

FIELD LOGBOOK

A field log shall be kept to document all groundwater field monitoring activities (see Appendix C, example table), and record the following for each well:

Site name, municipality, state.

Well identifier, latitude-longitude or state grid coordinates.

Measuring point description (e.g., north side of PVC pipe).

Well depth, and measurement technique.

Well screen length.

Pump depth.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, calculated or measured total volume pumped, and clock time of each set of measurements.

Type of tubing used and its length.

Type of pump used.

Clock time of start and end of purging and sampling activity.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analyses.

Field observations during sampling event.

Name of sample collector(s)

Weather conditions, including approximate ambient air temperature.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling/monitoring equipment used, including trade names, model number, instrument identification number, diameters, material composition, etc.

DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, field indicator parameters measured during purging, field instrument calibration information, and whatever other field logbook information is needed to allow for a full evaluation of data usability.

Note: the use of trade, product, or firm names in this sampling procedure is for descriptive purposes only and does not constitute endorsement by the U.S. EPA.

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APPENDIX A
PERISTALTIC PUMPS

Before selecting a peristaltic pump to collect groundwater samples for VOCs and/or dissolved gases (e.g., methane, carbon dioxide, etc) consideration should be given to the following:

- The decision of whether or not to use a peristaltic pump is dependent on the intended use of the data.
- If the additional sampling error that may be introduced by this device is NOT of concern for the VOC/dissolved gases data's intended use, then this device may be acceptable.
- If minor differences in the groundwater concentrations could effect the decision, such as to continue or terminate groundwater cleanup or whether the cleanup goals have been reached, then this device should NOT be used for VOC/dissolved gases sampling. In these cases, centrifugal or bladder pumps are a better choice for more accurate results.

EPA and USGS have documented their concerns with the use of the peristaltic pumps to collect water sample in the below documents.

- "Suction Pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, December 1987.
- "The agency does not recommend the use of peristaltic pumps to sample ground water particularly for volatile organic analytes" *RCRA Ground-Water Monitoring Draft Technical Guidance*, EPA Office of Solid Waste, November 1992
- "The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and volatiles loss", *Low-flow (Minimal drawdown) Ground-Water Sampling Procedures*, by Robert Puls & Michael Barcelona, April 1996, EPA/540/S-95/504.
- "Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in the loss of volatile analytes", USGS Book 9 Techniques of Water-Resources Investigation, Chapter A4. (Version 2.0, 9/2006).

APPENDIX B

SUMMARY OF SAMPLING INSTRUCTIONS

These instructions are for using an adjustable rate, submersible pump or a peristaltic pump with the pump's intake placed at the midpoint of a 10 foot or less well screen or an open interval. The water level in the monitoring well is above the top of the well screen or open interval, the ambient temperature is above 32°F, and the equipment is not dedicated. Field instruments are already calibrated. The equipment is setup according to the diagram at the end of these instructions.

1. Review well installation information. Record well depth, length of screen or open interval, and depth to top of the well screen. Determine the pump's intake depth (e.g., mid-point of screen/open interval).

2. On the day of sampling, check security of the well casing, perform any safety checks needed for the site, lay out a sheet of polyethylene around the well (if necessary), and setup the equipment. If necessary a canopy or an equivalent item can be setup to shade the pump's tubing and flow-through-cell from the sun light to prevent the sun light from heating the groundwater.

3. Check well casing for a reference mark. If missing, make a reference mark. Measure the water level (initial) to 0.01 ft. and record this information.

4. Install the pump's intake to the appropriate depth (e.g., midpoint) of the well screen or open interval. Do not turn-on the pump at this time.

5. Measure water level and record this information.

6. Turn-on the pump and discharge the groundwater into a graduated waste bucket. Slowly increase the flow rate until the water level starts to drop. Reduce the flow rate slightly so the water level stabilizes. Record the pump's settings. Calculate the flow rate using a graduated container and a stop watch. Record the flow rate. Do not let the water level drop below the top of the well screen.

If the groundwater is highly turbid or colored, continue to discharge the water into the bucket until the water clears (visual observation); this usually takes a few minutes. The turbid or colored water is usually from the well being disturbed during the pump installation. If the water does not clear, then you need to make a choice whether to continue purging the well (hoping that it will clear after a reasonable time) or continue to the next step. Note, it is sometimes helpful to install the pump the day before the sampling event so that the disturbed materials in the well can settle out.

If the water level drops to the top of the well screen during the purging of the well, stop purging the well, and do the following:

> Wait for the well to recharge to a sufficient volume so samples can be collected. This may take awhile (pump maybe removed from well, if turbidity is not a problem). The project manager will need to make the decision when samples should be collected and the reasons recorded in the site's log book. A water level measurement needs to be performed and recorded before samples are collected. When samples are being collected, the water level must not drop below the top of the screen or open interval. Collect the samples from the pump's tubing. Always collect the VOCs and dissolved gases samples first. Normally, the samples requiring a small volume are collected before the large volume samples are collected just in case there is not sufficient water in the well to fill all the sample containers. All samples must be collected, preserved, and stored according to the analytical method. Remove the pump from the well and decontaminate the sampling equipment.

If the water level has dropped 0.3 feet or less from the initial water level (water level measure before the pump was installed); proceed to Step 7. If the water level has dropped more than 0.3 feet, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are be collected.

7. Attach the pump's tubing to the "T" connector with a valve (or a three-way stop cock). The pump's tubing from the well casing to the "T" connector must be as short as possible to prevent the groundwater in the tubing from heating up from the sun light or from the ambient air. Attach a short piece of tubing to the other end of the end of the "T" connector to serve as a sampling port for the turbidity samples. Attach the remaining end of the "T" connector to a short piece of tubing and connect the tubing to the flow-through-cell bottom port. To the top port, attach a small piece of tubing to direct the water into a calibrated waste bucket. Fill the cell with the groundwater and remove all gas bubbles from the cell. Position the flow-through-cell in such a way that if gas bubbles enter the cell they can easily exit the cell. If the ports are on the same side of the cell and the cell is cylindrical shape, the cell can be placed at a 45-degree angle with the ports facing upwards; this position should keep any gas bubbles entering the cell away from the monitoring probes and allow the gas bubbles to exit the cell easily (see Low-Flow Setup Diagram). Note,

make sure there are no gas bubbles caught in the probes' protective guard; you may need to shake the cell to remove these bubbles.

8. Turn-on the monitoring probes and turbidity meter.

9. Record the temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential measurements. Open the valve on the "T" connector to collect a sample for the turbidity measurement, close the valve, do the measurement, and record this measurement. Calculate the pump's flow rate from the water exiting the flow-through-cell using a graduated container and a stop watch, and record the measurement. Measure and record the water level. Check flow-through-cell for gas bubbles and sediment; if present, remove them.

10. Repeat Step 9 every 5 minutes or as appropriate until monitoring parameters stabilized. Note at least one flow-through-cell volume must be exchanged between readings. If not, the time interval between readings will need to be increased. Stabilization is achieved when three consecutive measurements are within the following limits:

Turbidity (10% for values greater than 5 NTUs; if three Turbidity values are less than 5 NTUs, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (±10 millivolts).

If these stabilization requirements do not stabilize in a reasonable time, the probes may have been coated from the materials in the groundwater, from a buildup of sediment in the flow-through-cell, or a gas bubble is lodged in the probe The cell and the probes will need to be cleaned. Turn-off the probes (not the pump), disconnect the cell from the "T" connector and continue to purge the well. Disassemble the cell, remove the sediment, and clean the probes according to the manufacturer's instructions. Reassemble the cell and connect the cell to the "T" connector. Remove all gas bubbles from the cell, turn-on the probes, and continue the measurements. Record that the time the cell was cleaned.

11. When it is time to collect the groundwater samples, turn-off the monitoring probes, and disconnect the pump's tubing from the "T" connector. If you are using a centrifugal or peristaltic pump check the pump's tubing to determine if the tubing is completely filled with water (no air space).

All samples must be collected and preserved according to the analytical method. VOCs and dissolved gases samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

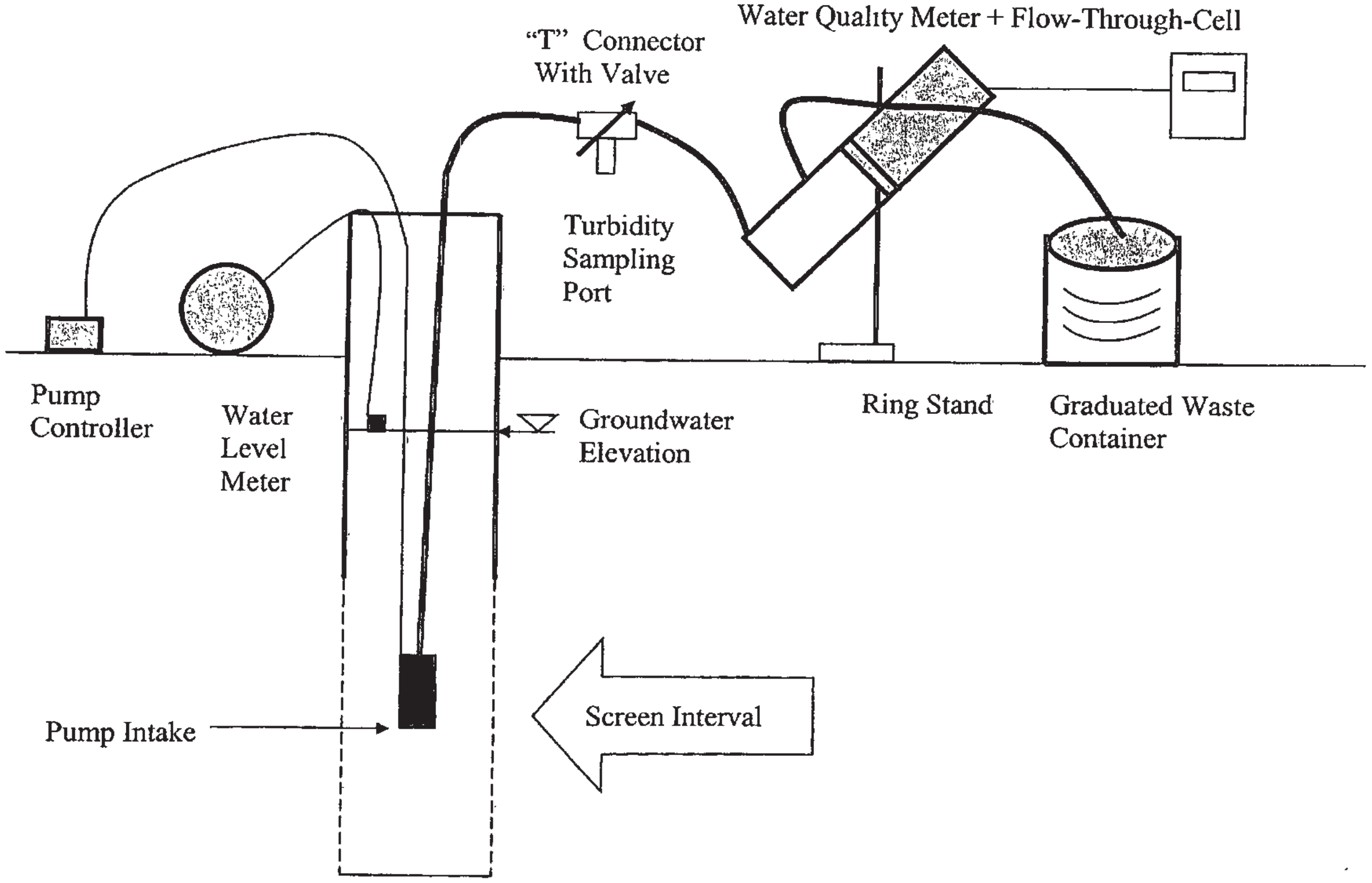
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

> All samples must be collected and preserved according to the analytical method. The VOCs and the dissolved gases (e.g., methane, ethane, ethene, and carbon dioxide) samples are collected last. When it becomes time to collect these samples increase the pump's flow rate until the tubing is completely filled. Collect the samples and record the new flow rate.

12. Store the samples according to the analytical method.

13. Record the total purged volume (graduated waste bucket). Remove the pump from the well and decontaminate the sampling equipment.

Low-Flow Setup Diagram



APPENDIX C
EXAMPLE (Minimum Requirements)
WELL PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)________________________

Well Number________________Date________________

Field Personnel________________________

Sampling Organization________________________

Identify MP________________________

Depth to ________/________ of screen
(below MP) top bottom

Pump Intake at (ft. below MP)__________

Purging Device; (pump type)__________

Total Volume Purged __________

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. °C	Spec. Cond.[2] µS/cm	pH	ORP[3] mv	DO mg/L	Turb-idity NTU	Comments
Stabilization Criteria					3%	3%	±0.1	± 10 mv	10%	10%	

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. µSiemens per cm(same as µmhos/cm)at 25°C.
3. Oxidation reduction potential (ORP)

BAE SYSTEMS

BAE SYSTEMS ORDNANCE SYSTEMS INC.
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

Low-Flow Groundwater Sampling and Analysis Plan

Updated September 2002

TABLE OF CONTENTS

LIST OF APPENDICES

1.0 INTRODUCTION

This Sampling and Analysis Plan (SAP) is for utilization in the groundwater monitoring program at the for the hazardous waste management units (Units) located at the Radford Army Ammunition Plant (Radford AAP). This document meets the groundwater sampling and analysis plan requirements of 40 CFR 264 Subpart F. This SAP is based on the USEPA SW-846 and the RCRA Groundwater Monitoring Technical Enforcement Guidance Document (TEGD), "Low Stress (low flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells", and "Ground Water Issue, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures.

2.0 PURGING AND SAMPLE COLLECTION PROCEDURES

Purging and sample collection procedures govern all the activities in the field prior to sample preservation. This section contains several initial activities that are significant in maintaining the integrity of the sample and data. These include maintaining a field log book, measurement of static water level, detection of immiscible layers, well evacuation, sample withdrawal, and analysis of field parameters.

2.1 Field Log Sheet/Book

A Field Log Sheet (Appendix A) is utilized to record the field information at each well location. The Field Log Sheet in conjunction with a Field Log Book is used to record field activities for each well. The Field Log Sheet includes the following information:

- well identification
- static water level measurement and equipment used
- presence of immiscible layers noted
- reference point for static water level measurements
- purge volume and pumping rate
- well yield comments
- well purging (evacuation) procedure, time, and equipment
- well sampling date, time, and equipment
- sample identifications (by constituents)
- preservatives used
- constituents to be analyzed
- field measurements; pH , T°C, specific conductivity, dissolved oxygen, ORP, and salinity
- headspace in containers review
- time and meters used in field analysis
- sample preparation date, time, and filtering method
- sampler's and sample preparer's names

2.2 Measurement of Static Water Levels

Prior to all sampling activities, plastic sheeting will be placed around each well to protect the sampling equipment from coming in contact with contamination around the well head and to facilitate the collection of spilled purge water as recommended by the TEGD.

The measurement of the static water level measurement should be performed in each well at the Unit prior to each sampling event. The total depths of all of the wells at Radford AAP have been established. This information is used to assist in determining if the horizontal and vertical flow gradients have changed since initial site characterizations and/or prior sampling events.

The field crew utilizes well logs to assist in the water level measurements. The measurements are taken with an electronic water level probe. The probe is decontaminated with alconox soap followed by isopropanol and deionized water rinses. The probe is then lowered into the well, the water level is measured to the nearest 0.01 foot. The permanent reference point is the top of the casing. To determine the desired value of depth to water from ground surface, the length of casing is measured and subtracted from the depth to water from the top of casing. Any changes in length of casing measurement (i.e., modification of well pad or apron) should be noted and corrected. The same value for length of casing above ground should be used each time the water level is measured in the well. Any damage to well or well casing should be noted at this time.

2.3 Detection of Immiscible Layers

The detection of immiscible layers (i.e., LNAPLS and DNAPLS) is an important process in waste management. These two types of liquids can provide valuable information concerning types of existing contamination within the monitored aquifer. This detection requires specialized equipment such as a flame ionization detector (FID) or a photoionization detector (PID) organic vapor analyzer, interface probe, and a modified bailer as well as sample collection prior to well purging.

In the event immiscible layers are suspected the air in the well head should be sampled with a FID. A manometer will be used to detect the static liquid level. The interface probe will then be lowered into the well to determine the presence of any immiscible layer(s). The probe will register the depths of light and/or dense liquid as well as the water level.

The collection of varying layers requires a modified Teflon® bailer. For the light phase immiscible, the bailer should be slowly lowered until contact is made with the air and light phase liquid interface. The bailer should then be lowered to a depth that is less than the immiscible/water interface depth as determined by the preliminary interface probe measurements. This collection method works best with immiscible layers of two (2) feet or greater thickness. If the layer is less than two (2) feet thick but the depth to the surface of the light phase layer is less than 25 feet use a peristaltic pump. In the event that a peristaltic pump can not be used, a modified bailer will be used. The bailer should have the bottom check valve sealed with plastic sheeting and the top check valve removed to allow the sample to enter the top. A bottom check valve bailer without the top check valve can be used if the modification is performed on the bottom check valve. To compensate for buoyancy of the bailer, a section of one-inch stainless steel pipe can be placed on the retrieval line. The bailer should be lowered carefully to the depths indicated from the preliminary measurements. The target sampling depth is to lower the bailer to one-half thickness of the immiscible layer and collect the sample.

The dense phase immiscibles are to be collected with a double check valve bailer. The bailer should be lowered and raised in a slow controlled method. The decontamination procedures specified below shall be performed after collection of the sample.

2.4 Low-Flow Well Purging and Sampling Procedures

2.4.1 Well Purging

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established Unit sampling objectives. Flow rates on the order of 0.1 – 0.5 l/min are used; however, this is dependent on Unit specific hydrogeology. Water quality indicator parameters are used to determine purging needs. Once parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, and temperature have stabilized purging is considered complete. In-line flow cells will be used to continuously measure the above parameters.

The stagnant water within the casing is not representative of the in-situ groundwater quality. The well needs to have this stagnant water removed so that formation water can be sampled. To remove the stagnant formation water the pump will be started at the lowest speed setting and slowly increased until discharge occurs. The water level will then be checked. The pump speed will be adjusted until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceed 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Water level and pumping rates will be monitored and recorded every three minutes during purging. Any pumping rate adjustments (both time and flow rate) will be recorded in the field logbook. Pumping rates will, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 – 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments will be made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" the stabilized drawdown value will be recorded, not the initial drawdown. The water level will not be allowed to fall to the intake level (if the static water level is above the well screen, the water level will not lowered to the screen). The final purge volume will be greater than the stabilized drawdown volume plus the extracted tubing volume. This volume will be calculated by the following equation:

$$V_{total} = V_{tubing} + V_{drawdown}$$

$$V_{tubing} = (h_{tubing})(\pi\, r_{tubing}^2)$$

$$V_{drawdown} = (h_{water} * \pi\, r_{well}^2) - (h_{purged} * \pi\, r_{well}^2)$$

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates. If the recharge rate of the well is lower then extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well will be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (the intake will not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

Water level, extraction rate, and drawdown information will be recorded in a field logbook. The extraction rate (final pump dial setting) will be duplicated in future sampling efforts.

2.4.2 Measurement of Indicator Field Parameters

During well purging, indicator field parameters (temperature, specific conductance, pH, Eh, DO) will be monitored every three minutes (or less frequently, if appropriate). Purging will be considered complete and sampling may begin when all above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three-minute intervals, are within the following limits:

Constituent	Variability
DO	10%
Specific conductance	3%
Temperature	3%
PH	± 0.1 unit
ORP/Eh	± 10 millivolts

All measurements will be obtained using a flow through-cell. A transparent flow-through-cell will be used, because they allow field personnel to watch for particulate build-up with in the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, the cell will be disconnected while the pump remains running. The cell will be cleaned and reconnected and monitoring activities will continue.

The flow-through-cell will be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off, water in the cell must not drain out. Monitoring probes will remain submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe will come first (this parameter is most susceptible to error if air leaks into the system).

2.4.3 Sample Withdrawal

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (the cell will be disconnected prior to obtaining samples).

VOC samples will be collected first and directly into pre-preserved sample containers. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence will fill all sample containers.

During purging and sampling, the tubing will remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. Quarter inch or three-eighths inch (inside diameter) tubing will be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, one of the following procedures will be used to collect samples: (1) a clamp, connector (Teflon® or stainless steel) or valve to constrict sampling end of tubing will be added; (2) a small diameter Teflon® tubing will be inserted into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, samples will be collected from the small diameter tubing; (3) non-VOC samples will be collected first, then the flow rate will be increased slightly until water completely fills the tubing, at that time collection of remaining samples and the new drawdown, flow rate and new indicator field parameter values are then recorded.

2.5 Alternative Well Purging and Sampling Procedures

2.5.1 Alternative Well Purging and Sampling Equipment

In the event of malfunctions with any of the dedicated low-flow pumps, well purging will be conducted using either decontaminated non-dedicated Teflon® or stainless steel bailers, or new disposable polyethylene bailers. In order to reduce the possibility of cross-contamination during sample collection upon completion of well purging, sampling personnel will use either freshly decontaminated non-dedicated Teflon® or stainless steel bailers, or use new, disposable polyethylene bailers for collecting samples from each well.

Any non-dedicated sampling equipment will be decontaminated prior to use at each well. In addition, equipment blanks will be collected from non-dedicated sampling equipment.

2.5.2 Purge Volume Calculations

The Field Log Sheet (Appendix A) will be used to document the calculation of the minimum purge volume of water from the well prior to sample collection. The form also will be used to record the field pH, specific conductivity and temperature measurements for each well sampled.

Prior to collecting groundwater samples from each well, a volume of water equal to three (3) times the combined volume of the wetted well casing and the sand filter pack shall be purged from the well. The goal is to ensure that all of the stagnant water within the well is replaced with fresh formation water upon completion of the process.

The purge volumes will be calculated using the following methods:

- For each well, measure the depth to water (DTW) and total depth of the well (TD) with respect to the top of the well casing prior to disturbing the water column.

- Subtract the depth to water from the total well depth (TD-DTW) in order to obtain the height of the water column in the well casing in feet (h_w).

- For wells with water levels above the top of the sand filter pack, the equation for calculating the purge volume shall be:

  $$3 * [(\Pi r_b^2 h_s - \Pi r_c^2 h_s) * 0.3 + (\Pi r_c^2 h_w)]$$

  For wells with water levels below the top of the sand filter pack, the equation for calculating the purge volume shall be:

  $$3 * [(\Pi r_b^2 h_w - \Pi r_c^2 h_w) * 0.3 + (\Pi r_c^2 h_w)]$$

  Where: r_b = radius of well borehole;
  r_c = radius of well casing;
  h_s = height of sand filter pack;
  h_w = height of the water column.

In the event that a well has a low yield, it shall be purged to dryness if dryness occurs prior to purging the required three well casing volumes. A minimum of one well volume will be purged in this instance.

2.5.3 Measurement of Indicator Field Parameters

During well purging, indicator field parameters temperature, specific conductance, and pH will be measured. Purging shall continue until temperature, specific conductance, and pH readings have stabilized. "Stability" is defined as variation less than 10% of the preceding reading for two consecutive readings. Water temperature, specific conductance, and pH shall be measured a minimum of two times per well volume or once per 2.5 gallons of purge water (whichever is less). Each measurement of temperature, specific conductance, and pH shall be recorded along with the cumulative purge volume and the time-of-day.

2.5.4 Sample Withdrawal

For each monitoring well, the samples will be collected using either freshly decontaminated non-dedicated Teflon® or stainless steel bailers, or new, disposable polyethylene bailers upon completion of well purging. Individual sample aliquots will be collected in order of decreasing constituent volatility. VOC samples will be collected first and directly into pre-preserved sample containers.

Low yield wells must be sampled within 24 hours of purging. If yield is insufficient to obtain the required sample volume, the samples should be noted as "not obtainable due to insufficient well yield" on the Field Log Sheet for that well and in the Field Log Book.

2.5.5 Equipment Decontamination

Any non-dedicated sampling equipment will be decontaminated prior to use at the site, and after use at each well. Decontamination will be performed in a manner such that the decontamination solutions may be captured. The non-dedicated sampling equipment will be decontaminated as follows:

- Wash equipment with phosphate-free detergent.
- Rinse equipment with deionized water.
- Rinse equipment with isopropanol.
- Rinse equipment with deionized water.

Following decontamination, the equipment will be allowed to air dry or dried using clean disposable wipes.

2.6 Sample Preservation and Handling

Samples will be preserved with the proper preservatives in accordance with USEPA SW-846 (Test Methods for Evaluating Solid Waste, latest edition). Prior to sample collection, sample bottles will be prepared by the analyzing laboratory. Preservatives (as required by analytical methods) will be added to samples immediately after they are collected if the sample containers are not pre-preserved by the laboratory. More detailed preservation information is provided in Table 1.

The groundwater-monitoring program requires certain special handling considerations. Initially, the samples should not be transferred to another container due to loss of analyte and volatilization. The VOCs, TOX, and TOC containers should be slowly filled to eliminate any headspace within the container. Any headspace remaining in these containers should be noted in the logbook.

All sample containers shall be packed in a cooler with ice as soon as they are collected. Upon the completion of activities at the Unit, the coolers will be packed with additional ice for transport to the contract laboratory. The samples will be relinquished directly from the samplers to representatives from the contract analytical laboratory for transport to the laboratory, or the samples will be shipped to the laboratory by common carrier.

In the event that final receipt by the laboratory of any shipping container or sample bottle indicates evidence of compromised sample integrity, the laboratory QA/QC officer or his/her representative shall notify the operator within 24 hours of receipt. Subsequent to notification, sample integrity will be evaluated and appropriate actions will be taken to assure representative samples. Sample integrity determinations and needs for additional actions will be conducted according to QA/QC guidance from USEPA SW-846 (Test Methods for Evaluating Solid Waste, latest edition). Resampling will be conducted if determined necessary.

TABLE 1

SAMPLING AND PRESERVATION PROCEDURES

PARAMETER	ANALYTICAL METHOD	CONTAINER[a]/ VOLUME REQUIRED	PRESERVATIVE	MAXIMUM HOLDING TIME
INORGANICS ANALYSES				
Metals (total) except Mercury	6010/6020	P - 1L	HNO_3 to pH<2	6 months
Mercury (total)	7470A	P - 300 ml	HNO_3 to pH<2	28 days
Cyanide	9010	P, G - 500 ml	Cool to ≤6°C, NaOH to pH>12, 0.6 g ascorbic acid	14 days
ORGANICS ANALYSES				
Acrolein and acrylonitrile	8260	2 - 40 ml VOA[b] w/ G, Teflon-lined septum	Cool to ≤6°C HCL to pH 4-5	14 days
Purgeable Volatile Compounds	8260	2 – 40 ml VOA[b] G, Teflon-lined septum	Cool to ≤6°C HCL to pH 4-5	14 days
Benzidines	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction, 40 days after extraction
Haloethers	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction, 40 days after extraction
Phthalate esters	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C	7 days until extraction, 40 days after extraction
Nitrosamines	8270C	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction
Nitroaromatics and cyclic ketones	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction
Phenol	8270	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction
Polynuclear aromatic Hydrocarbons	8270-SIM	G, Teflon-lined cap – 1 L Amber	Cool to ≤6°C, store in dark	7 days until extraction, 40 days after extraction

NOTES:

[a] Container Types

P	Plastic (polyethylene)
G	Glass

[b] Do not allow any headspace in the container

2.7 Chain-of-Custody Documentation

The groundwater-monitoring program incorporates a chain-of-custody program to track the route and handlers of the groundwater samples. The monitoring of sample possession from field sampling to laboratory analysis is important in the event that unexpected lab results occur and the security of transportation is evaluated. This documentation contains several records and logs that assist in the quality control of the program.

Sample labels are used to prevent misidentification of samples. The labels are filled and affixed to the sample containers prior to field sampling. The labels contain the following information:

- Sample identification number
- Name of sampler (initials)
- Date and time of sample collection
- Sampling location
- Constituents to be analyzed

Sample seals should be used when a common carrier transports the sample shipment to the laboratory. These seals ensure that the samples have not been disturbed during transportation. The sample identification and date will be included on the sample seal.

The chain-of-custody record is filled out for each Unit and accompanies the samples to the contract laboratory. The completed form is returned to Radford AAP with the analysis for each Unit. This record is shown in Figure 7.1. The sample possession is established from time of collection to the time of analysis. This record contains the following information:

- sample identification and location
- signature of sampler
- date and time of sampling
- sample type
- well identification
- number of containers
- required analysis
- signatures of person(s) involved in possession
- times and dates of possession
- method of transportation
- statement for packing on ice
- temperature during shipment (min & max)
- internal temperature upon arrival at laboratory

A sample analysis request sheet can further clarify the samples for each requested constituent. This additional check sheet will be utilized when necessary (i.e., beginning of a new contract with a new laboratory). This sheet sent along with the samples will contain the following information:

- name of person receiving samples
- laboratory sample number

- date of sample receipt
- analysis to be performed
- internal temperature during shipping

2.8 Sample Transport

The samples will be relinquished directly from the samplers to representatives from the contract analytical laboratory for transport to the laboratory. In the event that a laboratory courier is unavailable, the samples will be shipped to the laboratory by a certified carrier.

2.9 Analytical Procedures

The analytical methods set forth in USEPA SW-846 (Test Methods for Evaluating Solid Waste, latest edition) will be used to analyze all constituents. Suggested analytical methods and associated practical quantitation limits (PQLs) for each Unit are listed in Appendix B.

The laboratory shall perform the necessary preparation on all samples, including blanks and duplicates.

All records of analysis will be distributed to the appropriate agency as well as maintained on site.

2.10 Quality Assurance/Quality Control

The SAP addresses the Quality Assurance/Quality Control (QA/QC) program to ensure the reliability and validity of field and analytical laboratory data gathered as part of the overall groundwater monitoring program.

2.10.1 Field QA/QC Program

The field QA/QC program is designed to ensure the reliability and validity of the field data gathered as part of the overall groundwater monitoring program. The field QA/QC program consists of regular calibration of field analytical instruments, and routine collection and analysis of trip blanks, and blind field duplicates. In the event that non-dedicated sampling equipment is used, equipment blanks will be collected and analyzed as well.

Field analytical instruments shall be calibrated in the field at each Unit prior to sampling the first well using standard solutions prepared by the manufacturer of the instrument or other laboratory. Calibration of these instruments shall be checked against standard solutions between each well and after sampling the final well at the Unit. All calibration data shall be recorded, indicating time-of-day and value.

For each sampling event, one trip blank per Unit shall be filled with laboratory-grade reagent water in the laboratory that has been selected to conduct the groundwater analyses. The trip blank shall be analyzed only for the same Unit-specific volatile organic compounds for which the samples will be analyzed. The trip blank shall accompany the sampling kit, in the transport cooler, at all times.

One blind field duplicate sample will also be taken for every 20 samples per Unit, whether that sampling event occurs on one day or longer. The blind field duplicate will be analyzed for the Unit-specific constituents. The monitoring well from which the blind field duplicate is collected should be noted on the Field Log Sheet for that well and in the Field Log Book.

Equipment blanks will be used to monitor the decontamination of non-dedicated equipment used in the sampling process. The blank consists of filling sample bottles with Type II reagent grade water through the sampling device, transfer to sample bottles, and return to the laboratory for analysis. Again, this blank is handled like a groundwater sample. One equipment blank every 20 samples will be used whether that sampling event occurs over one day or longer. The equipment blank will be analyzed for the Unit-specific constituents.

The occurrence of constituents in blank samples may serve to invalidate the analytical results of the affected constituents. Additional blanks or duplicate samples may be prepared and analyzed to address specific, unanticipated conditions.

2.10.2 Laboratory QA/QC Program

The contract laboratory is to provide a QA/QC plan for laboratory analysis according to USEPA SW-846 (Test Methods for Evaluating Solid Waste, latest edition). This plan utilizes standards, laboratory blanks, duplicates, batch spikes, and matrix spikes for calibration and identification of potential matrix interferences. This data is on file at the laboratory and is routinely reviewed by Radford AAP personnel. This data is a measure of performance as well as an indicator of potential sources of cross contamination. This control data is for performance review and not for correction of groundwater analysis data.

The contract laboratory will keep a logbook to document the processing steps that are applied to the sample. All sample preparation techniques and instrumental methods must be identified in this logbook. The results of the analysis of all quality control samples should be identified specific to each batch of groundwater samples analyzed. The logbook should also include the time, date, and name of person who performed each processing step.

Dilution during analyses has a major impact on the overall quality and usability of the ground water monitoring data. Large dilution factors may mask hazardous constituents that are present at low concentrations, which may result in constituent concentrations not being identified completely throughout the plume. Therefore, when multiple analyses using sequential dilutions are required, the results from these multiple analyses will be reported.

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APPENDIX A

Field Log Sheet

APPENDIX B

Unit-Specific Groundwater Monitoring Constituent Lists

Hazardous Waste Management Unit 5
Groundwater Compliance Monitoring (Semiannual) Constituent List
Radford Army Ammunition Plant, Radford, Virginia

Analyte	METHOD	PQL (ug/l)
Antimony, total	6010/6020	1
Arsenic, total	6010/6020	10
Barium, total	6010/6020	10
Beryllium, total	6010/6020	1
Cadmium, total	6010/6020	1
Chromium, total	6010/6020	5
Cobalt, total	6010/6020	5
Copper, total	6010/6020	5
Lead, total	6010/6020	1
Mercury, total	7470A	2
Nickel, total	6010/6020	10
Selenium, total	6010/6020	10
Silver, total	6010/6020	2
Thallium, total	6010/6020	1
Vanadium, total	6010/6020	10
Zinc, total	6010/6020	10
Acetone	8260	10
Bis (2-ethylhexyl) phthalate (DEHP)	8270	6
2-Butanone (Methyl ethyl ketone; MEK)	8260	10
Chloroform	8260	1
Dichlorodifluoromethane	8260	1
1,2-Dichloroethane	8260	1
Diethyl ether	8260	12
Diethyl phthalate	8270	10
2,4-Dinitrotoluene	8270	10
2,6-Dinitrotoluene	8270	10
Methylene chloride (Dichloromethane)	8260	1
o-Nitroaniline; 2-	8270	10
p-Nitroaniline; 4-	8270	20
Nitrobenzene	8270	10
Toluene	8260	1
Xylenes (total)	8260	3

Groundwater Compliance Monitoring (Semiannual) Constituent List
Hazardous Waste Management Unit 16
Radford Army Ammunition Plant, Radford, Virginia

Analyte	METHOD	PQL (ug/l)
Arsenic, total	6010/6020	10
Barium, total	6010/6020	10
Beryllium, total	6010/6020	1
Cadmium, total	6010/6020	1
Chromium, total	6010/6020	5
Cobalt, total	6010/6020	5
Copper, total	6010/6020	5
Lead, total	6010/6020	1
Mercury, total	7470	2
Nickel, total	6010/6020	10
Vanadium, total	6010/6020	10
Zinc, total	6010/6020	10
Benzene	8260	1
2-Butanone	8260	10
Carbon tetrachloride	8260	1
Chloroethane	8260	1
Dichlorodifluoromethane	8260	1
1,1-Dichloroethane	8260	1
Diethyl ether	8260	12.5
Dimethyl ether,	8260	12 5
Ethylbenzene	8260	1
Methylene chloride	8260	1
Tetrachloroethene; PCE	8260	1
Chloromethane	8260	1
Toluene	8260	1
1,1,1-Trichloroethane	8260	1
Trichloroethene	8260	1
1,1,2-Trichloro-1,2,2-Trifluoroethane	8260	1
Trichlorofluoromethane	8260	1
Xylenes, total	8260	3
Diethyl phthalate	8270	5
2,4-Dinitrotoluene	8270	10
2,6-Dinitrotoluene	8270	10

Notes:

ug/l = micrograms per liter
PQL = Practical Quantitation Limit

Appendix H. 9

INVESTIGATIVE DERIVED WASTE POLICY

ATTACHMENT 1

APPENDIX H.9

INVESTIGATIVE DERIVED WASTE POLICY

Department of Environmental Quality
Waste Operations
Policy for the Handling of Investigation Derived Waste (IDW)

The Department of Environmental Quality (DEQ), Waste Operations has received a request for guidance from the regulated community concerning the Commonwealth of Virginia's requirements regarding the management and disposal of investigation derived waste (IDW). Because Virginia administers an authorized state RCRA program, the Virginia Solid Waste Management Regulations (VSWMR) and the Virginia Hazardous Waste Management Regulations (VHWMR) will serve as the governing requirements in lieu of Federal RCRA regulations contained in the Code of Federal Regulations (40 CFR 260 - 270) except for the Land Disposal Restrictions of 40 CFR 268. For reference, please see the Virginia Waste Management Act, Code of Virginia §10.1-1400 et seq.; the Virginia Hazardous Waste Management Regulations (VHWMR) (VR 672-10-1); the Virginia Solid Waste Management Regulations (VSWMR) (VR 672-20-10); Federal: the Resource Conservation and Recovery Act (RCRA), 42 USC 6901; and the U. S. Department of Transportation Rules for the Transportation of Hazardous Materials, 49 CFR Part 107, 171.1 - 172.558.

With regard to IDW, it is the site manager's responsibility to determine whether the wastes generated during an investigation meet the definition of a solid or hazardous waste. The site manager will be either the on-scene coordinator (i.e., either the federal official predesignated by the Environmental Protection Agency (EPA) or the U.S. Coast Guard to coordinate and direct federal responses under subpart D or the official designated by the lead agency to coordinate and direct removal actions under subpart E of the National Contingency Plan (NCP)), or the remedial project manager (i.e., the official designated by the lead agency to coordinate, monitor, or direct remedial or other response actions under subpart E of the NCP).

If there is a possibility that either the ground water or the soil at the location where a monitoring well is installed is contaminated, the site manager must determine whether or not the well cuttings, purge water, and/or other IDW are contaminated (i.e., whether they are solid or hazardous wastes). In these cases, the site manager may use knowledge of the contaminated media to declare that the IDW is solid or hazardous waste. If analysis shows that no contamination is present in the soil or the ground water at the location where the monitoring well is installed, neither the well cuttings, nor the purge water would be regulated as a solid waste. An example of a situation where the site manager might use knowledge to determine proper disposition (i e., testing would not be required) would involve materials generated at locations where wells are installed for the purpose of ascertaining naturally occurring levels of inorganic constituents and there is no basis to expect contamination, i.e., there is no past history of hazardous waste management activities or releases in these areas. If this is the case, the soils, cuttings, purge water, etc. would not be regulated as solid wastes. Test results or knowledge of the waste should be used to screen the well cuttings, purge water and other IDW to demonstrate that concentrations of contaminants are below or equal to background levels.

Purge water, well cuttings from monitoring wells, and other IDW, if tested, must be done so in accordance with EPA SW-846, Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, 3rd edition, 1986, as updated. If contaminant levels are found to be above background levels, the IDW would be considered a solid waste. Should test results further indicate that the IDW contains a listed hazardous waste, or if the IDW exhibits a characteristic of hazardous waste, the IDW is a hazardous waste and must be managed and disposed in accordance with the VHWMR. Alternatively, contaminated IDW that contains a listed hazardous waste must be managed as a hazardous waste until it no longer "contains" the hazardous waste, i.e., until the constituent levels are below site specific risk based levels. This is consistent with EPA's Contained In Policy. The DEQ should be contacted directly to determine the site specific risk based levels that would apply to IDW that contains listed hazardous waste.

If the IDW is not a hazardous waste, but contains levels of contaminants above background levels, the IDW must be managed in accordance with the VSWMR. Solid waste generated from cleanup or investigation activities is considered a special waste under Part VIII of the VSWMR. Prior to acceptance of a special waste for disposal at a solid waste management facility, the operator must obtain prior authorization from the Department. Purge water, on the other hand, must be disposed at a publicly owned treatment works (POTW) or other wastewater treatment system operating in accordance with its Virginia Pollutant Discharge Elimination System (VPDES) permit, provided that all other pertinent criteria are satisfied.

The on-site treatment, storage, or disposal of IDW must be authorized by a permit from the DEQ. A generator of hazardous IDW may accumulate such wastes in tanks or containers in accordance with VHWMR §6.4.E. Treatment of hazardous waste in tanks or containers within the 90 day accumulation period may only occur upon prior written approval from the appropriate DEQ Regional Office.

ADDENDUM

Department of Environmental Quality
Waste Operations
Policy for the Handling of
Investigation Derived Waste (IDW)

This Addendum is being provided to clarify the distinction between the disposal requirements for Investigation Derived Waste (IDW) that is generated from an undefined area, and the requirements for soil and sediment IDW when soil and sediment is generated from an area of known contamination subject to further response measures with oversight from DEQ and/or EPA.

"DEQ Policy for the Handling of Investigation Derived Waste" dated July 5, 1995, specifies that IDW contaminated above background levels is considered a solid waste and must be managed in accordance with the Virginia Solid Waste Management Regulations. If the IDW contains a listed hazardous waste or exhibits a characteristic of hazardous waste, it must be managed as hazardous waste in accordance with the Virginia Hazardous Waste Management Regulations. Under this policy, returning contaminated IDW to the location from which it is generated is prohibited.

However, this policy was not intended to address the requirements associated with soil and sediment IDW generated from an area of known contamination when this area is subject to future response activities with oversight from DEQ or EPA. In such a case, the management and disposal of the IDW should be in accordance with the pertinent EPA guidance governing the applicability of RCRA land disposal restrictions. ("Management of IDW During SI's", EPA/540/G-91/009).

Under the EPA guidance, replacement of soil and sediment IDW into the area of contamination from which it is generated is permissible provided that the waste is not treated prior to placement. Therefore, the above-referenced DEQ IDW policy now recognizes that if soil and sediment IDW is generated from an area of known contamination, and this area is subject to further response measures with oversight from DEQ and/or EPA, the IDW may be placed back into the area from which it is taken provided there is no treatment of this waste prior to placement.

Signed Hassan Vakil Date 7/24/96

Hassan Vakili, Director
Division of Waste Operations

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 1

APPENDIX I

ANNUAL GROUNDWATER SAMPLING CONSTITUENT LIST

(APPENDIX IX 40 CFR PART 264)

APPENDIX IX METHOD/DETECTION LIMITS

Analyte	METHOD	PQL(ug/l)	MDL (ug/1)
1,1,1,2-Tetrachloroethane	8260	1	0.08
1,1,1 -Trichloroethane	8260	1	0.13
1,1,2,2-Tetrachloroethane	8260	1	0.184
1,1,2-Trichloro-1,2,2-trifluoroethane	8260	1	0.12
1,1,2-Trichloroethane	8260	1	0.079
1,1 -Dichloroethane	8260	1	0.135
1,1 -Dichloroethene	8260	1	0.223
1,2,3-Trichloropropane	8260	1	0.073
1,2,4,5-Tetrachlorobenzene	8270	10	2
1,2,4-Trichlorobenzene	8260	1	0.13
1,2,4-Trichlorobenzene	8270	10	0.43
1,2-dibromo-3-chloropropane	8260	1	0.204
1,2-dibromoethane	8260	1	0.05
1,2-Dichlorobenzene	8260	1	0.082
1,2-Dichlorobenzene	8270	10	0.48
1,2-Dichloroethane	8260	1	0.147
1,2-Dichloropropane	8260	1	0.107
1,3-Dichlorobenzene	8260	1	0.047
1,3-Dichlorobenzene	8270	10	0.52
1,3-Dichloropropane	8260	1	0.091
1,3-Dinitrobenzene	8270	10	2
1,4-Dichlorobenzene	8260	1	0.061
1,4-Dichlorobenzene	8270	10	0.37
1,4-Dioxane	8260	200	45.48
1,4-Napthoquinone	8270	10	0.2
1 -Naphthylamine	8270	10	0.2
2,3,4,6-Tetrachlorophenol	8270	10	0.68
2,4,5-Trichlorophenol	8270	10	0.81
2,4,6-Trichlorophenol	8270	10	0.63
2,4-Dichlorophenol	8270	10	1.59
2,4-Dimethylphenol	8270	10	0.99

Analyte	METHOD	PQL (ug/l)	MDL (ug/l)
2,4-Dinitrophenol	8270	10	1.7
2,4-Dinitrotoluene	8270	10	0.5
2,6-Dichlorophenol	8270	10	0.2
2,6-Dinitrotoluene	8270	10	0.46
2-Acetylaminofluorene	8270	10	0.2
2-Butanone	8260	10	0.42
2-Chloronaphthalene	8270	10	0.49
2-Chlorophenol	8270	10	0.98
2-Hexanone	8260	10	0.39
2-Methylnaphthalene	8270	10	0.29
2-Naphthylamine	8270	10	0.2
2-Nitroaniline	8270	10	0.36
2-Nitrophenol	8270	10	1.27
2-Picoline	8270	10	0.1
2-Propanol	8260	50	1.71
3,3 '-Dichlorobenzidine	8270	10	0.48
3,3 '-Dimethylbenzidine	8270	10	0.2
3-Methylcholanthrene	8270	10	0.2
3-Nitroaniline	8270	10	0.3
4,6-Dinitro-2-methylphenol	8270	10	1.18
4-Aminobiphenyl	8270	10	0.2
4-Bromophenyl phenyl ether	8270	10	0.56
4-Chloro-3-methylphenol	8270	10	1.01
4-Chloroaniline	8270	10	0.66
4-Chlorophenyl phenyl ether	8270	10	0.32
4-Methyl-2-pentanone	8260	10	0.91
4-Nitroaniline	8270	10	0.73
4-Nitrophenol	8270	10	0.28
4-Nitroquinoline-1 -oxide	8270	50	5
5-Nitro-o-toluidine	8270	10	0.2
7,12-Dimethylbenz(a)anthracene	8270	10	0.2
a,a-Dimethylphenethylamine	8270	50	5
Acenaphthene	8270	10	0.35

Analyte	METHOD	PQL(ug/l)	MDL(ug/l)
Acenaphthylene	8270	10	0.48
Acetone	8260	10	0.12
Acetonitrile	8260	100	31.67
Acetophenone	8270	10	0.2
Acrolein	8260	10	1.1
Acrylonitrile	8260	10	0.47
Allyl chloride	8260	10	0.82
Aniline	8270	10	0.32
Anthracene	8270	10	0.52
Antimony	6020,6010	1	0.4
Aramite	8270	10	0.2
Arsenic	6020/6010	10	2
Barium	6020/6010	10	1
Benzene	8260	1	0.07
Benzo(a)anthracene	8270	10	0.45
Benzo(a)pyrene	8270	10	1.5
Benzo(b)fluoranthene	8270	10	1.2
Benzo(g,h,i)perylene	8270	10	0.42
Benzo(k)fluoranthene	8270	10	1.6
Benzyl alcohol	8270	10	0.52
Beryllium	6020/6010	1	0.2
Bis(2-chlorethoxy)methane	8270	1	0.46
Bis(2-chloroethyl)ether	8270	1	0.44
Bis(2-chloroisopropyl)ether	8270	10	0.19
Bis(2-ethylhexyl)phthalate	8270	10	0.54
Bromodichloromethane	8260	1	0.088
Bromoform	8260	1	0.106
Bromomethane	8260	1	0.542
Butyl benzyl phthalate	8270	10	0.46
Cadmium	6020/6010	1	0.2
Carbon disulfide	8260	10	0.37
Carbon tetrachloride	8260	1	0.16
Chlorobenzilate	8270	10	0.2

Analyte	**METHOD**	**PQL(ug/l)**	**MDL(ug/l)**
Chloroform	8260	1	0.03
Chloroprene	8260	10	0.46
Chromium	6020/6010	5	1
Chrysene	8270	10	0.31
Cobalt	6020/6010	5	1
Copper	6020/6010	5	1
Cyanide	9010	20	4
Diallate	8270	10	0.2
Dibenzo(a,h)anthracene	8270	10	0.38
Dibenzofuran	8270	10	0.58
Dibromochloromethane	8260	1	0.057
Dibromomethane	8260	1	0.065
Dichlorodifluoromethane	8260	1	0.148
Diethyl ether	8260	12.5	1.11
Diethyl phthalate	8270	10	0.29
Dimethoate	8270	10	0.2
Dimethyl ether	8260	12.5	0
Dimethyl phthalate	8270	10	0.46
Di-n-butyl phthalate	8270	10	0.52
Di-n-octyl phthalate	8270	10	0.7
Diphenylamine	8270	10	0.4
Disulfoton	8270	10	0.2
Ethyl methacrylate	8260	10	0.81
Ethyl methacrylate	8270	10	0.2
Ethyl methanesulfonate	8270	10	0.2
Ethylbenzene	8260	1	0.079
Famphur	8270	10	0.2
Fluoranthene	8270	10	0.42
Fluorene	8270	10	0.38

Analyte	METHOD	PQL (ug/I)	MDL (ug/I)
Heaxachloroethane	8260	10	0.11
Hexachlorobenzene	8270	10	0.87
Hexachlorobutadiene	8260	1	0.067
Hexachlorocyclopentadiene	8270	10	0.57
Hexachloroethane	8260	10	0.11
Hexachlorophene	8270	100	10
Hexachloropropene	8270	10	2
Indeno(1,2,3-cd)pyrene	8270	10	0.15
Iodomethane	8260	10	0.58
Isobutyl alcohol	8260	200	0
Isodrin	8270	10	0.2
Isophorone	8270	10	0.43
Isosafrole	8270	10	0.2
Kepone	8270	10	0.2
Lead	6020/6010	1	0.2
m,p-Cresol	8270	20	2.47
m,p-Xylene	8260	2	0.083
Mercury	7470	2	0.2
Methacrylonitrile	8260	100	9.75
Methapyrilene	8270	10	0.2
Methyl methacrylate	8260	10	3.58
Methyl methanesulfonate	8270	10	0.2
Methyl parathion	8270	10	0.2
Methylene chloride	8260	1	0.182
Naphthalene	8260	1	0.126
Nickel	6020/6010	10	2
Nitrobenzene	8270	10	0.33
N-Nitrosodiethylamine	8270	10	0.2
N-Nitrosodimethylamine	8270	10	0.5
N-Nitroso-di-n-butylamine	8270	10	0.2
N-Nitrosodi-n-propylamine	8270	10	0.48
N-Nitrosodiphenylamine	8270	10	0.58
n-Nitrosomethylethylamine	8270	10	0.2

Analyte	METHOD	PQL(ug/l)	MDL (ug/1)
N-Nitrosomorpholine	8270	10	0.4
N-Nitrosopiperidine	8270	10	0.2
N-Nitrosopyrrolidine	8270	10	0.2
o,o,o-Triethylphosphorothioate	8270	10	0.2
o,o-Diethyl-o-2-pyrazinyl phosphorothioate	8270	10	0.2
o-Cresol	8270	10	0.96
o-Toluidine	8270	10	0.2
o-Xylene	8260	1	0.125
Parathion	8270	10	0.2
p-Dimethylaminoazobenzene	8270	10	0.2
Pentachlorobenzene	8270	10	0.2
Pentachloroethane	8260	10	0.8
Pentachloronitrobenzene	8270	10	0.2
Pentachlorophenol	8270	10	2.92
Phenacetin	8270	10	0.2
Phenanthrene	8270	10	0.52
Phenol	8270	10	0.77
Phorate	8270	10	0.2
p-Phenylenediamine	8270	10	0.2
Pronamide	8270	10	0.2
Propionitrile	8260	100	10.22
Pyrene	8270	10	0.41
Pyridine	8270	10	0.29
Safrole	8270	10	0.2
Selenium	6020/6010	10	3
Silver	6020/6010	2	0.2
Styrene	8260	1	0.074
Sulfotep	8270	10	1
sym-Trinitrobenzene	8270	10	0.2
Tetrachloroethene	8260	1	0.06
Tetrahydrofuran	8260	25	0.79
Thallium	6020/6010	1	0.2
Toluene	8260	1	0.093

Analyte	METHOD	PQL (ug/l)	MDL (ug/l)
trans-1,2-Dichloroethene	8260	1	0.162
trans-1,3-Dichloropropene	8260	1	0.097
trans-1,4-Dichloro-2-butene	8260	10	0.97
Trichloroethene	8260	1	0.177
Trichlorofluoromethane	8260	1	0.176
Vanadium	6020/6010	10	1
Vinyl acetate	8260	10	3.29
Vinyl chloride	8260	1	0.153
Xylenes, Total	8260	3	0.208
Zinc	6020/6010	10	3

Notes:
ug/l = micrograms per liter
PQL = Practical Quantitation Limit
MDL = Method Detection Limit

ATTACHMENT 1

Appendix J

STATISTICAL PROCEDURES

PERMIT ATTACHMENT 1
Appendix J

STATISTICAL PROCEDURES

1.0 HIGHLIGHTS

In accordance with 40 CFR 264.97(g), the Permittees shall collect an appropriate number of samples from the monitoring wells specified in Permit Section V.D or Permit Section VI.D. The Permittees shall ensure that an appropriate number of background samples for the preferred method of statistical analysis shall have been collected prior to the scheduled date of the statistical analysis.

Statistical analysis of the ground water data shall include the following:

- Outliers
- Testing of normality
- Evaluation of data below detection limits or quantitation limits
- Selection of statistical method
- Verification sampling strategy (optional)
- Comparison of point of compliance monitoring well data to the Concentration Limit specified in Permit Attachment N (GPS) *(Ground Water Protection Standards - Concentration Limit of Constituents for Ground Water Protection)*

2.0 OUTLIERS

All data shall be investigated to verify outliers. An outlier refers to a data point that is an inconsistently large or small value. Outliers may be due to sampling, laboratory, transportation, or transcription errors. To remove the possibility of including data with this type of error, the Permittees should screen the historical data for each monitoring well and constituent for the existence of outliers (USEPA 1992, §6.2) using the method described by Dixon (1953). The Permittees shall receive approval from the Department before eliminating any outliers.

3.0 TESTING NORMALITY OF DATA DISTRIBUTION

The Permittees shall verify that the distribution of the monitoring data for the Hazardous Constituents is consistent with the assumptions of the selected statistical test method(s). The Permittees shall determine whether the distribution of the monitoring data is normal or lognormal using a multiple group version of the Shapiro-Wilk test. The monitoring data is log-normally distributed if, when the original monitoring data is transformed by taking the natural logarithms, the distribution of the transformed monitoring data is normally distributed.

The Permittees may use any other appropriate method for testing the distributional assumptions (see Gibbons 1994a for a review, also see USEPA 1992). However, the Permittees must demonstrate to the satisfaction of the Department that the alternative method can detect deviations from normality with similar power as the Shapiro-Wilk and Shapiro-Francia methods.

The Permittees is not required to test for normality when the percentage of non-detects or non-quantified values is greater than 50 percent.

4.0 EVALUATION OF MONITORING DATE BELOW DETECTION LIMITS OR QUANTITATION LIMITS

The Permittees shall evaluate the ground water monitoring data that is less than the laboratory detection limit or quantitation limit as specified below.

4.1 If the percentage of non-detects or non-quantified values is less than 25 percent, then the Permittees shall replace the non-detects or non-quantified values with one-half the laboratory limit of detection or quantitation in accordance with 40 CFR 264.97(h) and 264.97(i)(5).

4.2 If the percentage of non-detects or non-quantified values is between 25 percent and 50 percent, then the Permittees may adjust the mean and standard deviation using Atchison's method (USEPA 1992, §2.2.2 and Aitchison, 1955). An acceptable alternative to Aitchison's method is Cohen's maximum likelihood estimator (Cohen, 1961). Extensive tables and computational details are also provided in Gibbons, 1994a. The approach for selection between the two methods is described in USEPA (1992, §2.2.1.).

4.3 If the percentage of non-detects or non-quantified values is greater than 50 percent, then the Permittees may use a non-parametric method.

4.4 If 80 percent or greater of the data are non-detects, or if the data follow a Poisson distribution, then the Permittees may use an interval method which is based on the Poisson distribution (USEPA 1992, §2.2.4 and 2.2.5).

5.0 SELECTION OF STATISTICAL METHODS

5.1 Level of Significance (Performance Standards)

The Permittees shall select statistical methods that achieve a level of significance (Type I error) of no less than 0.01 for individual monitoring well comparisons, and no less than 0.05 for multiple comparisons, in accordance with 40 CFR 264.97(i)(2). However, these performance standards do not apply for prediction intervals, tolerance intervals, and control charts. The false positive rate for these interval methods or control charts may depend on the number of data points available from the background monitoring well(s) at the time of statistical comparison. A larger number of background data points can decrease the false positive rate for these tests.

If the Permittees uses an interval or other statistical method, and if the selected method requires additional samples, then the Permittees shall collect the additional samples prior to the date specified in Permit Section V.I.7. The statistical comparison shall not be delayed due to collection of an inadequate number of samples.

The false positive rate for a single constituent/well comparison shall not be lower than 0.01 unless the Permittees can demonstrate that an alternative false positive rate will provide at least 50 percent power to detect a 3 standard deviation increase above background levels and 80 percent power to detect a 4 standard deviation increase above background levels.

5.2 Selection Criteria

After determining the distribution of the data, the Permittees shall select appropriate statistical methods based on the following:

5.2.1 If the detection frequency is less than 20 percent (i.e. non-detects greater than 80 percent) and/or data are shown to fit a Poisson distribution, then the Permittees may use a Poisson prediction or tolerance limit.

5.2.2 If the detection frequency is less than 50 percent (i.e. non-detects greater than 50 percent) or transformation fails to bring about normality, then the Permittees may use a non-parametric method.

5.2.3 If the detection frequency is between 50 percent and 75 percent (i.e. non-detects between 25 percent and 50 percent), then the Permittees may use a parametric test performed with an adjustment for non-detects; Aitcheson's or Cohen's adjustments are recommended. Determination of the appropriate adjustment to be applied shall be based on the properties of the data set (USEPA, 1992, §2.2).

5.2.4 If the detection frequency is 75 percent or greater, then the Permittees may use an appropriate parametric test without adjusting for non-detects. Non-detects should be analyzed using one-half the limit of detection or quantitation.

5.3 Statistical Methods

5.3.1 Interval Methods

If the Permittees uses an interval method and the percentage of detects is greater than 50 percent, then the Permittees shall test the monitoring data from the background monitoring well(s) for normality. If the monitoring data from the background monitoring well(s) are normally or log-normally distributed, then the Permittees may use a parametric interval method. Appendix 2 (see below) provides the suggested minimum number of samples for calculation of parametric interval methods that are acceptable to the Department.

If the background monitoring well(s) monitoring data are neither normally nor log-normally distributed, then the Permittees may use either a non-parametric interval method or an interval method based on the Poisson distribution (if appropriate). Appendix 2 provides suggested test methods and recommended minimum sample size requirements.

The Permittees may conduct a statistical analysis with a smaller data set than the suggested size at any time. However, these methods can lead to higher false positive or false negative rates with smaller samples sizes. For each sampling event, the Permittees shall calculate the appropriate interval for the background monitoring well(s) based on the method selected, and compare the monitoring data from each point of compliance monitoring well to the calculated upper limit. If the point of compliance monitoring well data exceeds the upper limit for any constituent, then the Permittees shall report that there has been a statistical increase of contaminants in the ground water, in accordance with Permit Section V.I.6 or Permit Section VI.I.6.

5.3.2 Alternative Statistical Methods

The Permittees may use alternative statistical methods that meet the performance standards specified in 40 CFR 264.97(i). The Permittees shall obtain approval from the Department prior to using alternative statistical methods. If the Permittees selects any other statistical method not listed in 40 CFR 264.97(h), then the Permittees shall collect an appropriate number of samples and shall maintain the appropriate level of significance and power, as specified above.

6.0 VERIFICATION SAMPLING (OPTIONAL)

Verification resampling can be an integral part of the statistical methodology (USEPA, 1992, §5); however, it should be considered as a part of the statistical test and based on the site specific condition. Because the probability of an initial exceedance is very high for the site as a whole (considering only test wise false positive rates), the verification sample is considered as a part of the evaluation to conclude a statistically significant exceedance.

A pre-planned verification sample can be incorporated into the calculation of the statistical limits to calculate an upper limit using a smaller false positive rate. Without verification resampling, an attempt to minimize the false positive rates will lead to unacceptably large prediction limits. This will increase the false negative rates and decrease the power of the test to detect a release from the facility. All verification samples must be collected at the earliest time possible (prior to next scheduled sampling event) or as approved by the Department or as specified in this permit. The Department shall be informed of any planned verification resampling in advance.

Verification resampling can involve one or two samples. The Department's preferred strategy includes passing one verification resample or passing one of two verification resamples. Statistical analyses that incorporate verification samples must provide at least 50 percent power to detect a 3 standard deviation increase above background levels and 80 percent power to detect a 4 standard deviation increase above background levels.

7.0 COMPARISON OF GROUND WATER MONITORING WELL DATA TO THE CONCENTRATION LIMITS SPECIFIED IN PERMIT ATTACHMENT 2,

APPENDICES G, J AND K (UNIT 5) AND PERMIT ATTACHMENT 3 APPENDIX G (UNIT 16)

7.1 Comparison of Ground Water Monitoring Well Data to Background

In accordance with 40 CFR 264.92, the Permittees shall ensure that the Hazardous Constituents specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) do not exceed the Concentration Limits (GPS)beyond the point of compliance. The Permittees shall compare the point of compliance monitoring data for each Hazardous Constituent to the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). If a 95% confidence upper limit calculated from the background ground water monitoring data exceeds the maximum contaminant levels (MCLs) taken from EPA's *Drinking Water Regulations and Health Advisories*, or alternate concentration limits (ACLs), then **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) will specify the background a 95% confidence upper limit as the Concentration Limit.

If the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) is based on background monitoring data, (i.e. tolerance or prediction limit), then the ground water monitoring data shall be compared to the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16)using a point comparison. If the ground water monitoring data exceeds the background based Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.2 Comparison of Ground Water Monitoring Data to a Fixed- Standard

In accordance with 40 CFR 264.92, the Permittees shall ensure that the Hazardous Constituents specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16)do not exceed the specified Concentration Limit beyond the point of compliance. The Permittees shall compare the point of compliance monitoring data to the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16).

If the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) is based on a fixed-standard rather than background monitoring data, then the Permittees shall compare the ground water monitoring data to the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) using the 95 percent lower confidence limit (LCL), computed from the last four sampling values (collected during the last 12 months).

Fixed-standards are based on the following:

- the maximum contaminant levels (MCLs) taken from EPA's *Drinking Water Regulations and Health Advisories* in effect at the time of the permit issuance;
- alternate concentration limits (ACLs) calculated using the Department's *Risk Exposure Analysis Modeling System* (REAMS);
- Table 1 to 40 CFR 264 or,
- the Department accepted Quantitation Limit (QL) listed in SW-846, if the MCL and/or ACL is less than the Department accepted Quantitation Limit (QL).

7.2.1 Parametric Confidence Interval

If the data are either normally or log-normally distributed, then the Permittees may use a parametric confidence interval to compare the ground water monitoring data at the point of compliance to the fixed- standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). The Permittees shall calculate the 95 percent lower confidence limit (LCL) on the last four samples (collected during the last 12 months) and shall compare the calculated LCL to a fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). If the calculated LCL of the ground water monitoring data exceeds the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.2.2 Non-parametric Confidence Interval

If the data are neither normally nor log-normally distributed, then the Permittees may use the minimum concentration from the last four samples (collected during the last 12 months) to compare the ground water monitoring data at the point of compliance to the fixed- standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). If the minimum concentration of the ground water data exceeds the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.2.3 Alternative Statistical Methods

Alternative statistical methods for comparing the lower limits of ground water monitoring data at or beyond the point of compliance to the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16) based on a fixed- standard shall be approved by the Department prior to implementation. If the lower confidence limit or minimum concentration exceeds the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.3 Comparison of Ground Water Monitoring Well Data Using a Point Comparison (Non-statistical)

7.3.1 The Permittees may choose to use a point comparison (non-statistical approach), rather than one of the statistical methods specified above, to compare the point of compliance monitoring data with the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). If the point of compliance monitoring data exceeds the Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.3.2 If fewer than the minimum of four concentration values have been collected during the last 12 months, then the Permittees may also use a point comparison (non-statistical approach) to compare the point of compliance monitoring data to the fixed-standard Concentration Limit as specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16). If the ground water monitoring data exceeds the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), then the Permittees shall notify the Director of this finding in writing within seven days, in accordance with **Permit Section V.I.**

7.3.3 If a point comparison indicates that the point of compliance monitoring data exceeds the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16), and the facility chooses not to use data from the previous three sampling events, then the Permittees shall collect additional samples (at least three additional samples are necessary to calculate a confidence interval) within the next 3 months and shall perform a statistical comparison to the fixed-standard Concentration Limit specified in **Permit Attachment 2, Appendices G, J and K** (Unit 5) and **Appendix G in Permit Attachment 3** (Unit 16).

APPENDIX J.1

COCHRAN'S APPROXIMATION TO THE BEHRENS-FISHER STUDENT'S T-TEST

Using all the available background data (n_b readings), calculate the background mean (X_b) and background variance (s_b^2). For the single monitoring well under investigation (n_m reading), calculate the monitoring mean (X_m) and monitoring variance (s_m^2).

For any set of data ($X_1, X_2 \ldots X_n$) the mean is calculated by:

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \cdot X_n}{n}$$

and the variance is calculated by:

$$s^2 = \frac{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \cdots (X_n - \overline{X})^2}{n - 1}$$

where "n" denotes the number of observations in the set of data.

The t-test uses these data summary measures to calculate a t-statistic (t^*) and a comparison t-statistic (t_c). The t^* value is compare to the t_c value and a conclusion reached as to whether there has been a statistically significant change in any indicator parameter.

The t-statistic for all parameters except pH and similar monitoring parameters is:

$$t^* = \frac{\overline{X}_m - \overline{X}_b}{\sqrt{\frac{s_m^2}{n_m} + \frac{s_b^2}{n_b}}}$$

If the value of this t-statistic is negative then there is no significant difference between the monitoring data and background data. It should be noted that significantly small negative values may be indicative of a failure of the assumption made for test validity or errors have been made in collecting background data.

The t-statistic (t_c), against which t^* will be compared, necessitates finding t_b and t_m standard (one-tailored) tables where,

t_b=t-tables with (n_b-1) degrees of freedom, at the 0.05 level of significance.

t_m=t-tables with (n_m-1) degrees of freedom, at the 0.05 level of significance.

Finally, the special weightings W_b and W_m are defined as:

$$W_b = \frac{s_b^2}{n_b}$$

$$W_m = \frac{s_m^2}{n_m}$$

and so the comparison t-statistic is:

$$t_c = \frac{W_b t_b + W_m t_m}{W_b + W_m}$$

The t=statistic (t^*) is now compared with the comparison t-statistical (t_c) using the following decision rule:

If t^* is equal to or larger than t_c then include that are most likely has been a significant increase in this specific parameter.

If t^* is less than t_c then conclude that there most likely there has been a change in this specific parameter.

The t-statistic for testing pH and similar monitoring parameters is constructed in the same manner as previously described except the negative sign (if any) is discarded and the caveat concerning the negative value is ignored. The standard (two-tailed) tables are used in the construction t_c for pH and similar monitoring parameters.

If t^* equal to or larger than t_c, then conclude that there most likely has been a significant increase (if the initial t^* had been negative, this would imply a significant decrease). If t^* is less than t_c, then conclude that there most likely has been no change.

A further discussion of the test may be found in Statistical methods (6th Edition, Section 4.14) by G.W. Snedecor and W.G. Cochran, or Principles and Procedures of Statistics (1st Edition, Section 5.8) by R.G.D. Steel and J.H.Torrie.

TABLE 1

Standard T-Tables for 0.05 Level of Significance

Degree of Freedom	one-tail t-values	two-tail t-values
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110
18	1.734	2.101
19	1.729	2.093
20	1.725	2.086
21	1.721	2.080
22	1.717	2.074
23	1.714	2.069
24	1.711	2.064
25	1.708	2.060
30	1.697	2.042
40	1.684	2.021

Adapted from Table III of "Statistical Tables for Biological Agricultural and Medical Research" (1947, R.A. Fisher and F.Yates) [47 F R 32367, July 26, 1982]

APPENDIX J.2

SUGGESTED MINIMUM SAMPLES

STATISTICAL TEST	PARAMETRIC	NON-PARAMETRIC	NON-PARAMETRIC INTERVAL %CONFIDENCE
CABF T-test	4	NA	NA
Wilcoxon Rank Sum	NA	5	NA
Confidence Interval	4	NA	NA
Tolerance Interval	8	19	95%
Prediction Interval	8	13	99% #
Poisson Prediction Interval	8	NA	NA
Shewhart CUSUM Chart+	8	NA	NA

NOTES:

* The above tests can be used with fewer samples, however it will increase the false positive rate.

\# Includes one verification re-sample, use 19 samples for a 95% Prediction Interval with no verification re-samples.

\+ For Intra-well testing only.

APPENDIX J.3

STATISTICAL REFERENCES

Aitchison, J. On the distribution of a positive random variable having discrete probability mass at the origin, Journal of American Statistical Association, 50(272), 901-908 (1955).

Cohen, A.C. Tables for maximum likelihood estimates: Singly truncated and singly censored samples, Technometrics, 3, 535-541 (1961).

Gibbons, R.D. Statistical Methods for Groundwater Monitoring, John Wiley and Sons, Inc., 1994.

Gibbons, R.D. Some conceptual and statistical issues in analysis of groundwater monitoring data, Environmetrics, 7, 185-199 (1996).

USEPA. Statistical analysis of groundwater monitoring data at RCRA facilities. Addendum to Interim Final Guidance. Office of Solid Waste, July 1992.

USEPA. Statistical analysis of groundwater monitoring data at RCRA facilities - Interim Final guidance (April 1989).

ATTACHMENT 1

Appendix K

METHODOLOGY FOR GROUNDWATER MONITORING WELL ABANDONMENT

Appendix K to ATTACHMENT 1
METHODOLOGY FOR GROUNDWATER MONITORING WELL ABANDONMENT

The Permittees shall receive prior approval from the Department to abandon any monitoring wells and/or piezometers. The following procedures shall be used

A. Monitoring wells and/or piezometers will be abandoned by pressure grouting methods. Surface installations (protective covers or manholes) will be removed and an attempt to pull the casing string with the rig will be made. Once this has either been accomplished or has failed, grouting operations will commence as described below.

   1. Monitoring well abandonment will be accomplished by lowering a tremie pipe to the bottom of the borehole.

   2. Portland cement/bentonite grout will then be pumped down the tremie pipe until an even flow of consistent grout returns at the surface.

   3. The tremie pipe will be removed from the borehole on completion of grouting operations and a minimum four inch thick and six foot diameter concrete cap will be constructed over the grouted borehole.

B. Removed casings will be steam cleaned, cut up into manageable sections, and disposed of as refuse.

C. All tremie rods and other downhole equipment will be steam cleaned prior to introduction into the hole or well.

D. All decontamination fluid will be containerized and handled pursuant to decontamination fluid handling procedures contained in Permit Condition I.B.2.

ATTACHMENT 2
UNIT 5

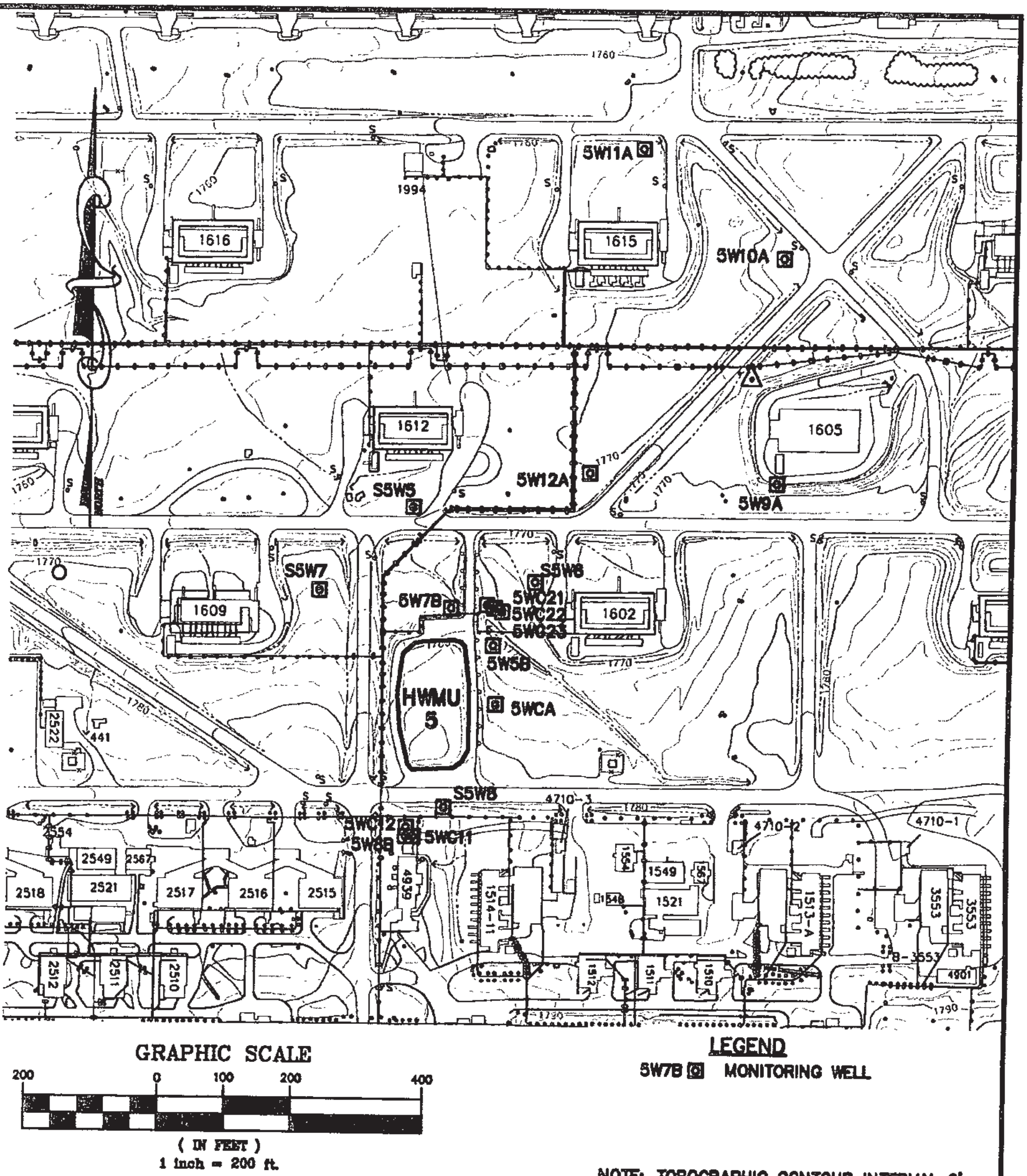
APPENDIX A

HYDROLOGICAL AND GEOLOGICAL INFORMATION

ATTACHMENT 2
UNIT 5

APPENDIX A.1

UNIT TOPOGRAPHIC MAP AND WELL LOCATION MAP



NOTE: TOPOGRAPHIC CONTOUR INTERVAL 2'

HWMU-5 SITE MAP

RADFORD ARMY AMMUNITION PLANT

RADFORD, VIRGINIA

SCALE: 1"=200'

PLAN NO. B03204-301B

Draper Aden Associates
Engineering • Surveying • Environmental Services

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Blacksburg, VA 24060
540-552-0444 Fax: 540-552-0291

Richmond, VA
Charlottesville, VA
Hampton Roads, VA

DESIGNED	RGM
DRAWN	JFF
CHECKED	MDL
DATE	02/22/10

FIGURE

1

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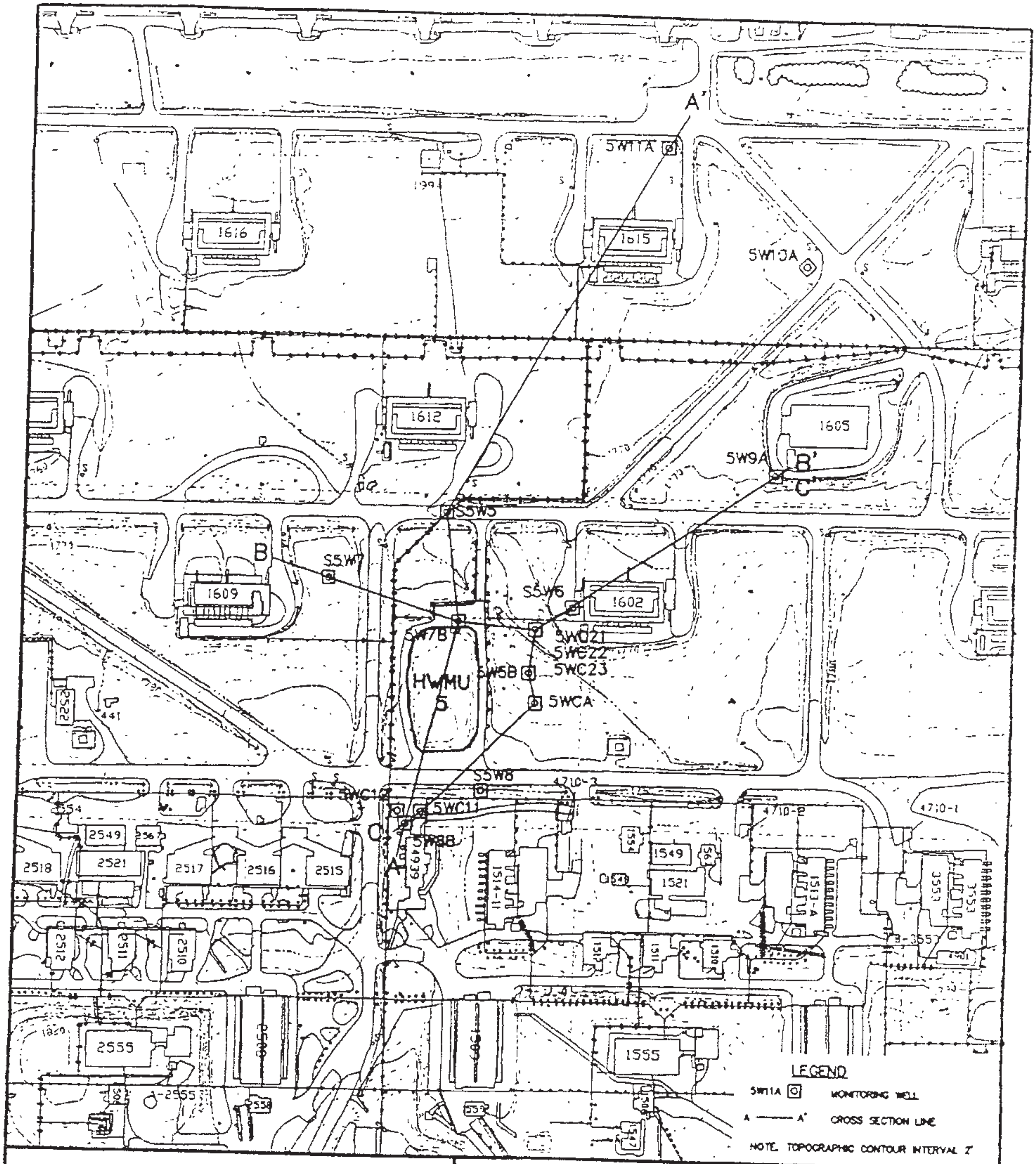
ATTACHMENT 2
UNIT 5

APPENDIX A.2

GEOLOGICAL CROSS SECTIONS

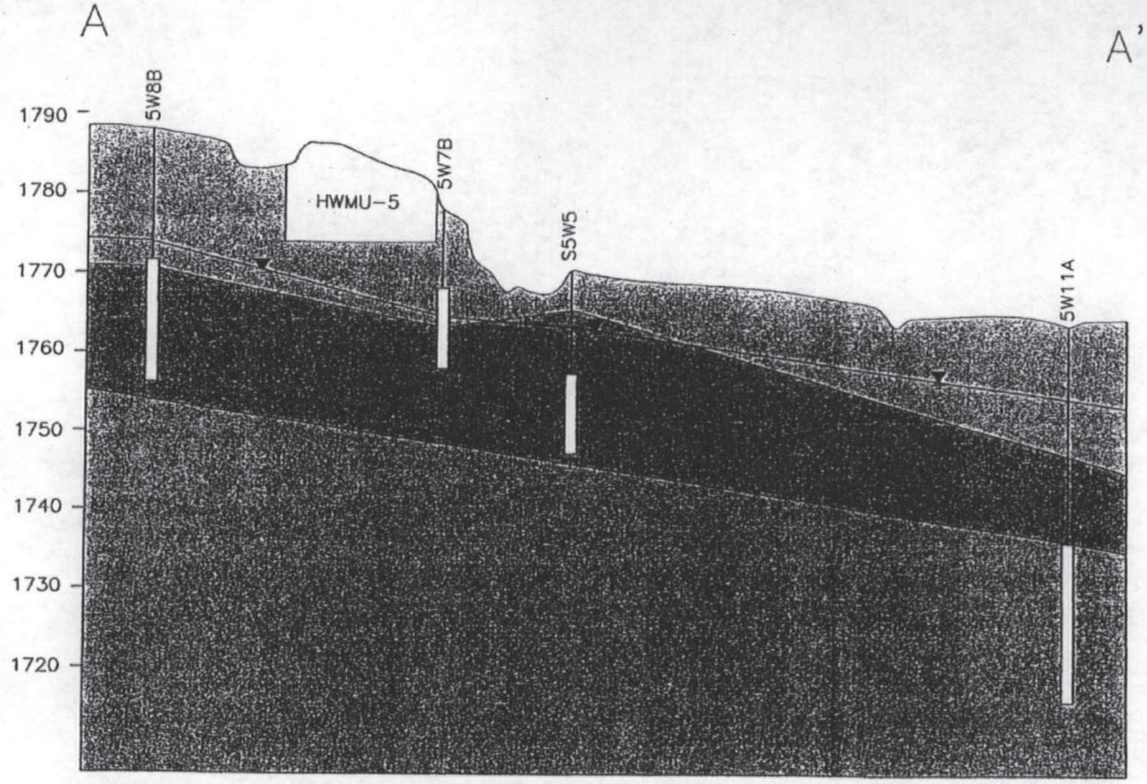


CROSS SECTION LOCATION MAP
HWMU–5 TCE ALTERNATE SOURCE DEMONSTRATION

RADFORD ARMY
AMMUNITION PLANT
RADFORD, VIRGINIA

Draper Aden Associates
CONSULTING ENGINEERS
Blacksburg, VA - Richmond, VA

JOB No.	DATE:	SCALE:	FIGURE
B00316	02-06-01	1" = 200'	3



LEGEND

▨ ALLUVIUM (SILT, SAND, AND GRAVEL)

▨ WEATHERED BEDROCK (SANDY SILT AND CLAY, RELICT ROCK TEXTURE)

▨ ELBROOK FORMATION (LIMESTONE AND SHALE, BRECCIATED)

GROUNDWATER MONITORING WELL

SCREENED INTERVAL

BOTTOM OF WELL

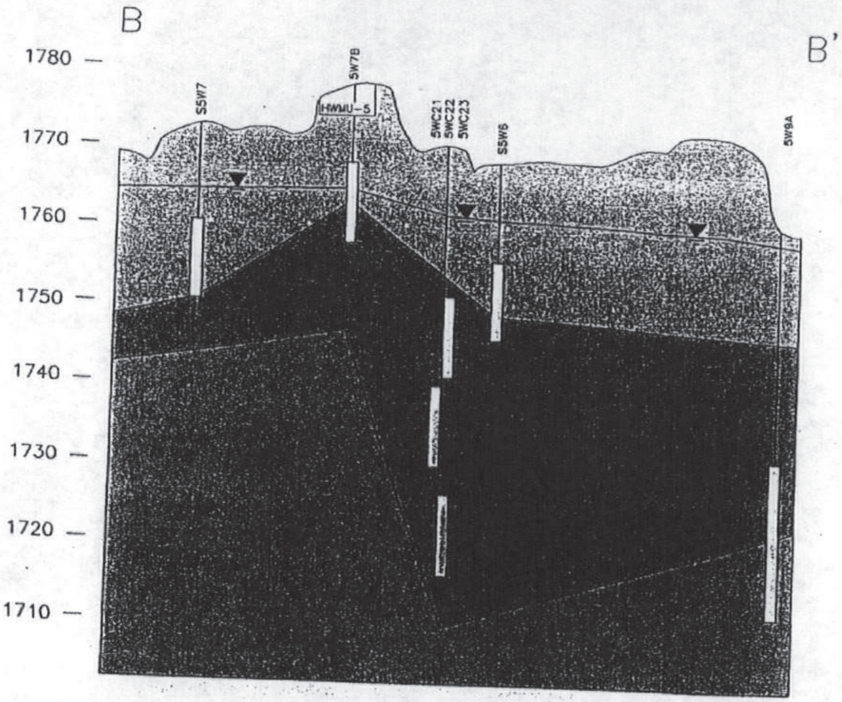
BORING TERMINATION

▼ POTENTIOMETRIC SURFACE

VERTICAL EXAGGERATION = 10X

NOTE: 5WC21, 5WC22, AND 5WC23 ARE THREE NESTED WELLS

Draper Aden Associates CONSULTING ENGINEERS Blacksburg, Virginia – Richmond, Virginia	DESIGNED RGM DRAWN BTM CHECKED AEK DATE 02-10-01	GEOLOGIC CROSS-SECTION A-A' – HWMU 5 TCE ALTERNATE SOURCE DEMONSTRATION RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA	SCALE: H:1"=150' V:1"=15' PLAN NO. B00316	FIGURE 4



LEGEND

▨	ALLUVIUM (SILT, SAND, AND GRAVEL)
▨	WEATHERED BEDROCK (SANDY SILT AND CLAY, RELICT ROCK TEXTURE)
▨	ELBROOK FORMATION (LIMESTONE AND SHALE, BRECCIATED)
│	GROUNDWATER MONITORING WELL
▯	SCREENED INTERVAL
	BOTTOM OF WELL
⊥	BORING TERMINATION
▼	POTENTIOMETRIC SURFACE

VERTICAL EXAGGERATION = 10X

NOTE: 5WC21, 5WC22, AND 5WC23 ARE THREE NESTED WELLS

Draper Aden Associates
CONSULTING ENGINEERS
Blacksburg, Virginia - Richmond, Virginia

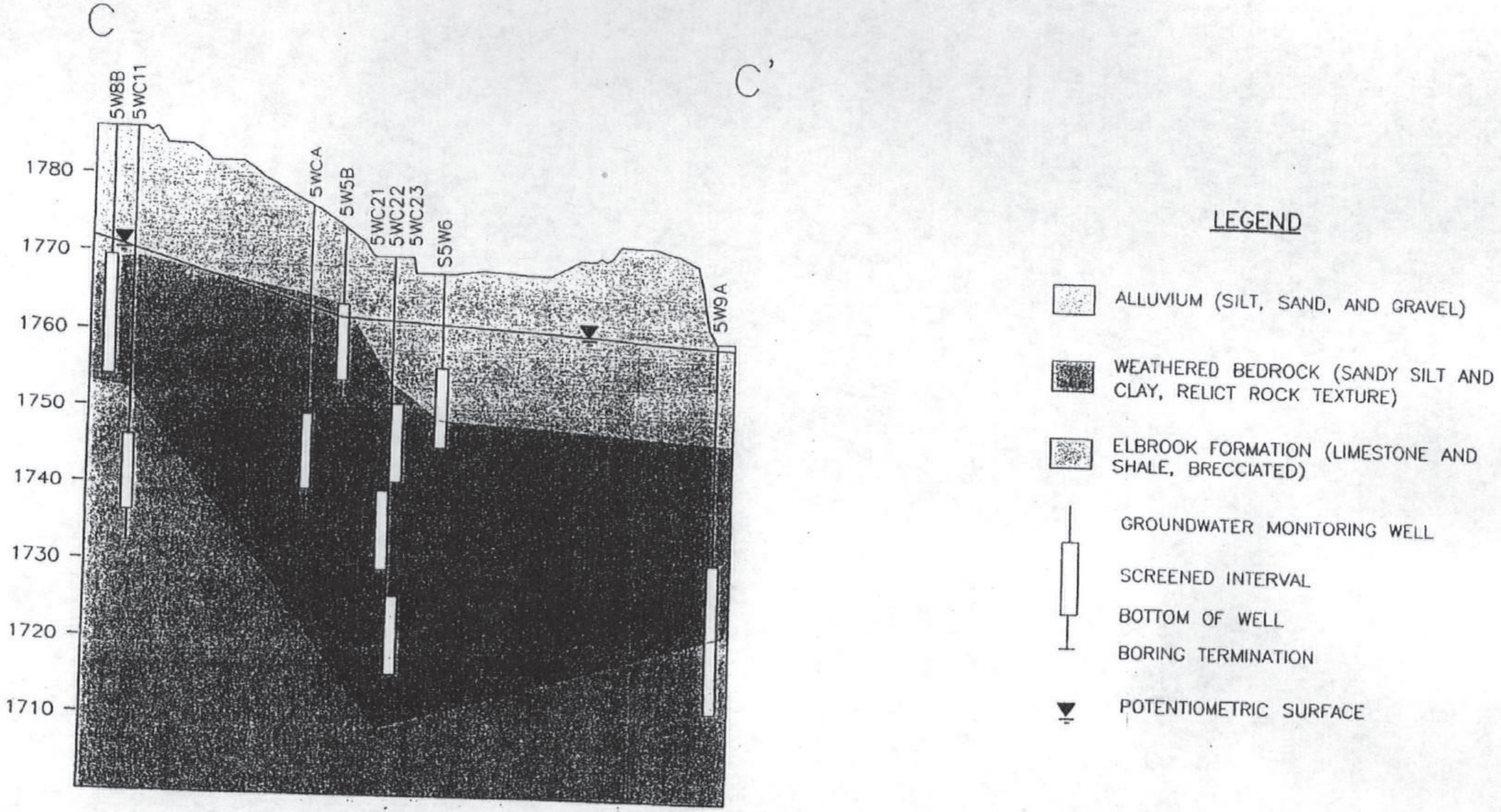
DESIGNED: RGM
DRAWN: BTM
CHECKED: AEK
DATE: 02-10-01

B00316-CRS-X1.DWG

GEOLOGIC CROSS-SECTION B-B' -HWMU 5 TCE ALTERNATE SOURCE DEMONSTRATION
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SCALE: H:1"=150' V:1"=15'
PLAN NO. B00316

FIGURE 5



VERTICAL EXAGGERATION = 10X

NOTE: 5WC21, 5WC22, AND 5WC23 ARE THREE NESTED WELLS

Draper Aden Associates
CONSULTING ENGINEERS
Blacksburg, Virginia • Richmond, Virginia

DESIGNED RGM
DRAWN BTM
CHECKED AEK
DATE 02-07-01

GEOLOGIC CROSS-SECTION C-C'' – HWMU 5 TCE ALTERNATE SOURCE DEMONSTRATION
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

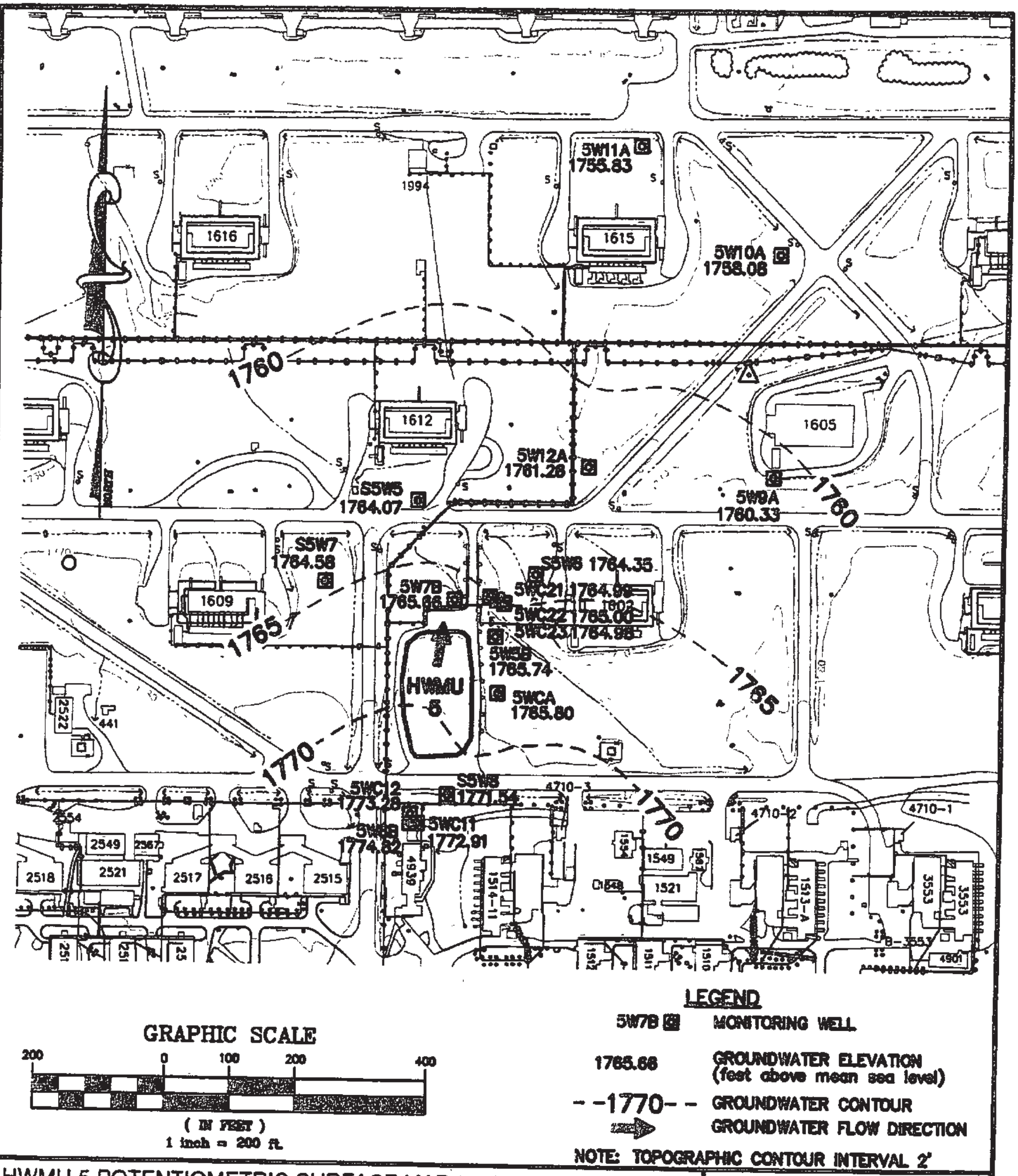
SCALE: H:1"=150'
V:1"=15'
PLAN NO. B00316

FIGURE
6

ATTACHMENT 2
UNIT 5

APPENDIX A.3

POTENTIOMETRIC SURFACE MAPS (GROUNDWATER ELEVATION)



HWMU-5 POTENTIOMETRIC SURFACE MAP (2nd QUARTER 2010)

RADFORD ARMY AMMUNITION PLANT

RADFORD, VIRGINIA

SCALE: 1"=200'

PLAN NO. B03204-08

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DESIGNED RGM
DRAWN JFF
CHECKED MDL
DATE 07-27-10

FIGURE

1

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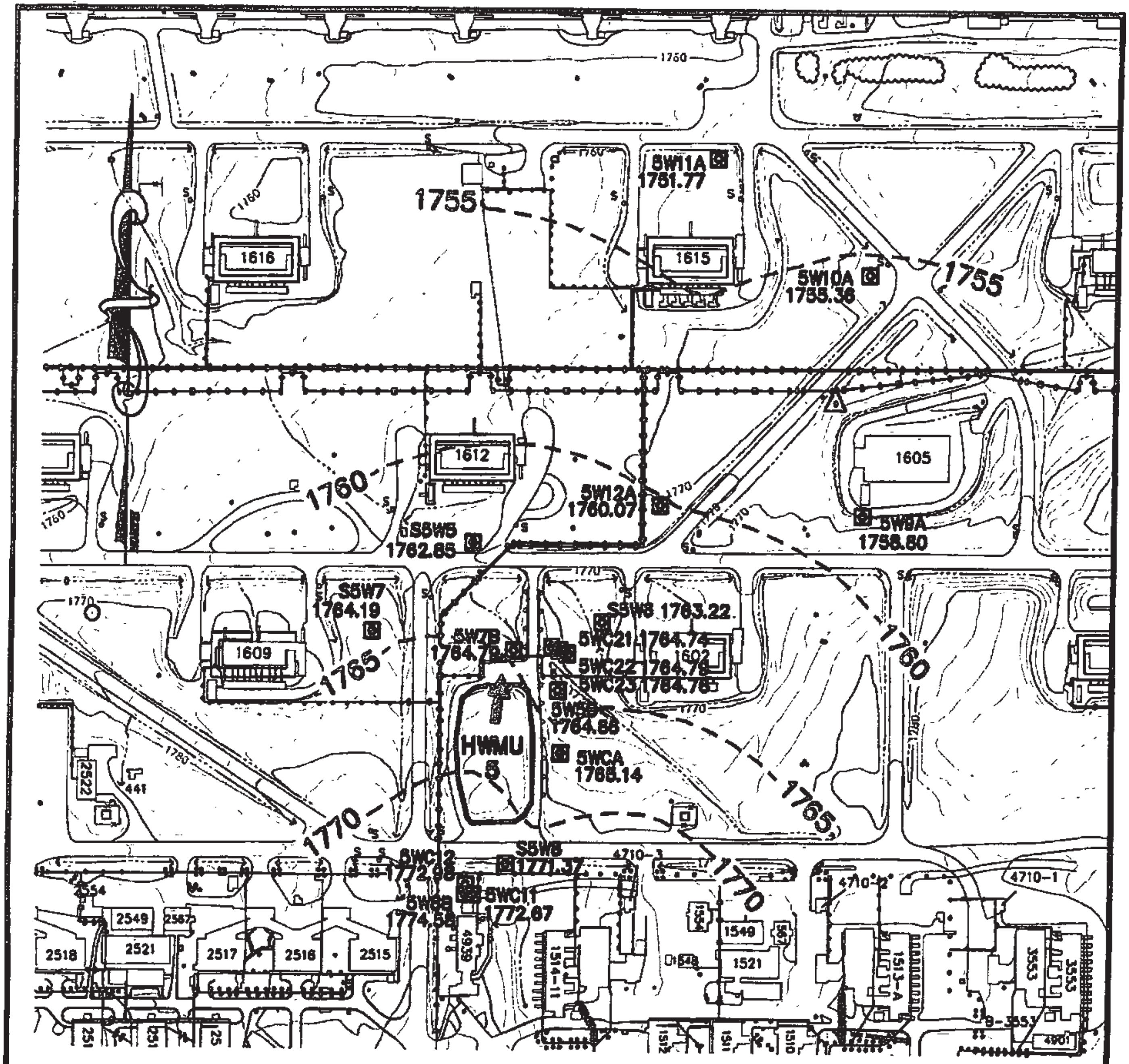

GRAPHIC SCALE

200 0 100 200 400

(IN FEET)
1 inch = 200 ft.

LEGEND

5W7B ⊡	MONITORING WELL
1764.79	GROUNDWATER ELEVATION (feet above mean sea level)
- -1770- -	GROUNDWATER CONTOUR
➡	GROUNDWATER FLOW DIRECTION

NOTE: TOPOGRAPHIC CONTOUR INTERVAL 2'

HWMU-5 POTENTIOMETRIC SURFACE MAP (4th QUARTER 2010)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SCALE: 1"=200'
PLAN NO. B03204-08

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Charlottesville, VA
Hampton Roads, VA

DESIGNED	RGM
DRAWN	JFF
CHECKED	MDL
DATE	01-27-11

FIGURE
1

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ATTACHMENT 2
UNIT 5

APPENDIX B

(RESERVED)

ATTACHMENT 2
UNIT 5

APPENDIX C

DESCRIPTION OF WASTES

B. GENERAL INFORMATIONAL REQUIREMENTS

The Radford Army Ammunition Plant (Radford AAP) is submitting this revised RCRA Hazardous Waste Management Part B Permit Application for Hazardous Waste Management Unit Number 5 (HWMU-5) in accordance with Virginia Hazardous Waste Management Regulations 9 VAC 20-60-1010 and in response to the Virginia Department of Environmental Quality's (VDEQ's) review of the *RCRA Part B Permit Application for Radford Army Ammunition Plant (November 1984, revised October 1985)*. For the purposes of this permit, the term "Facility" refers to all contiguous portions of the Radford AAP under the control of either the United States Army or Alliant Ammunition and Powder Company, L.L.C. (Alliant). The Facility specifically includes both the Horseshoe Area and the Main Manufacturing Area. The subject Part B Permit Application will be effective for only a portion of the Facility (i.e., HWMU-5), which will be designated herein as the "Unit." All other HWMUs at the Radford AAP Installation will be, or have been, addressed under separate Permit Documentation. General Information is provided to demonstrate the context of HWMU-5 within the overall history and function of the Radford AAP Installation.

B.1 General Facility Description

Location

The Radford AAP is located in the mountains of southwestern Virginia within Pulaski and Montgomery Counties. The installation consists of two noncontiguous areas - the Radford Unit (or Main Section) and the New River Ammunition Storage Area Unit. The Main Section is located approximately 4 miles northeast of the city of Radford, approximately 10 miles west of Blacksburg, and 47 miles southwest of Roanoke, Virginia. The New River Unit is located approximately 6 miles west of the Main Section, near the town of Dublin, Virginia. All uses of the terms "Radford AAP" or "the Facility" in this document refer to the Main Section only.

The Radford AAP is situated in one of a series of narrow valleys typical of the Valley and Ridge physiographic province of the Appalachian Highland Region of North America. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long. The valley has a width of approximately eight miles at the southwest end and narrows to approximately two miles at the northeast end. The Radford AAP lies along the New River in the relatively narrow northeast corner of the valley. The maximum elevation at Radford AAP is 2,225 feet above mean sea level (MSL) in the southeast corner and the minimum elevation is approximately 1,675 feet above MSL along the New River at the northern property boundary.

The Radford AAP is divided by the New River into two areas (Figure I-1, Section I of this Application). The southern area, which comprises approximately two-thirds of Radford AAP, is called the "Main Plant Area." The remaining northern one-third section is called the "Horseshoe Area," and is located within the meander of the New River. The entire Radford AAP is secured by artificial barriers to prevent unknowing or unauthorized entry. The Facility perimeter is surrounded by a six-foot chain link fence with three-strand barbed wire top guard. The access gates and perimeter fencing at the Radford AAP are posted with no trespassing signs. The signs are posted in sufficient number so as to be seen from any approach to the restricted portions of the property.

Forty three (43) Solid Waste Management Units (SWMUs) and eight (8) HWMUs are located in both the Main Plant Area and the Horseshoe Area (Figure I-2). This Part B Permit Application is specifically for HWMU-5. As shown on Figure I-2, HWMU-5 is located in the Main Plant Area. HWMU-5 is a former lined surface impoundment. Influent into HWMU-5 included: spills, runoff, and wash down waters from an acid tank farm. HWMU-5 was closed by the U.S. Army Corps of Engineers in 1989 in accordance with a Commonwealth of Virginia-approved closure plan. The basin was drained of all waters, the soil was treated in-place with flyash and cement kiln dust to achieve a target pH between 6.3 and 10.5, and the basin was filled with soil and stone and capped. No waste has been processed through the Unit since it was closed. As shown on the Site Plan (Figure I-3), intermittent drainages are located to the west and northeast of the Unit. As illustrated on Figure I-2, the New River is located approximately 3,000 feet northeast of the Unit.

History

The Radford AAP is a government-owned, contractor-operated (GOCO) military industrial installation supplying solvent and solventless propellant grains and trinitrotoluene (TNT) explosives. From its inception as a GOCO installation in 1940 until 1995, the Radford AAP was operated by Hercules Incorporated. On March 6, 1995, Alliant Techsystems, Inc. bought out Hercules Incorporated and took over operation of the Radford AAP. On April 1, 1999, the division of Alliant Techsystems, Inc. which operates the Radford AAP became a limited liability corporation under the name of Alliant Ammunition and Powder Company, L.L.C.

Construction of the Radford AAP production facility began in 1940 with the impending participation of the United States in World War II, and the determination by Congress of a need for increased ammunition production facilities. Initially, Radford AAP consisted of two distinct areas - a smokeless-powder plant (Radford Ordnance Works [ROW]) and a bag-manufacturing and loading plant for artillery, cannon, and mortar projectiles (New River Ordnance Works [NROW]). These two production facilities were operated separately from 1940 to 1945. Late in 1945, ROW was designated as the Radford Arsenal, and NROW was designated as a subpost. By January 1950, NROW was made an integral part of the Radford Arsenal and no longer considered a subpost. The arsenal was renamed Radford Ordnance Plant in 1961 and was finally redesignated as the Radford AAP in August 1963 (USATHAMA, 1984).

Expansion of both ROW and NROW continued throughout World War II. Late in 1945, the Radford Unit was placed on standby status. The following year, the nitric acid area of the plant was reactivated to produce ammonium nitrate fertilizer, an activity that continued until 1949 under contract with Hercules Powder Company (later Hercules Incorporated). In September 1945, the NROW was declared surplus; but in April 1946, the magazine areas were changed from surplus to standby status. Between December 1946 and January 1948, large parcels of the NROW plant manufacturing area were sold (USATHAMA, 1984). These parcels were excess land holdings that had never been used for production purposes.

Between 1952 and 1958, Goodyear Aircraft Corporation of Akron, Ohio was contracted to manufacture component parts used in missile production at the Radford AAP. The close coordination required between Goodyear and Hercules resulted in Goodyear moving its assembly and coating operations to Radford AAP. In 1958, Hercules took over the Goodyear operations at the Plant (USATHAMA, 1984).

In mid-1968, the continuous TNT plant was put into production and remained in operation until destroyed by an explosion in May 1974. The TNT plant had five main operational areas: the nitration lines, the finishing buildings, the red water concentration facility, the acid neutralization facility, and the spent acid recovery plant. The C-line in the TNT area ran from 1983 to 1986, when the TNT plant was placed on standby. Later, in December 1988, a facility cleanup was conducted and the TNT plant was prepared for long-term standby status. Between 1990 and 1992, two nitroglycerin facilities went on line at Radford AAP. Although there was an explosion at one of these in 1993, they both remain active. A chronological listing of major Radford AAP activities is presented in Table B-1.

Responsibility

Based on discussions with Facility personnel, the general responsibilities assigned to the Radford AAP have not changed from those outlined by USATHAMA (1976), these include:

- Manufacturing of explosives and propellants;
- Handling and storage of strategic and critical materials as directed for other government agencies;
- Operation and maintenance, as directed, of active facilities in support of current operations. Maintenance and/or lay-away, in accordance with Ammunition Procurement and Supply Agency instructions, of standby facilities, including any machinery and packaged lines received from industry, in such conditions as will permit rehabilitation and resumption of production within the time limitations prescribed;
- Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service Stock and industrial stock as required or directed;
- Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials;
- Mobilization planning, including review and revision of plant as required;
- Custodial maintenance and administrative functions of subinstallations; and
- Support services for tenants.

These responsibilities are met through the efforts of the operating contractor, Alliant Ammunition and Powder Company, L.L.C. The Administrative Contracting Officer (ACO) and his staff provide technical assistance and administer the contracts with the civilian operating contractors. Radford AAP provides logistics support for tenant activities such as the U.S. Army Research, Development and Acquisition Information Systems Agency, (USARDAISA) which is charged with performing data processing activities during peacetime.

Industrial Operations

From 1941 to the present the principal end products produced at Radford AAP have been TNT, single-base and multi-base propellants, and cast and solventless propellants. Intermediate products produced are oleum (concentrated sulfuric acid), nitric acid, nitroglycerine (NG), and nitrocellulose (NC).

Production at Radford AAP is accomplished at the primary and secondary manufacturing areas. The primary manufacturing processes are the production of single-base and multi-base solvent propellants, cast and solventless propellants, and TNT. Separate process areas are provided for the production of solventless propellant, referred to as rolled powder. The process steps are essentially the same for the production of solvent-type single-, double-, and triple-base propellants; the major differences are in the specific chemical and explosive ingredients added. Single-base and double-base propellants may include one or more of the following chemicals: barium nitrate, potassium nitrate, ethyl centralite, graphite, carbon black, potassium sulfate, lead carbonate, dibutylphthalate, and diphenylamine. Triple-base propellants consist of ethyl centralite and potassium sulfate cryolite, while special high-energy propellants contain high melting point explosives (HMXs). The secondary manufacturing processes include the production of oleum, nitric acid, NG, and NC.

Propellant Production

The separate processes used in the production of the various propellants are discussed below.

Single-base solvent propellant - In this batch process, nitrocellulose is dehydrated and mixed with appropriate chemicals and solvents for the desired blend. The mixture then undergoes a series of operations where it is shaped into a cylindrical block, extruded into strands, and cut to desired size. The solvents ethyl alcohol and ethyl ether are recovered, and the grains are water and air dried. The last major operation includes glazing, blending, and packaging.

Multibase solvent propellant - The manufacture of the multibase solvent propellant is similar to the single base except for the addition of nitroglycerin, nitroguanidine, and other chemicals for the formulation desired. The ethyl alcohol and acetone solvents are recovered, and the mix is forced-air dried.

Cast propellant - The manufacturing of cast propellants for rocket grains requires the mixing of nitroglycerin with triacetin, diethyl phthalate, ethyl centralite and 2-nitrodiphenylamine (2-NDPA) (depending on formulation), and a casting solvent, followed by the addition of the base grain. The rocket grain is then cast, cured, machined, assembled, and packaged.

Solventless propellant (rolled powder) - The solventless propellant is prepared by a batch process in which nitrocellulose, nitroglycerin, and other chemicals are slurried in water, wrung to a wet cake, and dried to a paste. After the paste is blended, the mixture is rolled into sheets. The propellant is then wound into a carpet roll for extrusion into small rocket grains. The propellant is also rolled and finished for mortar increments.

TNT Production

Before its destruction in May 1974, the TNT plant consisted of three manufacturing lines (A, B, and C), each with a rated capacity of 50 tons/day using the modern Canadian Industries, Limited (CIL), continuous nitration and purification process and an advanced drying, solidifying, and packaging operation. When the TNT plant reopened in 1983, the B and C lines were restored, and improved safety equipment, process equipment, and a TNT wastewater treatment facility were added. The overall volume of TNT production was reduced. Operations for fume recovery, red water concentration and destruction, waste neutralization, and spent acid recovery were located in the TNT plant area. These operations directly support the manufacture of TNT.

Secondary Manufacturing Operations

The secondary manufacturing operations at Radford AAP are the production of oleum, sulfuric and nitric acids, nitroglycerin, and nitrocellulose, as described below:

- Oleum 40 percent is manufactured by absorbing sulfur trioxide (SO_3) in 100 percent sulfuric acid. A new plant, constructed in 1970, uses a sulfur acid regeneration (SAR) process.

- The ammonia oxidation process (AOP) is used to make weak, 60 percent nitric acid. A new plant was constructed in 1970.

- The sulfuric acid concentration (SAC) process produces 93 percent sulfuric acid, and concentrates the sulfuric acid residue from the nitric acid concentration (NAC) and TNT processes. This process was replaced by the SAR process in 1970.

- The NAC process is used to concentrate the weak nitric acid produced in the AOP plant and to recover the spent acids from the manufacture of NC and NG. This was replaced by a new facility constructed in 1970.

NG was manufactured at Radford AAP by both the batch and continuous (Biazzi) processes. The batch process employed three steps: nitration of glycerin to produce NG, separation, and neutralization of the NG charge. The continuous process is a fully automated controlled method in which the NG is produced by reactions similar to the batch process. In 1984, the batch process became inoperative and was replaced by a continuous process. Since 1984, only the continuous process has been operating.

The manufacture of NC starts with the preparation and air drying of cotton linters and wood pulp fibers and the preparation of mixed acid (nitric/sulfuric acid). The remaining major steps consist of nitration and purification. A dry charge of cotton linters or wood pulp fibers, depending on the type and grade of NC desired, is agitated with the mixed acid in a dipping pot. After nitration, the spent acid is separated from the NC. The raw NC from the nitration operation is stabilized by a stabilization acid boil and two neutral boils in the boiling tub house. It is then transferred to the beater house, where it is cut to suitable size and partially neutralized. Next, in the poacher house, a series of NC boils are performed; first, a soda boil neutralizes any remaining acid, then neutral boils and washes are performed to remove the soda. The NC is then screened, filtered, and washed. In the blender house, NC of various classes is mixed to produce the mixture or blend desired. The mixture is then wrung through centrifugal wringers in the final wringer house to obtain a product containing a small and uniform amount of moisture. The NC is then shipped to the green powder lines for processing into single-base solvent propellant and to the NG premix area for processing into multibase solvent and solventless propellant.

B.2 Chemical And Physical Analyses of the Hazardous Waste Handled at the Unit

The wastes handled by HWMU-5 were characteristically hazardous as corrosive (EPA I.D. No. D002). The acidic waste waters were both nitric ($N0_3$) and sulfuric ($S0_4$) in origin with a pH of 1.5 and a dominant constituent of mixed acids. According to EP toxicity analyses conducted on the lagoon influent water, several heavy metals were detected but in very low concentrations (i.e., nonhazardous). The results of the analyses conducted on the lagoon water are presented in Table B-2 at the end of this section.

In addition to acidic waste wasters, process waste water containing low concentrations of nitrocellulose (NC) was conveyed from the acid screen house to HWMU-5 until the process was discontinued in 1983. Microscopic examination of sludge samples from other acid waste lagoons that received similar waste streams indicated NC in concentrations less than one percent. According to test criteria used by the Radford AAP laboratory, sludges containing less than 26 percent NC are non-reactive when NC is the only reactive component present. Analyses for other explosive materials including nitroglycerin and dinitroglycerin showed very low concentrations of these constituents in the lagoon sludges. These results indicated that it was unlikely that the solids in HWMU-5 were reactive due to NC or other explosive materials which may have been present.

B.3 Waste Analysis Plan

As HWMU-5 has been closed since 1989, the most appropriate waste analysis plan for the facility is the analytical results associated with the *Ground Water Quality Assessment Report* (DAA, 1999). A copy of the most recent *Ground Water Quality Assessment Report* (GWQAR) is presented in Appendix B-1 at the end of this Section. The current groundwater monitoring list for HWMU-5 is presented as Table 1 in the GWQAR; this list was used to develop the groundwater monitoring list presented in the proposed Compliance Groundwater Monitoring Plan for the Unit presented in Appendix L-1 of Section L of this Application.

In addition to the GWQAR, soil analytical data was collected during the closure of HWMU-5. This data is presented in Appendix B-2 at the end of this Section.

TABLE B-1

CHRONOLOGICAL LIST OF MAJOR ACTIVITIES AT RADFORD AAP

DATE	ACTIVITY
August 1940	Contract signed with Hercules Powder Company for Construction and Operation of smokeless powder plant
September 1940	Construction of Radford Plant
April 1941	Production started at Radford Plant
1941	Separate New River bag loading plant constructed
1941/45	Construction of various facilities continued
1945	Consolidation of Radford and New River plants
1945	Production stopped-plant in standby
1946-49	Ammonium nitrate produced in Acid Area
1949	Limited resumption of powder production
1950	Plant reactivated for Korean Conflict
1950/51	Large areas of plant rehabilitated
1951	Multibase propellant and cast rocket grain facilities constructed
1967/68	Continuous TNT lines constructed
1970/72	New acid plants constructed
1971	Preproduction project work on Continuous Automated Multibase Line (CAMBL) started
1972	Continuous Automated Single-Base Line (CASBL) construction started
1972	Continuous nitrocellulose nitration construction started
1973	Military Construction, Army (MCA) pollution abatement facilities construction started
May 1974	TNT plant explosion
1976	Continuous Automated Single-Base Line M6/M1 conversion started
1978	Construction started on biological wastewater treatment plant
1980	C-line Nitrocellulose Manufacturing Area closed
1983	TNT plant reopened
1986	TNT plant placed on standby
1987	C-line Nitrocellulose Manufacturing Area reopened
December 1988	TNT plant cleanup, preparation for long-term standby
1990	Nitroglycerin facility went on line
November 1992	Pollution control system upgrade completed for explosive waste incinerators
1992	Second nitroglycerin facility went on line
January 1993	Upgrade to biological wastewater treatment plant began
1993	Explosion at nitroglycerin facility
October 1994	Operating permit approved for explosive waste incinerators
March 1995	Alliant Techsystems, Inc. buyout of Hercules complete

Source: Modified from USATHAMA, 1976

TABLE B-2

RESULTS OF ANALYSIS OF INFLUENT WASTE SAMPLE TAKEN DURING LOW FLOW FROM HWMU-5

PARAMETER	RESULT
pH	1.5
Arsenic	ND
Barium	ND
Cadmium	0.029 mg/l
Chromium	0.20 mg/l
Lead	ND
Mercury	0.020 mg/l
Selenium	ND
Silver	ND

ND = Not Detected

Source: USAEHA (December 1981)

ATTACHMENT 2
UNIT 5

APPENDIX D

CONTINGENCY PLAN

Please refer to Appendix B to Permit Attachment 1

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ATTACHMENT 2
UNIT 5

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING SEMIANNUAL CONSTITUENT LIST

ATTACHMENT 2, UNIT 5

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING SEMIANNUALCONSTITUENT AND REQUIRED ANALYTICAL METHOD LIST

Constituents	***Suggested SW-846 Methods***	**Practical Quantitation Limits (µg/l)**
Antimony, total	6010, 6020	3
Arsenic, total	6010, 6020	10
Barium, total	6010, 6020	10
Beryllium, total	6010, 6020	1
Cadmium, total	6010, 6020	1
Chromium	6010/6020	5
Cobalt, total	6010, 6020	7
Copper, total	6010, 6020	5
Lead, total	6010, 6020	1
Mercury, total	7470A	2
Nickel, total	6010, 6020	10
Selenium, total	6010/6020	10
Silver, total	6010, 6020	2
Thallium, total	6010, 6020	1
Vanadium, total	6010, 6020	10
Zinc, total	6010, 6020	10
Acetone	8260	10
Chloroform	8260	1
Dichlorodifluoromethane	8260	1
1,2-Dichloroethane	8260	1
Diethyl ether	8260	12
Methylene chloride	8260	1
Methyl ethyl ketone (2-Butanone)	8260	10
Toluene	8260	1
Trichloroethene	8260	1
Xylenes (total)	8260	3
Bis (2-ethylhexyl) phthalate	8270	10
Diethyl phthalate	8270	10
2,4-Dinitrotoluene	8270	10
2,6-Dinitrotoluene	8270	10

o-Nitroanilene; 2-	8270	10
p-Nitroanilene; 4-	8270	20
Nitrobenzene	8270	10

Note:

1- All methods are as described in EPA's *SW-846, Test Methods for Evaluating Solid Waste,* August 1, 2000. Web site: http://www.epa.gov/epaoswer/hazwaste/test/main.htm.

2- Single samples are required for each parameter and constituent during each sampling event.

3- Alternate SW-846 Methods may be approved by the Department if the request is in writing and submitted at least 30 days prior to the sample collection event. Proposed alternated methods shall achieve the same practical quantitation limit/estimated quantitation limit (or lower) as the specified method.

ATTACHMENT 2
UNIT 5

APPENDIX F

GROUNDWATER
INITIAL BACKGROUND DATA

ATTACHMENT 2: UNIT 5

APPENDIX F

GROUNDWATER INITIAL BACKGROUND DATA

Background concentrations were calculated for each constituent in the groundwater monitoring program using the analytical data from First Quarter 1996 through First Quarter 1999 for upgradient well 5W8B. The background concentration calculations were based on site wide 95% confidence, 95% coverage upper prediction intervals.

The calculated background concentrations for antimony, arsenic, selenium, chloromethane, 1,2-dichloroethane, trans-1,2-dichloroethene, methylene chloride, tetrachloroethene, toluene, 1,1,2-trichloroethane, trichlorofluoromethane, vinyl chloride, xylenes, bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, diethyl phthalate, diphenylamine, and 2,6-dinitrotoluene are the same as their respective detection limits.

TABLE 2
HWMU-5
CALCULATED BACKGROUND VALUES

Constituent	Background Concentration (µg/l unless otherwise noted)
Antimony	3
Arsenic	1
Barium	172.87
Beryllium	0.7
Cadmium	1.45
Cobalt	7
Copper	18
Lead	10
Mercury	0.9
Nickel	106
Selenium	1
Silver	2.3
Thallium	2
Vanadium	17
Zinc	75
Acetone	89
Benzene	0.1
Chloroform	0.5
Chloromethane	0.3
1,2-Dichloroethane	0.1
Methylene chloride	0.7
Methylethylketone	21.3
Tetrachloroethene	0.1
Toluene	0.1
trans-1,2-Dichloroethene	0.1
1,1,2-Trichloroethane	0.5
Trichloroethene	0.8
Trichlorofluoromethane	0.5
Vinyl chloride	0.1
Xylenes (total)	0.1
Bis (2-ethylhexyl) phthalate	10
Di-n-butylphthalate	5
Diethyl phthalate	5
Diphenylamine	10
2,4-Dinitrotoluene	0.18
2,6-Dinitrotoluene	0.08
Total Organic Carbon	253,000
Total Organic Halides	13.4
Specific Conductivity	450 µS/cm
pH	2.79 to 7.47 pH units

ATTACHMENT 2
UNIT 5

APPENDIX G

GROUNDWATER PROTECTION STANDARDS (GPS)

Attachment 2

APPENDIX G

GROUNDWATER PROTECTION STANDARDS: UNIT 5

Unit: µg/l Unless Otherwise Noted

Constituents	SW-846 Method	PQL (µg/l)	Back-ground (µg/l)	USEPA MCL (µg/l)	VDEQ ACL (µg/l)	EPA RSL (µg/l)	GPS (µg/l)
Antimony, total	6010, 6020	3	3	6			6
Arsenic, total	6010, 6020	10	1	10			10
Barium, total	6010, 6020	10	172.87	2,000			2,000
Beryllium, total	6010, 6020	1	0.7	4			4
Cadmium, total	6010, 6020	0.1	1.45	5			5
Chromium, total	6010, 6020	5	5	100			100
Cobalt, total	6010, 6020	7	7		4.7		7
Copper, total	6010, 6020	5	18	1,300*			1,300*
Lead, total	6010, 6020	1	10	15*			15*
Mercury, total	7470 A	2	0.9	2			2
Nickel, total	6010, 6020	10	106		300		300
Selenium, total	6010, 6020	10	1	50			50
Silver, total	6010, 6020	2	2.3		71		71
Thallium, total	6010,	1	2	2			2

	6020						
Vanadium, total	6010, 6020	10	17		63		63
Zinc, total	6010, 6020	10	75		4700		4700
Acetone	8260	10	89		12000		12000
Chloroform	8260	1	0.5	$80^{\#}$			$80^{\#}$
Dichlorodifluoromethane	8260	1	1		190		190
1,2-Dichloroethane	8260	1	0.1	5			5
Diethyl ether	8260	12	12			7300	7300
Methylene chloride	8260	1	0.7	5			5
Methyl ethyl ketone	8260	100	21.3		4900		4900
Toluene	8260	5	0.1	1,000			1,000
Trichloroethene	8260	1	0.8	5			5
Xylenes (total)	8260	1	0.1	10,000			10,000
Bis (2-ethylhexyl) phthalate	8270	10	10		4.8		10
Diethyl phthalate	8270	10	0.2		11000		11000
2,4-Dinitrotoluene	8270	10	0.18		0.2		10
2,6-Dinitrotoluene	8270	10	0.08		0.042		10
o-Nitroanilene; 2-	8270	10	10		150		150
p-Nitroanilene; 4-	8270	20	20		3.3		20
Nitrobenzene	8270	10	10		0.12		10

NOTES:

EPA MCL: Maximum Contaminant Level of USEPA National Primary Drinking Water Regulations (April, 2002). * - Action Level. Subject to change without notice as directed by DEQ.

Background: Calculated using analytical data from First Quarter 1996 through First Quarter 1999 for upgradient well 5W8B.

DEQ ACL: VA DEQ Alternate Concentration Limit, Dec 2013. Subject to change without notice as directed by DEQ.

RSL: Developed by Oak Ridge National Laboratory under an Interagency Agreement with EPA (June 2011). Subject to change when it is updated.

$^{\#}$: The MCL for total Trihalomethanes, including Bromodichloromethane, Bromoform, Dibromochloromethane, and Chloroform, is 80 gm/l.

For any monitoring event, if a GPS for a constituent in the table above is based on a PQL, the Permittee will perform verification of a detection (i e value greater than the Detection Limit) of such a constituent using low-level analytical methods, if such methods are standard methods that are routinely available from commercial laboratories Furthermore, the low-level analytical method will be used only if the PQL achievable by that method is less than, or equal to, the ACL or RBC for the subject constituent If the verification event confirms a quantifiable detection (i e value greater than the PQL) above the applicable ACL or RBC, a revised background concentration will be established using low-level analytical methods, if appropriate, and the GPS will be updated based on the new background concentration if warranted

ATTACHMENT 2
UNIT 5

APPENDIX H

BORING LOGS AND WELL CONSTRUCTION DIAGRAMS

TABLE 1
Monitoring Well Survey Data
Hazardous Waste Management Unit 5
Radford AAP, Radford, Virginia

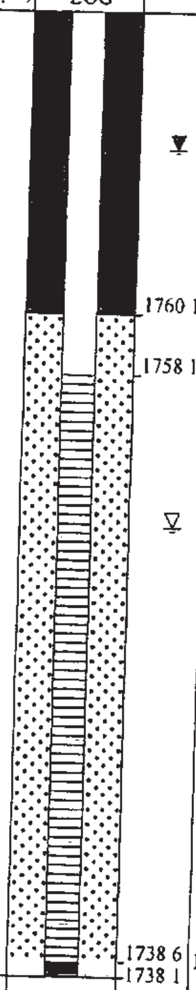
WELL ID	ELEVATION AT TOP OF PVC CASING (NAVD 88)	NORTHING (NAD 83)	EASTING (NAD 83)
5W8B	1788.45	3597013.8437	10889252.8779
5WC11	1789.14	3597013.7930	10889263.3700
5WC12	1789.20	3597026.8562	10889253.7294
S5W8	1783.91	3597056.3385	10889309.4175
5WCA	1779.28	3597208.7913	10889384.8283
5W5B	1773 94	3597294.1823	10889379.5167
5W7B	1773.79	3597348.5604	10889315.7553
5WC21	1773.71	3597353.5337	10889369.7108
5WC22	1773.72	3597348.9117	10889380.8472
5WC23	1773.10	3597343.9377	10889391.9867
S5W5	1771.23	3597495.8112	10889256.6655
S5W6	1770 69	3597387.7138	10889440.2909
S5W7	1775.59	3597373.2666	10889116.7232
5W9A	1760.66	3597536.6534	10889800 3133
5W10A	1769.93	3597864.5629	10889805.8722
5W11A	1764.95	3598022.7203	10889592.8933
5W12A	1772.46	3597548.9323	10889518.8907

DRAPER ADEN ASSOCIATES
Engineers • Geologists • Hydrologists

LOG OF 5W12A
(1 of 1)

Client	**Radford Army Ammunition Plant**	Project Number	**B03204-301**
Project	**HWMU-5 Well Installation**	Drilling Company	**Davidson Drilling**
Location	**RAAP HWMU-5**	Driller	**Chase Davidson**
Northing	**3,597,548.93230000**	Boring Method	**Geoprobe + 3.25 in HSA**
Easting	**10,889,518.89070000**	Logged by	**RGM**
Total Depth	**32.0'**	Completion Date	**February 22, 2010**
Elev GS	**1770.1**	Reference	**Ground Surface**

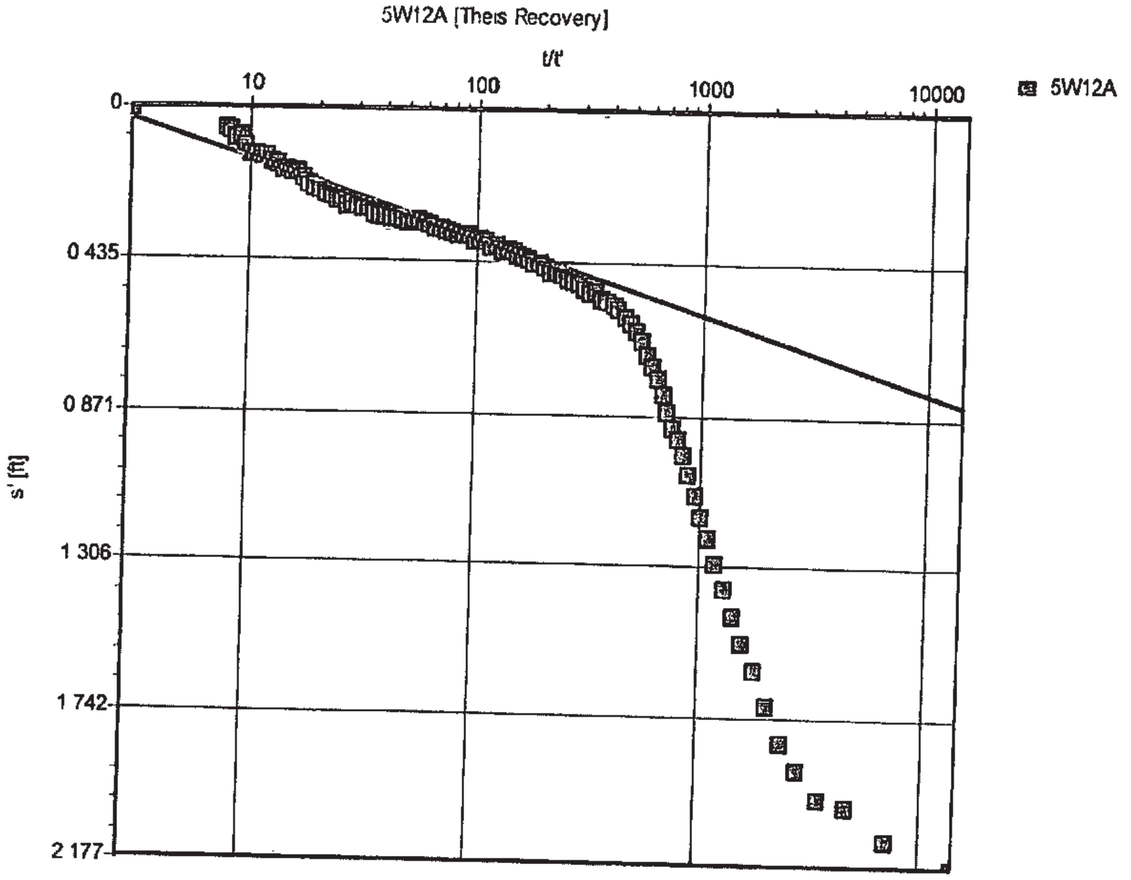
Samp ID	Blow Counts	N Value	Depth Scale	DESCRIPTION (USC)	Stratum Elev	PID (ppm)	H2O	REMARKS
				Dark brown fine silty sand with plant matter trace carbonate gravel moist	1769.9			Surface completion - ~2.5 ft locking stick up with 6x6x0.5 ft concrete well pad
				Brown fine silty sand, trace plant matter damp	1769.1			
				Yellow brown fine clayey sand moist, to mottled (yellow-brown, red-brown) fine clayey sand damp	1766.1			
			10	Mottled (yellow-brown red-brown) fine sandy clay with black joint staining dry	1759.1		▼	Depth to water 2/25/2010 Measuring point elevation 1772.46 ft msl (top of PVC) Hydrated bentonite in outer annulus of PVC Riser - 2 in diameter schedule 40 PVC
				Mottled (yellow-brown, brown) fine sandy silt with black joint staining, trace coarse rounded sand, moist	1757.1			
				Mottled (yellow-brown, brown) fine silty sand with black joint staining trace medium to coarse sand moist	1753.1			
				Becoming wet at 17'	1750.6		∇	Depth to water during drilling 2/19/2010
			20	Yellow-brown fine to coarse sand trace rounded quartz gravel, wet 1 ft recovery between 20-24 ft	1746.1			Screen - 2 in diameter schedule 40 PVC with 0.01 in precut slots #2 sand in outer annulus of screen to 2 ft above screened interval
				Yellow-brown fine to coarse sand, wet	1743.1			
				Mottled (yellow-brown, brown) fine silty sand moist	1742.6			
			30	Brown medium to coarse sand, trace silt, damp to yellow-brown, fine to coase sand, wet	1739.1			
				Yellow-brown fine to coarse clayey sand with gravel, wet	1738.1			Pipe cap at bottom
				Probe refusal on gray carbonate rock, residuum at 32 ft bgs	1737.1			
			40					



Draper Aden Associates
2206 S. Main St.
Blacksburg, VA 24060
Phone 540-552-0444

Pumping Test Analysis Report

Project:	5W12A Pump and Recovery Test
Number:	B03204-301
Client:	Radford Army Ammunition Plant



Pumping Test: 5W12A Pump and Recovery

Analysis Method: Theis Recovery

Analysis Results:	Transmissivity:	3.42E-3 [ft²/s]	Conductivity:	1.25E-4 [ft/s]
Test parameters:	Pumping Well:	5W12A	Aquifer Thickness:	27.5 [ft]
	Casing radius:	0.084 [ft]	Unconfined Aquifer	
	Screen length:	20 [ft]		
	Boring radius:	0.29 [ft]		
	Discharge Rate:	1.8343583 [U.S. gal/min]		
	Pumping Time	70.718 [min]		

Comments: Depth to static water level measured from top of casing.
Manually adjusted best fit line

Evaluated by: KMW-WDN
Evaluation Date: 3/3/2010

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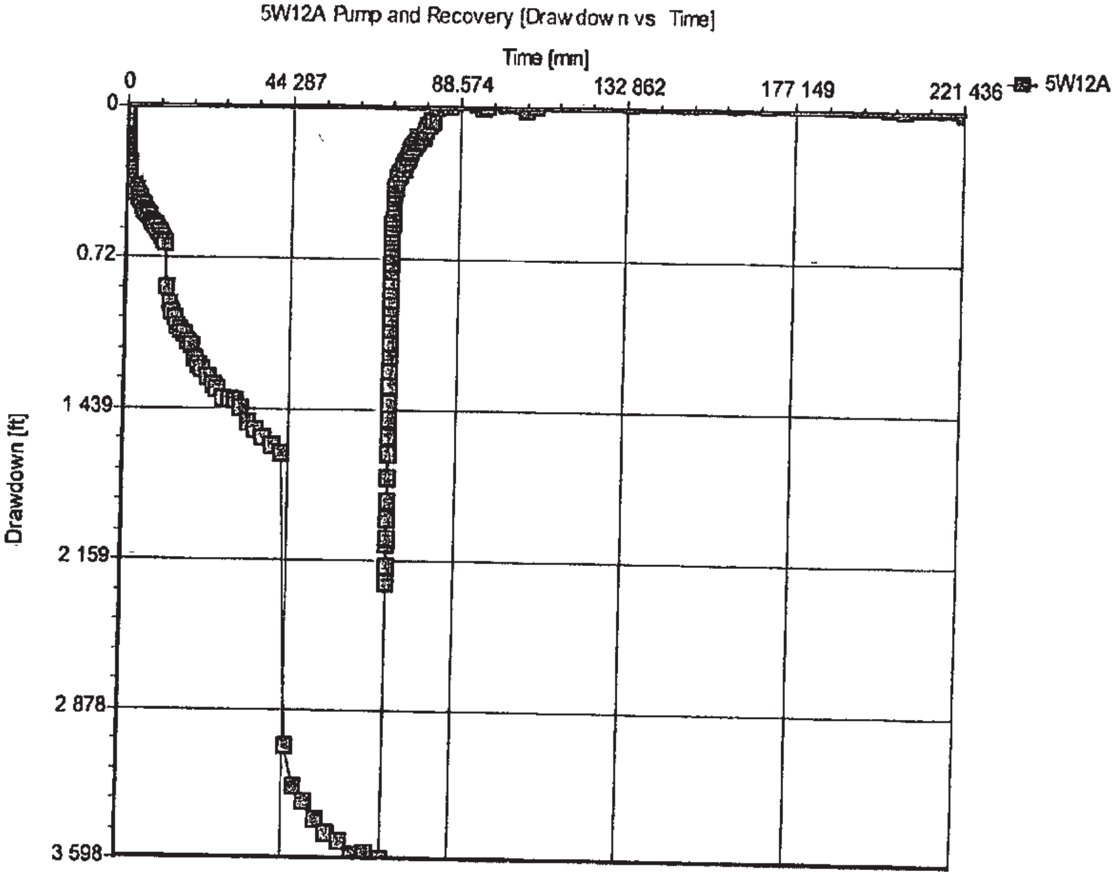
Pumping Test Analysis Report
Project: 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant



Pumping Test: **5W12A Pump and Recovery**

Analysis Method: **Drawdown vs. Time**

Analysis Results:

Test parameters:				
	Pumping Well:	5W12A	Aquifer Thickness:	27.5 [ft]
	Casing radius:	0.084 [ft]		
	Screen length:	20 [ft]		
	Boring radius:	0 29 [ft]		
	Discharge Rate:	1.8343583 [U S. gal/min]		

Comments:
Time 0 - 9 949 minutes - pumping rate 1 gal/min.
Time 9 949 - 42.098 minutes - pumping rate 2 gal/min
Time 42 098 - 70.718 minutes - pumping rate 3 gal/min.
Time 70.718 - 221.463 minutes - recovery.

Evaluated by	KMW-WDN
Evaluation Date	3/3/2010

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Pumping Test Data Report

Project: 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW:	0 [ft]	Pumping Well:	5W12A
Depth to Static WL:	6.89 [ft]	Casing radius:	0.084 [ft]
Location:	HWMU-5	Boring radius:	0.29 [ft]
Recorded by	DWK	Screen length	20 [ft]
Date:	2/25/2010	Aquifer Thickness:	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
1	0	6.89	0.00
2	0.005	6.87	-0.02
3	0.01	6.86	-0.03
4	0.015	6.86	-0.03
5	0.02	6.87	-0.02
6	0.025	6.88	-0.01
7	0.03	7.03	0.14
8	0.035	7.05	0.16
9	0.04	6.93	0.04
10	0.045	6.90	0.01
11	0.05	6.94	0.05
12	0.055	6.97	0.08
13	0.06	7.00	0.11
14	0.065	7.03	0.14
15	0.07	7.04	0.15
16	0.075	7.05	0.16
17	0.08	7.05	0.16
18	0.085	7.07	0.18
19	0.09	7.07	0.18
20	0.095	7.08	0.19
21	0.1	7.09	0.20
22	0.106	7.10	0.21
23	0.112	7.10	0.21
24	0.119	7.10	0.21
25	0.126	7.12	0.23
26	0.133	7.13	0.24
27	0.141	7.12	0.23
28	0.149	7.12	0.23
29	0.158	7.12	0.23
30	0.167	7.14	0.25
31	0.177	7.14	0.25

Pumping Test Data Report
Project: 5W12A Pump and Recovery Test
Number B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW	0 [ft]	Pumping Well	5W12A
Depth to Static WL.	6.89 [ft]	Casing radius	0.084 [ft]
Location.	HWMU-5	Boring radius:	0.29 [ft]
Recorded by	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
32	0.188	7.14	0.25
33	0.199	7.16	0.27
34	0.21	7.16	0.27
35	0.223	7.16	0.27
36	0.236	7.16	0.27
37	0.25	7.16	0.27
38	0.265	7.17	0.28
39	0.28	7.17	0.28
40	0.297	7.19	0.29
41	0.315	7.19	0.30
42	0.333	7.19	0.30
43	0.353	7.19	0.30
44	0.374	7.20	0.31
45	0.396	7.20	0.31
46	0.42	7.21	0.32
47	0.445	7.22	0.33
48	0.47	7.22	0.33
49	0.496	7.22	0.33
50	0.525	7.22	0.33
51	0.555	7.22	0.33
52	0.586	7.23	0.34
53	0.621	7.25	0.36
54	0.658	7.27	0.38
55	0.696	7.27	0.38
56	0.738	7.28	0.39
57	0.781	7.27	0.38
58	0.828	7.28	0.39
59	0.876	7.29	0.40
60	0.928	7.29	0.40
61	0.983	7.30	0.41
62	1.041	7.30	0.41

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Pumping Test Data Report

Project·	5W12A Pump and Recovery Test
Number	B03204-301
Client:	Radford Army Ammunition Plant

Page 3

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW	0 [ft]	Pumping Well	5W12A
Depth to Static WL	6 89 [ft]	Casing radius·	0 084 [ft]
Location.	HWMU-5	Boring radius.	0.29 [ft]
Recorded by	DWK	Screen length:	20 [ft]
Date	2/25/2010	Aquifer Thickness:	27 5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
63	1 103	7 30	0 41
64	1 168	7 30	0 41
65	1 238	7 30	0 41
66	1 311	7 31	0 42
67	1 39	7 31	0 42
68	1 473	7 31	0 42
69	1 561	7 28	0 39
70	1 655	7 28	0 39
71	1 753	7 27	0 38
72	1 858	7 27	0 38
73	1 968	7 29	0 40
74	2 085	7 28	0 39
75	2 21	7 29	0 40
76	2 341	7 29	0 40
77	2 481	7 30	0.41
78	2 63	7 30	0 41
79	2 786	7 32	0 43
80	2 953	7 33	0 44
81	3 13	7 32	0 43
82	3 316	7 33	0 44
83	3 515	7 33	0 44
84	3 725	7 34	0 45
85	3 946	7 36	0 47
86	4 181	7 36	0 47
87	4 43	7 36	0 47
88	4 693	7 38	0 49
89	4 973	7 39	0 50
90	5 27	7 40	0 51
91	5 583	7 40	0 51
92	5 915	7 41	0 52
93	6 266	7 44	0 55

Pumping Test Data Report

Project: 5W12A Pump and Recovery Test

Number B03204-301

Client: Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW	0 [ft]	Pumping Well.	5W12A
Depth to Static WL.	6.89 [ft]	Casing radius:	0.084 [ft]
Location	HWMU-5	Boring radius:	0.29 [ft]
Recorded by:	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
94	6.64	7.44	0.55
95	7.035	7.45	0.56
96	7.453	7.46	0.57
97	7.896	7.47	0.58
98	8.366	7.49	0.60
99	8.865	7.50	0.61
100	9.391	7.51	0.62
101	9.95	7.53	0.64
102	10.541	7.54	0.65
103	11.168	7.76	0.87
104	11.831	7.84	0.95
105	12.535	7.87	0.98
106	13.28	7.91	1.02
107	14.07	7.94	1.05
108	14.906	7.96	1.07
109	15.791	7.98	1.09
110	16.73	8.01	1.12
111	17.723	8.03	1.14
112	18.776	8.10	1.21
113	19.891	8.13	1.24
114	21.073	8.15	1.26
115	22.325	8.18	1.29
116	23.65	8.22	1.33
117	25.055	8.24	1.35
118	26.543	8.28	1.39
119	28.118	8.29	1.40
120	29.786	8.30	1.41
121	31.555	8.33	1.44
122	33.428	8.40	1.51
123	35.411	8.43	1.54
124	37.513	8.47	1.58

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Pumping Test Data Report
Project: 5W12A Pump and Recovery Test
Number: B03204-301
Client Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW	0 [ft]	Pumping Well.	5W12A
Depth to Static WL	6.89 [ft]	Casing radius	0.084 [ft]
Location:	HWMU-5	Boring radius.	0.29 [ft]
Recorded by	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
125	39.74	8.51	1.62
126	42.098	8.55	1.66
127	44.596	9.95	3.06
128	47.243	10.14	3.25
129	50.046	10.22	3.33
130	53.015	10.30	3.41
131	56.16	10.37	3.48
132	59.491	10.41	3.52
133	63.02	10.47	3.58
134	66.758	10.46	3.57
135	70.718	10.49	3.60
136	70.723	9.16	2.27
137	70.728	9.07	2.18
138	70.733	8.97	2.08
139	70.738	8.95	2.06
140	70.743	8.86	1.97
141	70.748	8.77	1.88
142	70.753	8.66	1.77
143	70.758	8.55	1.66
144	70.763	8.46	1.57
145	70.768	8.38	1.49
146	70.773	8.30	1.41
147	70.778	8.22	1.33
148	70.783	8.15	1.26
149	70.788	8.08	1.19
150	70.793	8.02	1.13
151	70.798	7.95	1.06
152	70.803	7.90	1.00
153	70.808	7.85	0.96
154	70.813	7.81	0.92
155	70.818	7.76	0.87

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Pumping Test Data Report
Project 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW:	0 [ft]	Pumping Well	5W12A
Depth to Static WL.	6.89 [ft]	Casing radius:	0.084 [ft]
Location:	HWMU-5	Boring radius:	0.29 [ft]
Recorded by	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness.	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
156	70.824	7.71	0.82
157	70.83	7.67	0.78
158	70.837	7.63	0.74
159	70.844	7.60	0.71
160	70.851	7.56	0.67
161	70.859	7.53	0.64
162	70.867	7.51	0.62
163	70.876	7.49	0.60
164	70.885	7.46	0.57
165	70.895	7.45	0.56
166	70.906	7.44	0.55
167	70.917	7.44	0.54
168	70.928	7.42	0.53
169	70.941	7.42	0.53
170	70.954	7.41	0.52
171	70.968	7.39	0.50
172	70.983	7.38	0.49
173	70.998	7.38	0.49
174	71.015	7.37	0.48
175	71.033	7.36	0.47
176	71.051	7.36	0.47
177	71.071	7.34	0.45
178	71.092	7.33	0.44
179	71.114	7.33	0.44
180	71.138	7.32	0.43
181	71.163	7.32	0.43
182	71.188	7.31	0.42
183	71.214	7.30	0.41
184	71.243	7.29	0.40
185	71.273	7.30	0.41
186	71.304	7.28	0.39

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Pumping Test Data Report
Project: 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW:	0 [ft]	Pumping Well:	5W12A
Depth to Static WL	6.89 [ft]	Casing radius	0.084 [ft]
Location:	HWMU-5	Boring radius:	0.29 [ft]
Recorded by:	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness:	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
187	71.339	7.29	0.40
188	71.376	7.27	0.38
189	71.414	7.26	0.37
190	71.456	7.27	0.38
191	71.499	7.25	0.36
192	71.546	7.25	0.36
193	71.594	7.25	0.36
194	71.646	7.25	0.36
195	71.701	7.24	0.35
196	71.759	7.23	0.34
197	71.821	7.24	0.35
198	71.886	7.22	0.33
199	71.956	7.22	0.33
200	72.029	7.22	0.33
201	72.108	7.21	0.32
202	72.191	7.22	0.33
203	72.279	7.22	0.33
204	72.373	7.21	0.32
205	72.471	7.21	0.32
206	72.576	7.20	0.31
207	72.686	7.20	0.31
208	72.803	7.20	0.31
209	72.928	7.18	0.29
210	73.059	7.18	0.29
211	73.199	7.17	0.28
212	73.348	7.17	0.28
213	73.504	7.18	0.29
214	73.671	7.16	0.27
215	73.848	7.15	0.26
216	74.034	7.14	0.25
217	74.233	7.14	0.25

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Pumping Test Data Report

Project: 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	5W12A	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW	0 [ft]	Pumping Well:	5W12A
Depth to Static WL	6.89 [ft]	Casing radius:	0.084 [ft]
Location	HWMU-5	Boring radius	0.29 [ft]
Recorded by	DWK	Screen length.	20 [ft]
Date:	2/25/2010	Aquifer Thickness	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
218	74.443	7.13	0.24
219	74.664	7.12	0.23
220	74.899	7.11	0.22
221	75.148	7.09	0.20
222	75.411	7.08	0.19
223	75.691	7.08	0.19
224	75.988	7.07	0.18
225	76.301	7.07	0.18
226	76.633	7.06	0.17
227	76.984	7.05	0.16
228	77.358	7.03	0.14
229	77.753	7.03	0.14
230	78.171	7.03	0.14
231	78.614	7.03	0.14
232	79.084	7.00	0.11
233	79.583	6.98	0.09
234	80.109	6.98	0.09
235	80.668	6.96	0.07
236	81.259	6.95	0.06
237	81.886	6.89	0.00
238	82.549	6.85	-0.04
239	83.253	6.84	-0.05
240	83.998	6.86	-0.03
241	84.788	6.88	-0.01
242	85.624	6.88	-0.01
243	86.509	6.86	-0.03
244	87.448	6.82	-0.07
245	88.441	6.81	-0.08
246	89.494	6.81	-0.08
247	90.609	6.85	-0.04
248	91.791	6.84	-0.05

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Pumping Test Data Report
Project. 5W12A Pump and Recovery Test
Number: B03204-301
Client: Radford Army Ammunition Plant

Data observed at:	5W12A	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW:	0 [ft]	Pumping Well	5W12A
Depth to Static WL:	6.89 [ft]	Casing radius	0.084 [ft]
Location:	HWMU-5	Boring radius.	0.29 [ft]
Recorded by	DWK	Screen length:	20 [ft]
Date:	2/25/2010	Aquifer Thickness.	27.5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
249	93.043	6.88	-0.01
250	94.368	6.89	0.00
251	95.773	6.88	-0.01
252	97.261	6.85	-0.04
253	98.836	6.84	-0.05
254	100.504	6.87	-0.02
255	102.273	6.87	-0.02
256	104.146	6.86	-0.03
257	106.129	6.90	0.01
258	108.231	6.88	-0.01
259	112.816	6.85	-0.04
260	115.314	6.84	-0.05
261	117.961	6.85	-0.04
262	120.764	6.84	-0.05
263	123.733	6.83	-0.06
264	126.878	6.85	-0.04
265	130.209	6.85	-0.04
266	133.738	6.86	-0.03
267	137.476	6.85	-0.04
268	141.436	6.85	-0.04
269	145.436	6.86	-0.03
270	149.436	6.86	-0.03
271	153.436	6.85	-0.04
272	157.436	6.85	-0.04
273	161.436	6.87	-0.02
274	165.436	6.86	-0.03
275	169.436	6.86	-0.03
276	173.436	6.86	-0.03
277	177.436	6.86	-0.03
278	181.436	6.86	-0.03
279	185.436	6.86	-0.03

Data observed at:	**5W12A**	**Pumping Test:**	**5W12A Pump and Recovery**
Distance from PW.	0 [ft]	Pumping Well:	5W12A
Depth to Static WL.	6 89 [ft]	Casing radius:	0 084 [ft]
Location:	HWMU-5	Boring radius.	0 29 [ft]
Recorded by:	DWK	Screen length.	20 [ft]
Date:	2/25/2010	Aquifer Thickness	27 5 [ft]

	Time [min]	Depth to WL [ft]	Drawdown [ft]
280	189 436	6 86	-0 03
281	193 436	6 87	-0 02
282	197 436	6 86	-0 03
283	201.436	6 87	-0 02
284	205 436	6 88	-0 01
285	209 436	6 87	-0 02
286	213 436	6 87	-0 02
287	217 436	6 87	-0 02
288	221 436	6 89	0 00

Site 5
Ground Water Monitoring Well Construction Details

Well I.D.	Ground Elevation	UTM Coordinates		Boring Termination Depth	Top of Well Screen	Total Well Depth	Screen Length	Comments
		Northing	Easting					
5W8B	1787.58	3,597,030	10,899,320	31.54	16.54	31.54	15	4,6
5W5B	1773.13	3,597,300	10,899,410	19.58	4.58	19.58	15	4,6
5W7B	1772.78	3,597,350	10,899,305	19.88	4.88	19.88	15	4,6
5WC21	1768.80	3,597,350	10,899,410	29.43	14.43	29.43	15	4,5
5WC22	1768.80	3,597,350	10,899,410	41.23	26.23	41.23	15	4,5
5WC23	1768.80	3,597,350	10,899,410	49.89	34.89	49.89	15	4,5
S5W5	1769.81	3,597,500	10,899,270	18.57	3.57	18.57	15	4,6
S5W7	1773.08	3,597,390	10,899,115	25.59	10.59	25.59	15	4,6
5W9A	1761.10	3,597,510	10,899,800	49	26.65	46.65	20	3,5
5W10A	1768.40	3,597,855	10,899,800	45	25	45	20	3,5
5W11A	1764.70	3,597,010	10,899,600	48	28	48	20	3,5

Comments:
1) Well construction details obtained from boring log.
2) Well screen length obtained from boring log.
3) Well screen length obtained from other data on file.
4) Well screen length assumed.
5) Total well depth obtained from boring log.
6) Total well depth obtained from field sampling log.

Attachment P

BORING LOGS AND WELL CONSTRUCTION DIAGRAMS

Appendix 1.	General Construction and Information
Appendix 2.	Well 5W8B (Background)
Appendix 3.	Well 5W5B (Point of Compliance)
Appendix 4.	Well 5W7B (Point of Compliance)
Appendix 5.	Well 5WC21 (Point of Compliance)
Appendix 6.	Well 5WC22 (Point of Compliance)
Appendix 7.	Well 5WC23 (Point of Compliance)
Appendix 8.	Well S5W5 (Compliance Well)
Appendix 9.	Well S5W7 (Compliance Well)
Appendix 10.	Well 5W9A (Compliance Well)
Appendix 11.	Well 5W10A (Compliance Well)
Appendix 12.	Well 5W11A (Compliance Well)
Appendix 13.	Other Wells

Appendix 2.

Well 5W8B (Background)

Betz-Converse-Murdoch-Inc. BCM

UNITS 5
W-8B

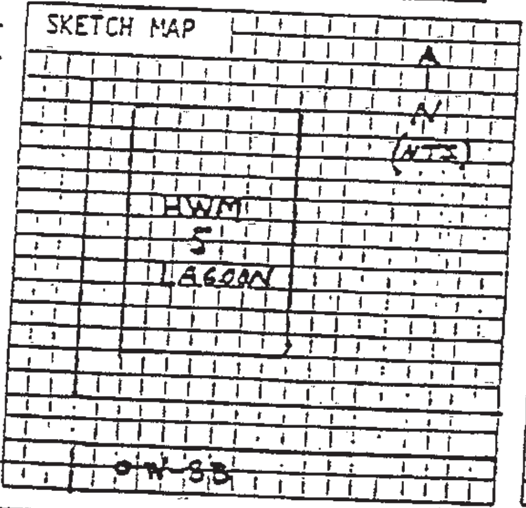
Drilling Log

Well Number W-8-B

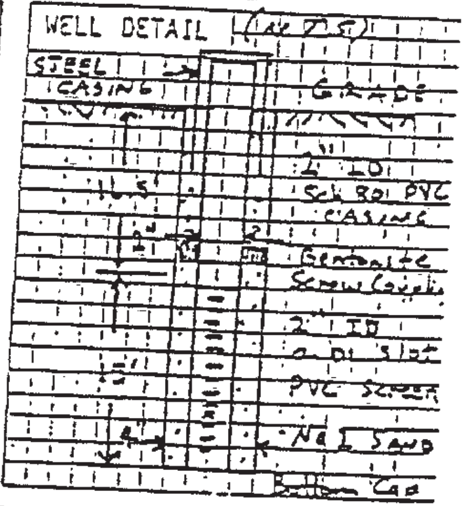
Client Corps of Engineers/Radford AAP
Project No. 00-0008-01
Well Location upgradient from lagoon No. 5
Driller/Company Dean/Cunningham
Drilling Method NX core
Hole Diameter nominal 4"
Date(s) Drilled 2/15 - 16/83
Sample Type split spoon/core
Sample Interval 5' spoon
No. Samples Retained 7
Surface Elevation 1787.58'
Casing Top Elevation 1789.55'
Total Well Depth 31.5
Casing Material and Size 2" ID PVC threaded couples
Cased Interval(s) 0 - 16.5 (+2's
Grouting Type sand cement
Grouted Interval 0-15.5 incl 1'
Screening Material and Size 2" ID PVC 0.010" slots
Screened Interval(s) 16.5 - 31.5
Packing Material and Size No. 1 sand
Packed Interval 15.5 - 31.5
Depth to Static Water 17'4"*
Date 2/18/83
Approx Well Yield <0.25 gpm
Development Method air
Development Time 3 hours
Logged by: Peter P. Jacobson

Comments
no core recovery
* measured from top of casing

SKETCH MAP



WELL DETAIL



Depth Scale	Sample	Spoon Blows	Description of Materials
0 - 1.5	spoon	1-5-6	medium brown to orange brown silty clay with angular pebbles
5 - 6.5	spoon	1-2-2	medium orange brown silty clay with minor fine sand
10 - 11.5	spoon	3-6-14	slightly moist mottled orange brown clay, minor silt and fine sand
14'4"			coarse sand and gravel layer
15 - 16.5	spoon	11-17-45	poorly sorted mix of sand silt gravel clay; coarsening downward; gravel ends at 17.5'
20 - 21.5	spoon	5-5-8	mottled orange/red brown clay, moist
25 - 26.5	spoon	1-2-2	wet soft brown clay with silt and fine sand
30 - 31.5	spoon	1-3-2	wet medium orange brown silty clay, minor sand
end of hole at 31.5'			

Appendix 3.

Well 5W5B (Point of Compliance)

Betz-Converse-Murdoch-Inc. BCM

UNITS
W-5B

Drilling Log

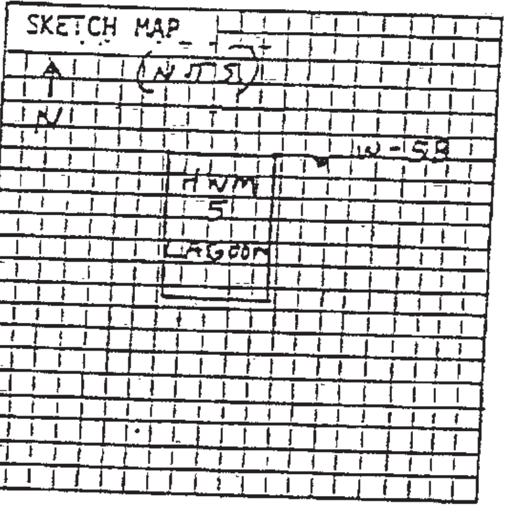
Well Number W-5B

Client Corps of Engineers, RAAP, Radford, VA
Project No. 00-0008-01
Well Location East of HWM 5 Lagoon
Driller/Company M. Dean, Cunningham Core Drilling and Grouting Corp, Salem, VA
Drilling Method Fishtail
Hole Diameter 4.5"
Date(s) Drilled 8/17-18/83
Sample Type Split Spoon
Sample Interval 5'
No. Samples Retained 4
Surface Elevation 1773.13
Casing Top Elevation 1775.08'*
Total Well Depth 22'
Casing Material and Size 2" ID Sch. 80 PVC
Cased Interval(s) 0-10'
Grouting Type Portland Cement with Sand
Grouted Interval 0-6'
Screening Material and Size 2" ID 0.01 Slotted PVC
Screened Interval(s) 10-20'
Packing Material and Size Fine to Coarse Silica Sand
Packed Interval 8-20'
Depth to Static Water 14.31 (T.O.C.)
Date 8/19/83
Approx Well Yield < 1 gpm
Development Method Air
Development Time 4 hours
Logged by: D. J. Varner

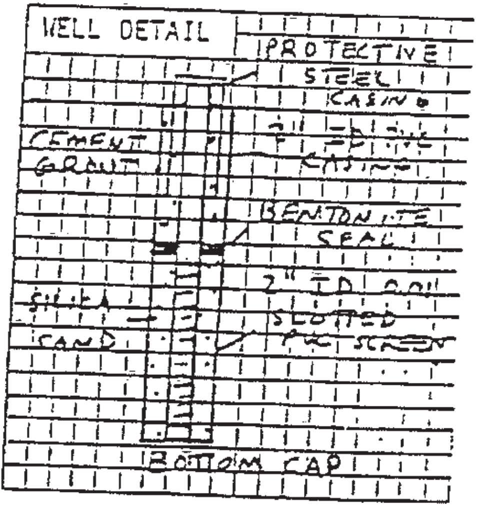
Comments
1) Drilling water obtained from RAAP hydrants
2) Replaces well W-5
3) Bentonite pellet seal in the 8-10' annular interval
Depth to water table measured from the top of the steel casing

*Top of steel casing

SKETCH MAP



WELL DETAIL



Depth Scale	Sample	Spoon Blows	Description of Materials
5-6.5	Spoon	2-3-4	Somewhat mottled buff to orange-brown fine sandy and silty clay
10-11.5	Spoon	4-7-9	Tan Clay with fine to coarse sand
15-16.5	Spoon	4-5-7	Tan clay with scattered sand
20-21.5	Spoon	2-2-4	Brown sandy clay
22			End of hole

Appendix 4.

Well 5W7B (Point of Compliance)

Betz·Converse·Murdoch·Inc. BCM

UNIT 5
W-7B

Drilling Log

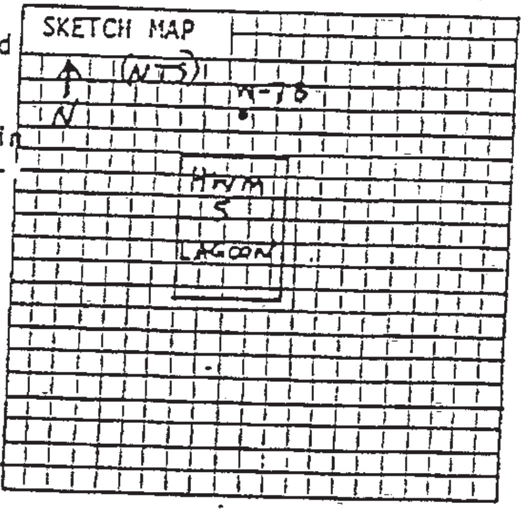
Well Number W-7B

Client Corps of Engineers, RAAP, Radford, VA
Project No. 00-0008-01
Well Location North of HWM5 Lagoon
Driller/Company M. Dean, Cunningham Core Drilling and Grouting Corp, Salem, VA
Drilling Method Fishtail/Core
Hole Diameter 4.5"
Date(s) Drilled 8/18/83
Sample Type Split Spoon
Sample Interval 5'
No. Samples Retained 4
Surface Elevation 1772.78
Casing Top Elevation 1774.90'*
Total Well Depth 20'
Casing Material and Size 2" ID Sch. 80 PVC
Cased Interval(s) 0-10'
Grouting Type Portland Cement with Sand
Grouted Interval 0-6'
Screening Material and Size 2" ID 0.01 Slotted PVC
Screened Interval(s) 10-20'
Packing Material and Size Fine to coarse silica sand
Packed Interval 8-20'
Depth to Static Water 13.58'(T.O.C.) Date 8/19/83
Approx Well Yield < 1 gpm
Development Method Air
Development Time 4 hours
Logged by: D. J. Varner

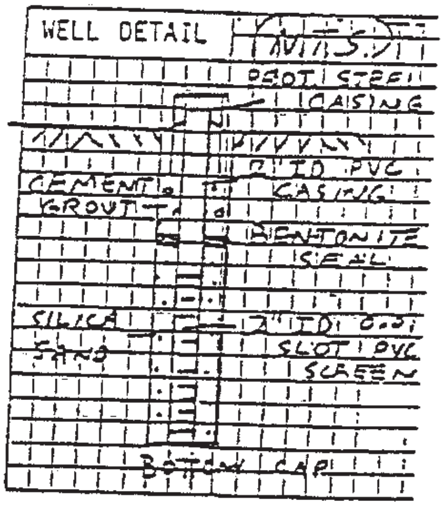
Comments
1) Drilling water obtained from RAAP hydrants
2) Replaces well W-7
3) Bentonite pellet seal in the 6-8' annular interval
4) Depth to water table measured from the top of the steel casing
5) Core size: HW

*Top of steel casing

SKETCH MAP



WELL DETAIL



Depth Scale	Sample	Spoon Blows	Description of Materials
5-6.5	Spoon	5-7-4	Light reddish-brown very silty fine sand with mica, black lignite, and some clay
10-11.5	Spoon	2-3-4	Light reddish-brown very silty fine sand with mica, black lignite, and some clay
15-16.5	Spoon	6-9-19	Orange-red and tan brecciated decomposed shale with a clay matrix and some lignite
20-21.5	Spoon	5-2-4	Orange-red and tan brecciated decomposed shale with a clay matrix and some lignite.
20			End of hole.

W-7B

Betz-Converse-Murdoch-Inc. BCM

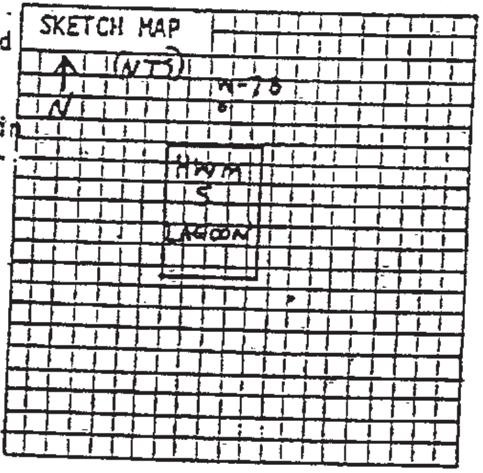
Drilling Log

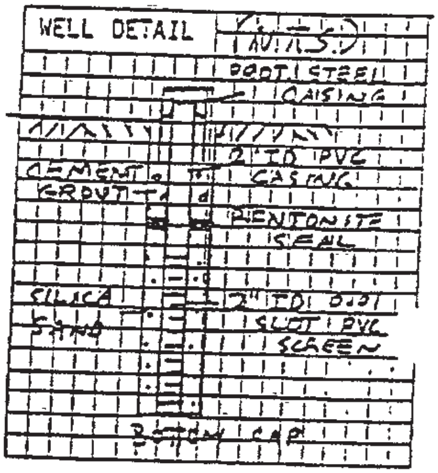
Well Number W-7B

Client Corps of Engineers, RAAP, Radford, VA — Project No. 00-0008-01
Well Location North of HWMS Lagoon
Driller/Company M. Dean, Cunningham Core Drilling and Grouting Corp, Salem, VA
Drilling Method Fishtail/Core Hole Diameter 4.5"
Date(s) Drilled 8/16/83
Sample Type Split Spoon Sample Interval 5'
No. Samples Retained 4
Surface Elevation 1772.78 Casing Top Elevation 1774.90'*
Total Well Depth 20
Casing Material and Size 2" ID Sch. 80 PVC
Cased Interval(s) 0-10
Grouting Type Portland Cement with Sand
Grouted Interval 0-6'
Screening Material and Size 2" ID 0.01 Slotted PVC
Screened Interval(s) 10-20'
Packing Material and Size Fine to coarse silica sand
Packed Interval 8-20'
Depth to Static Water 13.58'(T.O.C.) Date 8/19/83
Approx Well Yield < 1 gpm
Development Method Air
Development Time 4 hours
Logged by: D. J. Varner

Comments
1) Drilling water obtained from RAAP hydrants
2) Replaces well W-7
3) Bentonite pellet seal in the 6-8' annular interval
4) Depth to water table measured from the top of the steel casing
5) Core size: HW

*Top of steel casing





Depth Scale	Sample	Spoon Blows	Description of Materials
5-6.5	Spoon	5-7-4	Light reddish-brown very silty fine sand with mica, black lignite, and some clay
10-11.5	Spoon	2-3-4	Light reddish-brown very silty fine sand with mica, black lignite, and some clay
15-16.5	Spoon	6-9-19	Orange-red and tan brecciated decomposed shale with a clay matrix and some lignite
20-21.5	Spoon	5-2-4	Orange-red and tan brecciated decomposed shale with a clay matrix and some lignite.
20			End of hole.

Appendix 5.

Well 5WC21 (Point of Compliance)

Form No. 300

BORING LOG

HWMU5\5-WC2-1

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING • CHEMIC
"ONE HUNDRED YEARS OF SERVICE"

Report No. M-62084

Client Hercules Inc.			DATE May 1987
Project Radford Army Ammunition Plant		Radford, Virginia	
Boring No. 5-WC2-1	Total Depth 31.8 ft.	Elevation ---------	Location See Location Plan
Type of Boring Hollow Stem Auger	Started 5/5/87	Completed 5/5/87	Driller V. Simmons

Elevation	Depth 0.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
		Medium dense red brown silty fine SAND, trace mica (SM)	$^{3}6_{10}$	1.5 3.0		GROUNDWATER DATA
		-to-	$^{4}5_{9}$	4.5 6.0		
		Very loose to medium dense yellow brown silty medium to fine SAND (SM)	$^{2}2_{2}$	8.5 10.0		
		-ALLUVIUM-	$^{2}14_{6}$	13.5 15.0		
	16.5	Medium dense to very loose yellow brown silty coarse to fine SAND (angular rock fragments) (SM)	$^{9}14_{8}$	18.5 20.0		Subsurface water at: 22 ft. May 5, 1987 at 4:00 p.m. 29 ft, May 5, 1987 4:10 p.m.
		-RESIDUUM-	$^{*}*_{1}$	23.5 25.0		*Weight of hammer
			$^{1}2_{3}$	28.5 30.0		
	31.8	Boring terminated at 31.8 ft.				

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: Simmons
Inspector: Smith
Date Installed: 5/6/87

WELL No.
5-WC2-1

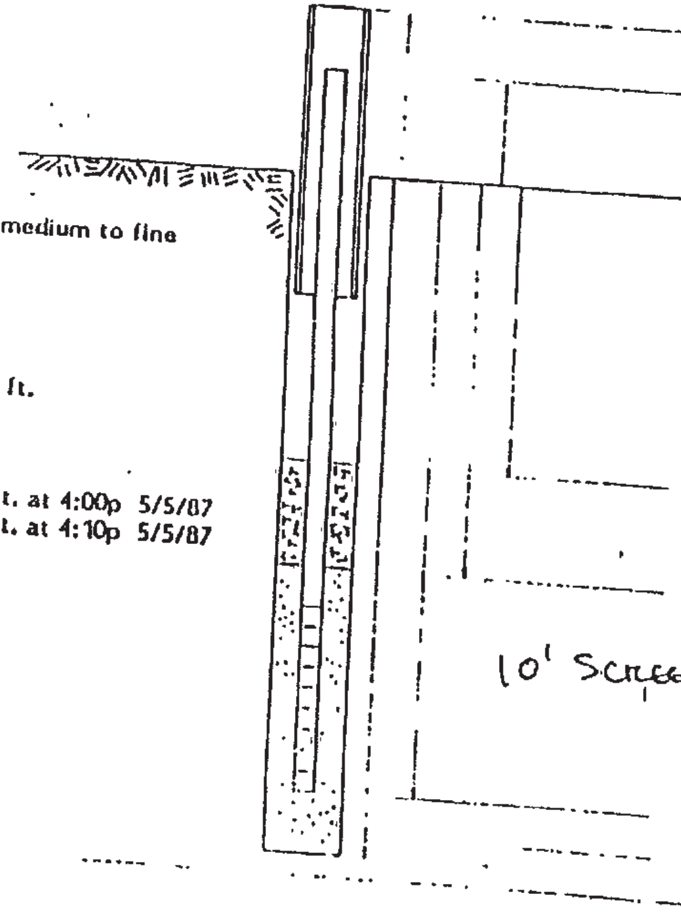
Sand Size: D(10)= 0.45-0.55 mm
Bore/ Core Size: 6 inch/ NX

Subsurface Conditions Summary.

Yellow to Red Brown silty medium to fine SAND (SM)

Cobbles encountered at 8.0 ft.

Subsurface water at; 22.0 ft. at 4:00p 5/5/87
29.o ft. at 4:10p 5/5/87



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=

Depth to Bentonite (ft.)= 14.8 ft.
Elev. =
Depth to Sand Filter(ft.)= --------
Elev. =

Depth to Well Bottom(ft.)= 29.3 ft.
Elev. =
Depth of Hole (ft.) = 31.8 ft.
Elev. =

Appendix 6.

Well 5WC22 (Point of Compliance)

Form No. 300

BORING LOG

HWMUS\5-WC2-2

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING-CHEMICA
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. 0-57084

Client: Hercules Inc.			DATE: May 1987
Project: Radford Army Ammunition Plant		Radford, Virginia	
Boring No. 5-WC2-2	Total Depth: 43.5 ft.	Elevation: --------	
Type of Boring: Hollow Stem Auger	Started: 5/6/87	Completed: 5/6/87	Location: See Location Plan
			Driller: V. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	No sampling conducted, see 5-WC2-1 for subsurface conditions				GROUNDWATER DATA
		Cobbles encountered at 15 ft.				
		Difficult augering at 35 ft. - 40 ft.				
		Boring terminated at 43.5 ft.				

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1"=5' unless otherwise noted

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: Simmons
Inspector: Smith
Date Installed: 5/6/87

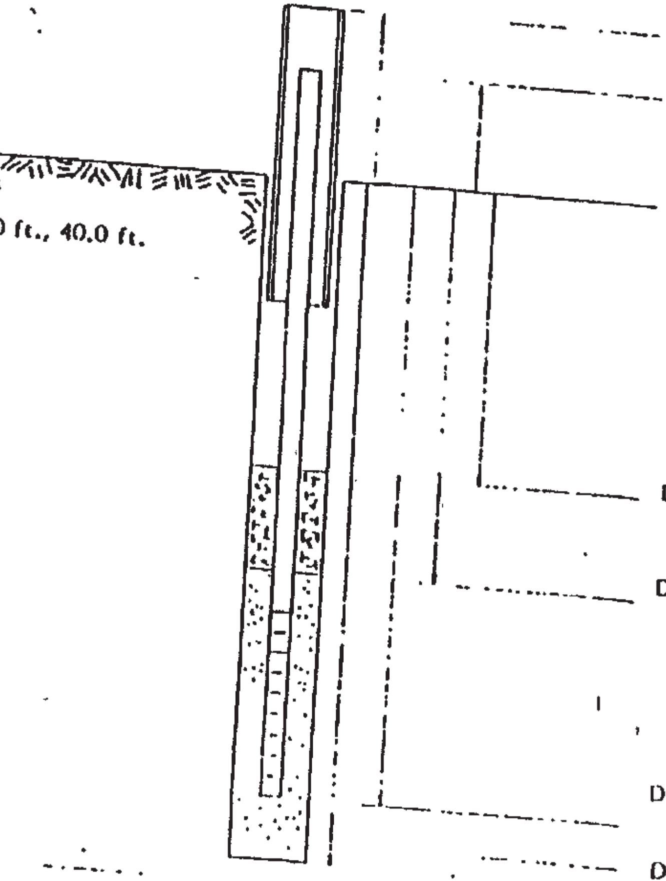
WELL No.
5-WC2-2

Sand Size: D(10)= 0.45-0.55 mm
Bore/ Core Size: 6 Inch/ NX

Subsurface Conditions Summary

See 5-WC2-1 for Conditions

Cobbles encountered at; 15.0 ft., 40.0 ft.



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=

Depth to Bentonite (ft.)= 28.0 ft.
Elev. =
Depth to Sand Filter(ft.)= -------
Elev. =

Depth to Well Bottom(ft.)= 40.5 ft.
Elev. =
Depth of Hole (ft.) = 43.5 ft.
Elev. =

Appendix 7.

Well 5WC23 (Point of Compliance)

Form No. 300

BORING LOG

HWMU 5\ 5-WC2-3

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES - ENGINEERING/CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. 0-62084
Client: Hercules Inc.
DATE May 1987
Project: Radford Army Ammunition Plant Radford, Virginia
Boring No.: 5-WC2-3
Total Depth 55.3 ft.
Elevation --------
Location See Location Plan
Type of Boring Hollow Stem Auger
Started 5/6/87
Completed 5/6/87
Driller W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0					GROUNDWATER DATA
		No sampling conducted, see 5-WC2-1 for subsurface conditions				
		Cobbles encountered at 15.0 ft.				
		Difficult augering at 53.0 ft. - 55.0 ft.				
		Boring terminated at 55.3 ft.				

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: Simmons
Inspector: Smith
Date Installed: 5/6/87

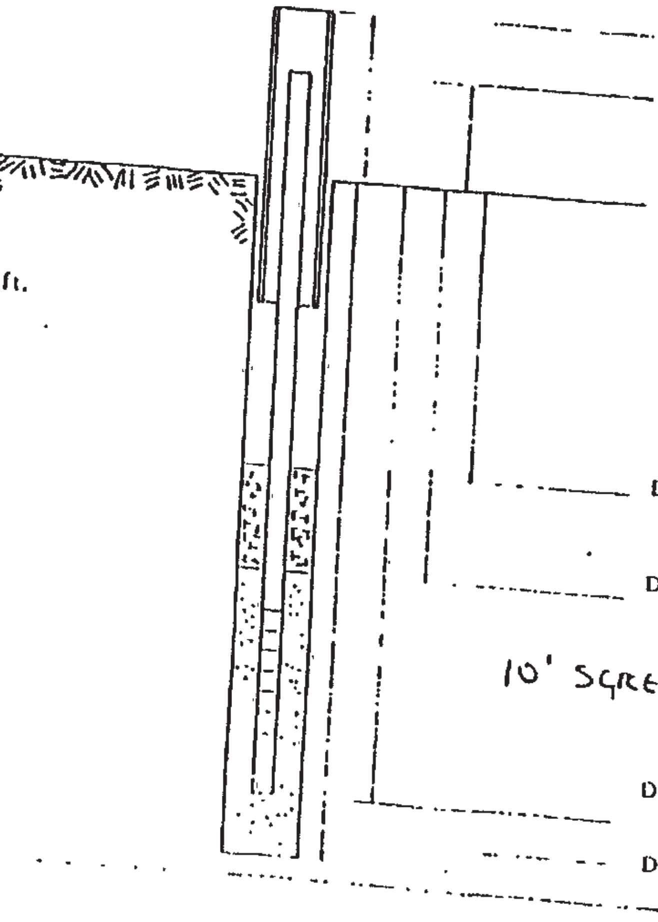
WELL No.
5-WC2-3

Sand Size: D(10)= 0.45-0.55 mm
Bore/ Core Size: 6 inch/ NX

Subsurface Conditions Summary

See 5-WC2-3 for Conditions

Cobbles encountered at 15.0 ft.



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=
Depth to Bentonite (ft.)= -------
Elev. =
Depth to Sand Filter(ft.)= -------
Elev. =
Depth to Well Bottom(ft.)= 53.6 ft.
Elev. = ~~55.3 ft.~~
Depth of Hole (ft.) = 55.3ft
Elev. =

Appendix 8.

Well S5W5 (Compliance Well)

55W5
MW-5

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of MOnitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981 (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81
DATE 5 April 81
LOCATION Site 5, north of lagoon next to building SR 1612
DRILLERS Smithson, Hoddinott Craig, Gates (logger)
DRILL RIG Acker II, w/ 4 in continuous flight auger
BORE HOLE MW 5

ID= 25ft.

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS Water level initial 7' 5" 24 hr. 8' 10"	
		Brown sandy silt with some gravel wet, plastic Perched lense of water	10 ft of Concrete grout	13 ft of schedule 40, 2 in ID PVC casing
5 ft.	MB 5-10 ▼	Yellowish brown silty clay w/ some mica flakes		
10 ft	MB 10-15	same material	Bentonite sand pack	screen
15 ft				

USAEHA Form 95, 12 Aug 74

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site 5, north of lagoon next to building S.R.1612

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight auger

BORE HOLE MW 5

DEPTH	SAMPLE TYPE BLOWS PER 6 IN.	DESCRIPTION	REMARKS
	MB 10-20		10 ft of slotted 2 in ID, schedule 40, PVC screen (0.008-0.01")
20 ft		water at 20 ft yellow coarse medium sand - saturated	
		change in engine pitch Elbrook FM	2 ft of trap
25 ft		TD 25 feet	Depth of well 25 ft
30 ft			

USAEHA Form 95, 12 Aug 74

Appendix 9.

Well S5W7 (Compliance Well)

55W7

MW-7

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site 5, west of lagoon next to building S.R. 1603

DRILLERS Smithson, Boddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight Auger

BORE HOLE MW 7

TD=26 ft

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	water level initial=14'10" 24 hr =10'10" REMARKS	
		Reddish brown silty clay dampmed plastic	Concrete Bentonite 24.5 ft of sand pack	12 ft of schedule 40, 2 in ID PVC casing
5ft	HB 5-10	same material getting damper and more plastic		
10 ft				
15 ft	▼	saturated silty medium coarse sand return on Auger- may have hit a lense of gravel		10 ft of slotted 2 in ID schedule 40 PVC screen

USAEHA Form 95, 12 Aug 74

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site 5, west of lagoon next to building S.R. 1603

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight Auger

BORE HOLE MW 7

DEPTH	SAMPLE TYPE BLOWS PER 6 IN.	DESCRIPTION	REMARKS	
	MB 15-20	same material saturated		screen
20 ft				
				3 ft of sediment trap
25 ft		Elbrook FM (weathered gray clay residuum)		depth of well 26 feet
		26 ft TD		
30 ft				

USAEHA Form 95, 12 Aug 74

Appendix 10.

Well 5W9A (Compliance Well)

W9A
HWMU-5

Form No. 500

ƆORING LOG

FROEHLING & ROBERTSON, INC.
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROM-62085

DATE November, 1985

Client Hercules, Inc.			
Project Monitoring Wells Radford Army Ammunition Plant Radford, Virginia			
Boring No W-9-A	Total Depth 49.0'	Elevation ---	Location See plan
Type of Boring Hollow stem auger	Started 11-6-85	Completed 11-6-85	Driller W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	Asphalt and crushed stone				
	1.5	Loose to medium dense brown fine sandy SILT little clay -ALLUVIUM-	5 7 9 3 8 1	4.5 6.0 8.5 10.0		GROUNDWATER DATA —
	13.0	Soft orange-brown silty CLAY to clayey SILT (CL/ML) Relict structure -RESIDUUM-	2 1 1	13.5 15.0	▽	Water level @ 16.0' Development Data: Sloshed for 2 hrs. Bailed down to 21'. Water level re-established at 16.0' after 1.5 hrs.
	39.0			39.0		Auger refusal @ 39.0'
	40.0					

No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6

Scale 1"=5' unless otherwise noted

Form No. 300

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.

[illegible]

ONE HUNDRED YEARS OF SERVICE

Report No. ROM-62085

DATE November, 1985

Client Hercules, Inc.			
Project Monitoring Wells Radford Army Ammunition Plant Radford, Virginia			
Boring No. W-9-A cont.	Total Depth 49.0'	Elevation ---	Location. See plan
Type of Boring Hollow stem auger	Started 11-6-85	Completed 11-6-85	Driller W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	RQD %	REMARKS
	40.0	Brown fine to medium grained SANDSTONE, changing to blue-gray fractured saccharoidal LIMESTONE and DOLOMITE			20%	0%	GROUNDWATER DATA
				44.0	30%	0%	
	49.0	Coring terminated @ 49.0'		49.0			

- 20' TEFLON SCREEN
- 10' PVC. 80
- ADAPTER
- 25' PVC. 40 (3' CUTOFF)

No. of blows req'd for a 140 lb hammer dropping 30 in to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1"=5' unless otherwise noted

Appendix 11.

Well 5W10A (Compliance Well)

W10A
HWMU-5

Form No. 500

BORING LOG

SINCE 1881

FROEHLING & ROBERTSON, INC.

"ONE HUNDRED YEARS OF SERVICE"

Report No. ROM-62085

DATE November, 1985

Client Hercules, Inc.

Project Monitoring Wells Radford Army Ammunition Plant Radford, Virginia

Boring No. W-10-A Total Depth 45.0' Elevation --- Location See plan

Type of Boring Hollow stem auger Started 11-6-85 Completed 11-6-85 Driller W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	RQD %	REMARKS
	0.0	Brown fine sandy SILT; roots, organics					
	1.0	Loose to medium-dense red brown fine sandy SILT with occasional cobble layers (ML) -ALLUVIUM-					GROUNDWATER DATA
			5 10 10	4.5 6.0			
			7 5 5	8.5 10.0			
			12 11 12	13.5 15.0			Water level @ 14.8'
	17.0	Medium-stiff gray-brown silty CLAY to clayey SILT, shale fragments, relict structure -RESIDUUM-					Development Data: Sloshed for 2 hrs. Bailed down for 1/2 hr. No change in water level.
			3 3 3	18.5 20.0			
			30 *	28.5 30.0	28.5		* 50/0.5'
	30.0	Gray green brecciated LIMESTONE and DOLOMITE, numerous calcite-healed fractures			20%	0%	
				35.0	12%	0%	
	40.0			40.0			

No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1"=5' unless otherwise noted

Form No. 100

ORING LOG

FROEHLING & ROBERTSON, INC.
[illegible]
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROM-62085

DATE November, 1985

Client Hercules, Inc.

Project Monitoring Wells Radford Army Ammunition Plant Radford, Virginia

Boring No. W-10-A cont. Total Depth 45.0' Elevation --- Location See plan

Type of Boring Hollow stem auger Started 11-6-85 Completed 11-6-85 Driller W. Simmons, Sr.

Elevation	Depth 40.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
		Gray sandy LIMESTONE (Calcarenite)			42%	GROUNDWATER DATA 16% —
	45.0	Boring terminated @ 45.0'		45.0		

- 20' TEFLON SCREEN
- 10' PVC·80
- ADAPTER
- 15' PVC·40

No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1" = 5' unless otherwise noted

Appendix 12.

Well 5W11A (Compliance Well)

W11A
HWMU-5

Form No. 500

BORING LOG

FROEHLING & ROBERTSON, INC.
[illegible]
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROH-62085

DATE November, 1985

Client	Hercules, Inc.		
Project	Monitoring Wells Radford Army Ammunition Plant Radford, Virginia		
Boring No.	W-11-A	Total Depth 48.0'	Elevation ---
Location	See plan		
Type of Boring	Hollow stem auger	Started 11-6-85	Completed 11-6-85
Driller	W. Simmons, Sr.		

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	RQD %	REMARKS
	0.0	Brown fine sandy SILT; roots, organics					
	1.0	Medium-dense to dense brown fine sandy SILT to silty fine SAND (ML/SM) -ALLUVIUM-					GROUNDWATER DATA
			9 11 11	4.5 6.0			
			4 9 22	8.5 10.0			
			12 7 11	13.5 15.0			Water level @ 14.8'
	17.0	Very soft yellow-brown coarse to fine sandy CLAY, some silt (CL) relict structure -RESIDUUM-					Development Data: Sloshed 2 hours. Bailed down to 19.0'. Recovered to 14.8' after 1.5 hrs.
			1 1 1	18.5 20.0			
	28.0	Gray-brown vuggy LIMESTONE, calcite healed fractures interbedded with gray-green -FAULT BRECCIA-		28.0 33.0	72%	30%	
				33.0 38.0	33%	7%	
				38.0			
	40.0						

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D. 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1" = 5' unless otherwise noted

Form No. 500

BORING LOG

FROEHLING & ROBERTSON, INC.
[illegible]
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROM-62085

DATE November, 1985

Client	Hercules, Inc.		
Project	Monitoring Wells Radford Army Ammunition Plant Radford, Virginia		
Boring No. W-11-A cont	Total Depth 48.0'	Elevation ---	Location See plan
Type of Boring Hollow stem auger	Started 11-6-85	Completed 11-6-85	Driller W. Simmons, Sr.

Elevation	Depth 40.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	RQD %	REMARKS
		Dark gray saccharoidal LIMESTONE		43.0	23%	0%	GROUNDWATER DATA —
				48.0	53%	0%	
	48.0	Coring terminated @ 48.0'					

- 20' PVC SCREEN
- 30' PVC RISER

---

*No. of blows req'd for a 140 lb hammer dropping 30 in to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 in increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1" = 5' unless otherwise noted

Appendix 13.

Other Wells

Form No. 300

BORING LOG

H.WMU515-WCA

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING, CHEMICA
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. CI-62084

Client Hércules Inc. DATE May 1987

Project Radford Army Ammunition Plant Radford, Virginia

Boring No.: 5-WCA | Total Depth: 40 ft. | Elevation: --------- | Location See Location Plan

Type of Boring Hollow Stem Auger | Started 5/7/87 | Completed 5/11/87 | Driller W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	Very loose gray brown medium to fine sandy SILT, trace coarse subrounded sand (ML)	$^{3}2_{2}$	1.5 3.0		GROUNDWATER DATA
		Very loose gray braown fine sandy SILT (ML) -ALLUVIUM-	$^{2}2_{1}$	4.5 6.0		
			$^{2}2_{4}$	8.5 10.0		
	11.5	Medium stiff gray to tan clayey SILT, manganese stains (ML)	$^{2}3_{4}$	13.5 15.0		
			$^{2}2_{3}$	18.5 20.0		
		Medium stiff to stiff mottled to gray silty fine SAND (SM) manganese stains -grading to-	$^{2}3_{6}$	23.5 25.0		
		Stiff mottled to gray silty CLAY/clayey SILT (CL/ML) -RESIDUUM-	$^{3}5_{7}$	28.5 30.0		
			$^{3}5_{9}$	33.5 35.0		
	40.0	Boring terminated at 40.0 ft.	$^{W}{}_{H}$	38.5 40.0		*Weight of Hammer

No. of blows req'd. for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N

Scale 1"=5' unless otherwise noted

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

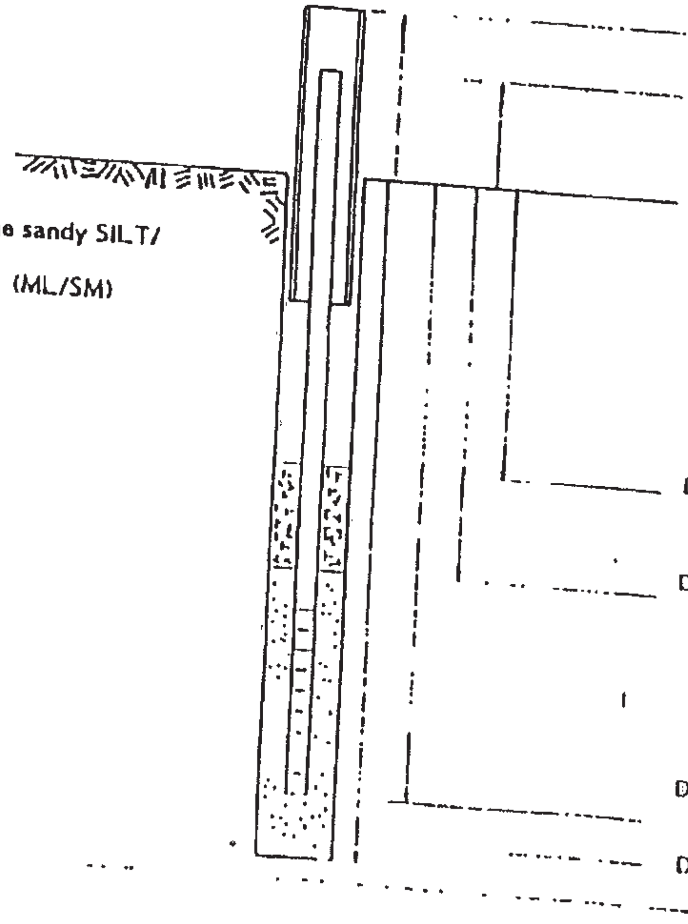
Driller: Simmons
Inspector: Smith
Date Installed: 5/11/87

WELL No.
S-WCA

Sand Size: D(10)= 0.45-0.55 mm
Bore/ Core Size: 6 inch/ NX

Subsurface Conditions Summary

Gray Brown medium to fine sandy SILT/
silty medium to fine SAND (ML/SM)



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=

Depth to Bentonite (ft.)= 4.0 ft.
Elev. =
Depth to Sand Filter(ft.)= 25.8 ft.
Elev. =

Depth to Well Bottom(ft.)= 37.1 ft.
Elev. =
Depth of Hole (ft.) = 40.0 ft.
Elev. =

55W6
MW-6

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site ~~6~~ 5, northwest of lagoon next to building S.R. 1602

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II w/ 4 in continuous flight auger

BORE HOLE MW ~~5~~ 6

TD= 25.5 ft

DEPTH	SAMPLE TYPE / BLOWS PER 6 IN.	DESCRIPTION	Water level initial 9.5 ft 24 hr. 9' 7" REMARKS	
		Brown silty clay, damp plastic	7 ft of concrete grout	13.5 ft of schedule 40, 2 in ID PVC casing
5 ft	MB 5-10	Reddish brown silty clay--slightly damp, tight drilling	4.5 ft of Bentonite (may have a void above sand next to water table)	
10 ft	▼	softer drilling, same material, getter wetter saturated	11.5 ft of sand pack	
15 ft				screen

HSE-ES Form 78, 1 Jun 80
Replaces USAEHA Form 95, 12 Aug 74, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981 (USAEHA Control No. 81-26-8251-81)

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site 5, northeast of lagoon next to building S.R. 1602

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight Auger

BORE HOLE MW 6

DEPTH	SAMPLE TYPE BLOWS PER 6 IN.	DESCRIPTION	REMARKS	
		Reddish brown silty coarse to medium sand, saturated (water is flowing)	Sand pack	10 ft of slotted schedule 40, 2 in ID PVC screen (0.008-0.010")
20 ft		Weathered Elbrook FM (red gray clay residuum over dolomite)		
				2 ft of sediment trap
25 ft				
		25.5 ft TD		Bottom of well 25.5 ft
30 ft				

USAEHA Form 95, 12 Aug 74

S5W8
MW-8

Army Pollution Abatement Program Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81
DATE 5 April 81
LOCATION Site 5, Background well, south of lagoon
DRILLERS Smithson Hoddinott Craig, Gates (logger)
DRILL RIG Acker II, w/ 4 in continuous flight Auger
BORE HOLE MW 8
TD= 34ft

DEPTH	SAMPLE TYPE / BLOWS PER 6 IN.	DESCRIPTION	water level initial=24 ft 24 hr.=14'11" REMARKS	
		gravel fill for road		
		Reddish brown sandy clay with some small gravels	8 ft of concrete grout	29 ft of schedule 40, 2 in ID PVC casing
5 ft				
		same material, wet, med plastic	5 ft of Bentonite	
10 ft				
		same material, getting wetter & sticky	sand pack	
15 ft				

HSE-ES Form 78, 1 Jun 80
Replaces USAEHA Form 95, 12 Aug 74, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81

DATE 5 April 81

LOCATION Site 5, background south of lagoon

DRILLERS Smithson, Hoddinott Craig, Gates (logger)

DRILL RIG Acker II, w/ 4 in continuous flight Auger

BORE HOLE MW 8

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
	MB 15-20	same material	21 ft of sandpack	PVC casing
20 ft				
	▼	same material		
25 ft				
30 ft				

HSE-ES Form 78, 1 Jun 80

Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Army Pollution Abatement Program Study, Installation of MOnitoring Wells, Radford Army Ammunition Plant, Radford, VA, 3-9 April 1981, (USAEHA Control No. 81-26-8251-81)

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

PROJECT RAAP 81-26-8251-81
DATE 5 Apr 81
LOCATION Site 5, background south of lagoon
DRILLERS Smithson, Hoddinott Craig, Gates (logger)
DRILL RIG Acker II. w/ 4 in continuous flight Auger
BORE HOLE MW 8

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS	
		same material		5 ft of slotted schedule 40, 2 in ID PVC screen
35 ft		Refusal Elbrook FM Note: ran short of screen, therefore, 5 ft of screen was installed in the saturated zone instead of 10 feet.	bottom of well 34 ft.	
40 ft				

HSE-ES Form 78, 1 Jun 80
Replaces USAEHA Form 95, 12 Aug 74, which will be used.

Form No. 300

BORING LOG

HWMU5\5-WC1-1

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING • CHEMICA
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. Q-62084

Client: Hercules Inc. DATE May 1987

Project: Radford Army Ammunition Plant Radford, Virginia

Boring No. 5-WC1-1 Total Depth 53.5 ft. Elevation --------

Type of Boring: Hollow Stem Auger Started: 5/5/87 Completed: 5/5/87 Location: See Location Plan

Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	40.0					GROUNDWATER DATA
		5-WC1-1 continued			45.0	RQD = 23
				43.5		
					36.7	RQD = 7
				48.5		
					61.7	RQD = 0
	53.5	Boring terminated at 53.5 ft.		53.5		

No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 300

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING/CHEMIC
"ONE HUNDRED YEARS OF SERVICE"

Report No. 07-62084

Client	Hercules Inc.			DATE	May 1987
Project	Radford Army Ammunition Plant		Radford, Virginia		
Boring No.	5-WC1-1	Total Depth: 53.5 ft.	Elevation	---------	Location: See Location Plan
Type of Boring	Hollow Stem Auger	Started: 5/5/87	Completed: 5/5/87		Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	No sampling conducted, see 5-WC1-2 for subsurface conditions				GROUNDWATER DATA
		Cobbles encountered at 13.0 ft. and 17.0 ft.				
	33.5	Auger refusal at 33.5 ft. Hard light gray dolomite, fractured and vuggy abundant calcareous infill, occasional shale infill: dolomite clasts in calcareous matrix: Probable slump structure	33.5 38.5	21 7		RQD - 0

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

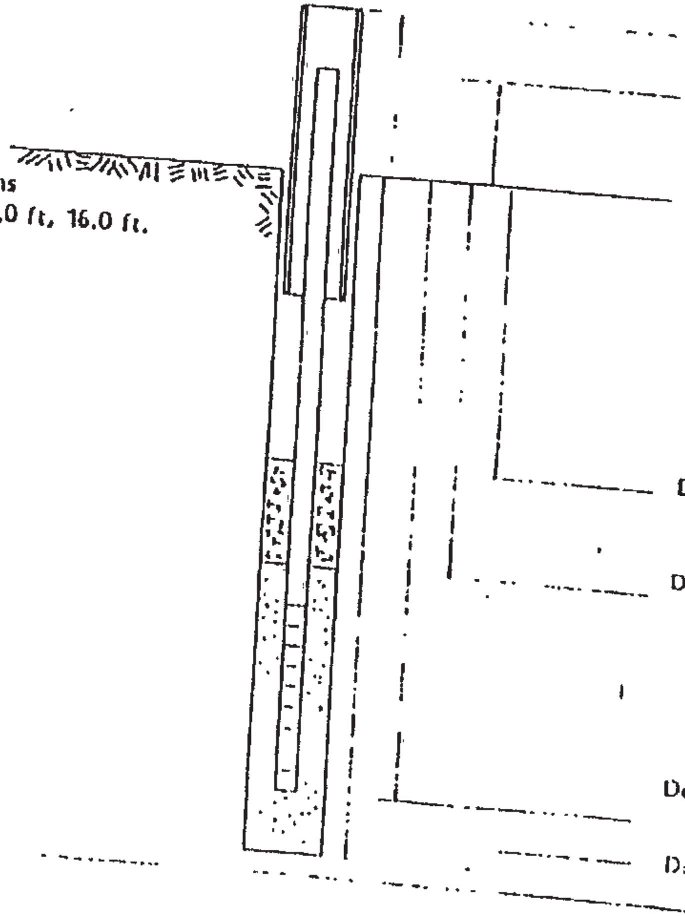
Scale 1"=5' unless otherwise no

HWMU 5 5WC1-1

Project: Radford Army Ammunition Plant		
Location: Radford, Virginia		
Client: Hercules Inc.	Driller: Simmons	WELL No.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen (10')	Inspector: Smith	5-WC1-1
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser	Date Installed: 5/5/87	
	Sand Size: D(10)= 0.45-0.55 mm	
	Bore/ Core Size: 6 Inch/ NX	

Subsurface Conditions Summary

See 5-WC1-2 for Conditions
Cobbles encountered at; 13.0 ft, 16.0 ft.



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=
Depth to Bentonite (ft.)= ---------
Elev. =
Depth to Sand Filter(ft.)= ---------
Elev. =
Depth to Well Bottom(ft.)= 49.3 ft.
Elev. =
Depth of Hole (ft.) = 53.5 ft.
Elev. =

Form No. 100

BORING LOG

HWMU 5\5-WC1-2

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICA
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. 01-62084

Client: Hercules Inc. DATE May 1987

Project: Radford Army Ammunition Plant Radford, Virginia

Boring No.: 5-WC1-2 | Total Depth: 76.8 ft. | Elevation: --------- | Location: See Location Plan

Type of Boring: Hollow Stem Auger | Started: 5/1/87 | Completed: 5/1/87 | Driller: W. Simmons

Elevation	Depth 0.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
		Very loose yellow brown silty medium to fine SAND (SM) -to- Loose tan to red brown clayey medium to fine SAND, trace rounded coarse sand (SC) -ALLUVIUM-				GROUNDWATER DATA
			1 1 1	4.5 6.0		
			2 2 7	8.5 10.0		
			11 13 16	13.5 15.0		
	16.5	Loose orange brown medium to fine sandy SILT, trace angular coarse sand (rock fragments), manganese stains (ML) -to- Medium stiff orange brown clayey SILT, little medium to fine sand (rock fragments) (ML/MH) -RESIDUUM-				
			6 7 3	18.5 20.0		
			2 1 3	23.5 25.0		
			1 5 4	28.5 30.0		
			1 1 2	33.5 35.0		Subsurface water at 34.5 ft. depth at 11:30 a.m. on May 1, 1987
	39.3	Auger refusal at 39.3 ft.		39.3		

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 300

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING • CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. 0-62084

Client Hercules Inc.			DATE May 1987
Project Radford Army Ammunition Plant		Radford, Virginia	
Boring No. S-WC1-2	Total Depth: 76.8 ft.	Elevation: --------	Location See Location Plan
Type of Boring Hollow Stem Auger	Started: 5/1/87	Completed 5/1/87	Driller V. Simmons

Elevation	Depth (ft.)	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
		Hard light gray dolomite, vuggy, fractured, with calcareous infilling, some with moderately developed crystals, occasional shale infill: occasional dolomite clasts in a calcareous matrix: probable flow structure		44.3	35.8	GROUNDWATER DATA RQD = 0
				49.3	46.7	RQD = 7
				54.8	34.9	RQD = 0
				59.8	33.3	RQD = 0
				64.8	25.8	RQD - 0
				69.8	19.2	RQD = 0
				74.8	88.3	RQD = 10
	76.8			75.8	33.3	RQD = 0
		Boring terminated at 76.8 ft.				

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: Simmons
Inspector: Smith
Date Installed: 5/1/87

WELL No.
5-WC1-2

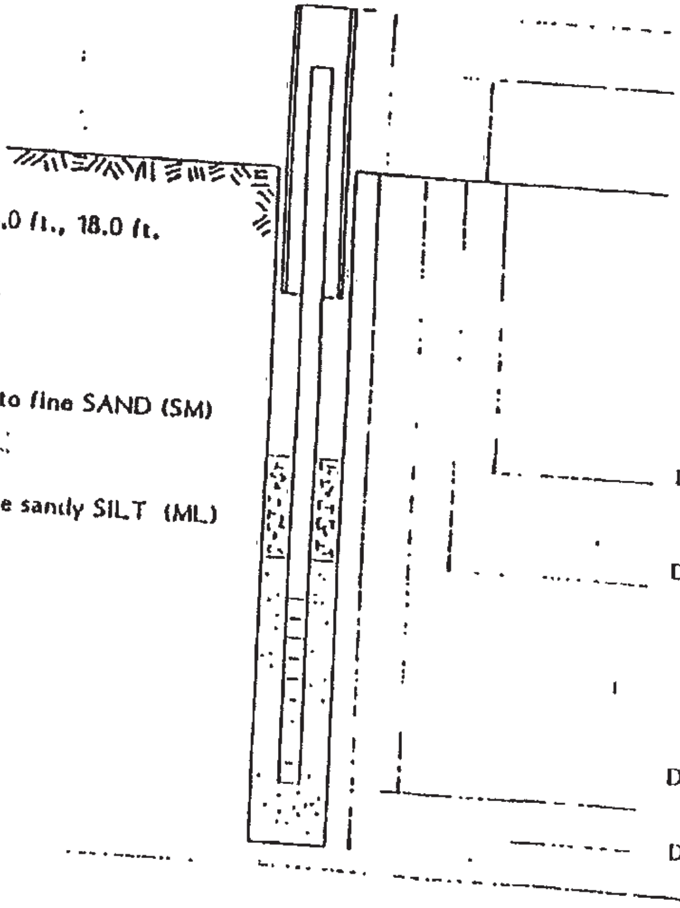
Sand Size: D(10)= 0.45-0.55 mm
Bore/ Core Size: 6 inch/ NX

Subsurface Conditions Summary

Cobbles encountered at; 15.0 ft., 18.0 ft.

Subsurface water at 34.5 ft.

Yellow Brown silty medium to fine SAND (SM)
to
Orange Brown medium to fine sandy SILT (ML)



Casing Stickup (ft.)= 3.0 ft.
Elev. =
Riser Stickup (ft.) = 3.0 ft.
Elev. =
Ground Elev.=
Depth to Bentonite (ft.)= --------
Elev. =
Depth to Sand Filter(ft.)= --------
Elev. =
Depth to Well Bottom(ft.)= 72.8 ft.
Elev. =
Depth of Hole (ft.) = 76.8 ft.
Elev. =

Appendix I- CORRECTIVE ACTION PLAN FOR HAZARDOUS WASTE MANAGEMENT UNIT 5

Final

Corrective Action Plan for Hazardous Waste Management Unit 5 (RAAP-042)

Radford Army Ammunition Plant

Radford, Virginia

April 2009

Corrective Action Plan for Hazardous Waste Management Unit 5 (RAAP-042)

Radford Army Ammunition Plant

Prepared for

Radford Army Ammunition Plant

Prepared by

ARCADIS
1114 Benfield Boulevard
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Tel 410 987 0032
Fax 410 987 4392

Our Ref

GP08RAAP

Date

April 2009

Tables

Figures

Appendices

Acronyms and Abbreviations

Bgs	below Ground Surface
CAP	Corrective Action Plan
CSM	Conceptual Site Model
ft	feet
FID	flame-ionization detector
GPS	Groundwater Protection Standard(s)
IDM	investigation derived material
µg/L	micrograms per Liter
mg/L	milligrams per Liter
mg/Kg	milligrams per Kilogram
MMA	Main Manufacturing Area
MNA	monitored natural attenuation
O&M	Operation and Maintenance
PID	pnoto-ionization detector
QA/QC	Quality assurance/quality control
QAPA	Quality Assurance Plan Addendum
RAB	restoration advisory board
RCRA	Resource Conservation and Recovery Act
RFAAP	Radford Army Ammunition Plant
RSLs	Regional Screening Levels
SBA	South Bank Area
TCE	trichloroethene
USEPA	United States Environmental Protection Agency
VADEQ	Virginia Department of Environmental Quality
VOCs	volatile organic compounds

1. Introduction

This Corrective Action Plan (CAP) for RAAP-042, Hazardous Waste Management Unit 5 (Unit 5), has been completed in support of the Hazardous Waste Management Post Closure Care Permit for the Radford Army Ammunition Plant (RFAAP), located in Radford, Virginia This CAP addresses concentrations of trichloroethene (TCE) detected in shallow overburden groundwater adjacent to Unit 5

1.1 Setting

RFAAP is located along the New River, at the Montgomery-Dublin County line near Radford, Virginia The location is shown on Figure 1 The Main Manufacturing Area (MMA) is composed of two sections, 1) The Horseshoe Area, contained within a loop of the New River and 2) the South Bank Area (SBA) Unit 5 is located in the SBA The Unit, Compliance Monitoring Wells and Piezometers are shown on Figure 2

1.2 Objective

This CAP presents data to support monitored natural attenuation (MNA) as a protective and technically appropriate remedial approach to address a small dilute TCE plume that has been delineated in Unit 5 groundwater The CAP also summarizes a two-phase subsurface investigation conducted in the vicinity of Unit 5 in 2008 The history of Unit 5 is discussed within the Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Post Closure Care Permit (the Permit), to which this document is included as Attachment 2, Appendix I The data and analysis provided in this document provide supporting detail for information already presented in the Permit

2. Background

2.1 History

Unit 5 is a former lined acid neutralization surface impoundment located in an open area of the SBA immediately downhill from an area of manufacturing facilities The Unit was operated as an unlined impoundment from 1970 to 1981, when it was retrofitted with a Hypalon™ liner The unit was taken out of operation in 1986 and was closed in 1989 Closure included stabilization of the waste material and capping with an impervious PVC liner

TCE has been historically detected at concentrations greater than the Groundwater Protection Standard (GPS) at four network monitoring wells located within 150 ft downgradient of Unit 5 5WC21, 5WC22, 5WC23 and 5W5B Detections of TCE have occurred consistently in the wells since 1996, however, the concentration in only one well (5W5B) was greater than the GPS in the most recent round of sampling (8 9

micrograms per Liter [µg/L] in December 2007)

2.2 Previous Investigations

Two previous subsurface investigations were conducted at Unit 5 in October 2002 (Alliant Ammunition and Powder Co , 2003) and February 2004 (Draper Aden, 2007) These investigations included soil and groundwater sampling beneath and in the vicinity of Unit 5 Results were generally consistent with the findings of the current investigation Results of the previous investigations are provided, as appropriate, in this document

2.3 Conceptual Site Model

The Conceptual Site Model (CSM) developed for Unit 5 and presented herein is based on stratrographic data gathered during the two previous investigations and the recent investigation conducted to characterize the contents of Unit 5 and to evaluate possible sources of the TCE in groundwater The TCE data were used in conjunction with other installation wide data to compile the CSM as it is presented in the permit The vicinity of Unit 5 is underlain by unconsolidated materials that range in depth from 40 to 50 feet below ground surface (bgs) The geologic setting is illustrated conceptually in Figure 3 These materials consist of alluvial terrace deposits and overlying residuum The alluvial terrace deposits consist predominantly of clay and silt, with sporadic basal deposits of river jack (rounded cobbles embedded in a fine-grained matrix) The residuum consists of the insoluble weathering products of the underlying dolomite, predominantly interbedded fine sand, silt and clay Beneath the unconsolidated materials lies competent dolomite of the Elbrook Formation

A profile of Unit 5 is shown on Cross Section A-A' (Figure 4) The Hypalon™ underliner at the bottom of the former impoundment is estimated to be at or near the predevelopment grade The total thickness of the Unit, including the PVC liner and clay cap is approximately 10 feet

Groundwater flow in the unconsolidated materials is from southwest to northeast, ultimately discharging to the New River approximately 3,000 feet downgradient The overburden groundwater system forms a discrete aquifer, and is inferred not to be significantly influenced by the bedrock aquifer Concentrations decline with depth and as such there is no evidence suggesting that TCE has migrated into bedrock

Quarterly monitoring data from 1996 to 2007 (Appendix A, Table A-1) consistently show that groundwater upgradient of Unit 5 does not contain detectable concentrations of TCE or its daughter products However, TCE, but not its daughter products, has been detected in shallow groundwater downgradient of Unit 5 at concentrations up to 26 µg/L, the historical maximum concentration (observed in 2003 at well 5WC21)

In the more than 12 years of quarterly groundwater monitoring, repeated TCE concentrations greater than the 5 µg/L GPS are limited to four wells 5W5B, approximately 80 ft downgradient of Unit 5, and 5WC21, 5WC22 and 5WC23, a well cluster located approximately 140 feet downgradient of Unit 5 Concentration trends show that an irregular pulse of TCE moved past well 5W5B between 1998 and 2001 The pulse appeared at well 5WC21 approximately 4 years later (from 2001 to 2005)

An average solute transport velocity of approximately 15 feet per year was estimated by evaluating the elapsed time between breakthrough peaks observed at wells 5W5B and 5WC21 The timing of the origin of the pulse coincides with closure of the Unit in 1989 (based on an origin in the southeast interior of the Unit) The pulse arrivals reflect a travel time of approximately 10 years to 5W5B and 15 years to the 5WC21

TCE concentrations documented in groundwater during the 2007 fieldwork reported herein at the four monitoring wells immediately downgradient of Unit 5 are between 2 5 µg/L to 8 9 µg/L (Figure 6) Based on these data, the current area of TCE levels greater than the 5 µg/L GPS is approximately 160 feet long and 40 feet wide

3. Scope of Recent Investigations

ARCADIS completed a thorough subsurface investigation in two phases the first, completed May 5 through 10, 2008 and the second June 18 through July 1, 2008 As described in Work Plan Addendum 25 (dated May 2008), the investigation was modeled on the United States Environmental Protection Agency's (USEPA's) interactive triad approach (USEPA, 2004), and therefore utilized adaptive field techniques each building upon the others to comprehensively define site conditions for the investigated area In keeping with the Triad approach, the scope of work for Phase 2 was finalized following completion of Phase 1, with regulatory concurrence provided by the appropriate VADEQ and USEPA personnel (Decision Point 1 Meeting June 17, 2008) The scope of both phases of investigations are described in the

following sections

3.1 Phase 1 – Direct Push Soil and Groundwater Sampling

Direct push soil borings were completed at seven locations east of Unit 5 Four locations, 5DitchGP01 through 5DitchGP04, were completed as a transect along the axis of a northwest trending ditch running from the vicinity of Building 1549 towards Unit 5, with borings spaced approximately 80 feet apart An additional three borings were completed east of Unit 5 borings 5GP-12A, 5GP-25, and 5GP-26 Boring locations are shown on Figure 5 At each location, the following activities were performed

- Continuous soil samples were collected and logged by a geologist Sample/boring logs are provided in Appendix A
- Groundwater samples were collected from just beneath the water table, and analyzed for volatile organic compounds (VOCs)
- Soil samples were collected at each boring and held pending groundwater analytical results Five of seven soil samples were analyzed for VOCs to confirm VOC results in groundwater samples

Table 1 summarizes the depth and sample intervals of the borings completed near Unit 5 during Phase I

3.2 Phase 2 – Vertical Aquifer Profiling

The second phase of field investigations consisted of additional direct-push soil and groundwater sampling Where possible, borings were advanced to the top of rock (15 to 45 ft bgs), and multiple groundwater samples were collected across the saturated overburden to vertically profile groundwater quality This second phase included three borings advanced directly adjacent to Unit 5 (5GP27, 5GP28 and 5GP34) and five borings completed on a transect in the road immediately south of Unit 5 (borings 5GP29 through 5GP33) Boring locations are shown on Figure 6

The following activities were performed at each location

- Continuous soil samples were collected and logged by a geologist Sample/boring logs are provided in Appendix A
- Groundwater samples were collected from just beneath the water table and, where feasible, approximately every 10 feet vertically to refusal At three of the eight locations, only one vertical interval was sampled due to shallow refusal Samples were analyzed for VOCs

At a subset of boring locations (5), the shallowest groundwater sample intervals were collected by setting temporary 1-inch PVC monitoring wells At these locations, groundwater levels were allowed to equilibrate so that an approximate water-table depth could be determined

Table 2 summarizes the depth and sample intervals of the borings completed near Unit 5 during Phase 2

4. Field Methods

Field tasks were completed in accordance with the RFAAP Master Work Plan (URS, 2003), and Work Plan Addendum 25 (ARCADIS, 2008) The tasks are described in more detail below

4.1 Utility Clearance

Prior to each boring program, a utility mark out was completed by Mid Atlantic Utility Locators using industry standard equipment and a facility utility map An ARCADIS representative escorted the subcontractor to the proposed work areas and provided oversight during their activities

4.2 Direct Push Borings

In both phases of work, direct-push drilling was completed by Columbia Technologies During Phase 1, continuous soil samples were collected using a Macrocore™ sampler, hammered by a track-rig Geoprobe™ The second phase of work completed soil sampling using a combination of Geoprobe sample tools, including Macrocores, dual-tube samplers, and stop-pin discrete interval samplers By all methods, undisturbed soil samples for lithologic characterization and laboratory analyses were obtained in dedicated, disposable Lexan™ liners Soil samples were field screened for the presence of VOCs using a photo-ionization detector (PID) In the second phase of work, the screening with the PID was supplemented with a flame-ionization detector (FID), because of its higher sensitivity to chlorinated VOCs

All borings were abandoned using bentonite chips Investigation derived material (IDM) wastes including soil cuttings, decontamination water, sample liners, and other disposable sampling equipment were contained in drums that were stored in a 90 day (maximum) storage area pending transport to an approved offsite treatment and disposal facility

4.3 Grab Groundwater Sampling and Vertical Aquifer Profiling

Grab groundwater samples were obtained from the direct push borings by two methods

- Hydropunch™ sampling devices By this method, a sealed sampler is advanced by the Geoprobe rig across the target interval through undisturbed soil By pulling back the tools, the sampling device opens exposing a 3 or 4 foot stainless steel well screen After allowing time for groundwater to enter the well and equilibrate, sampling may be conducted using a peristaltic or inertial pump

- Temporary well points For sampling locations at the top of the water table (e g , where vertical isolation of the sample interval is not required), samples could be collected by removing the Geoprobe tools and installing a temporary, dedicated 1-inch diameter PVC well, with a 5-foot screened section Temporary well points were used particularly at locations where aquifer yield was low, and significant time was required for water to enter the well and equilibrate Samples were collected via a peristaltic or inertial pump

Selection of groundwater sample intervals was made by the field geologist, biased to intercept zones of higher permeability For vertical aquifer profile borings, interval selection was also biased to collect representative samples of all discrete hydrostratigraphic intervals encountered

Temporary well points and hydropunch samplers were purged prior to sampling

Where feasible, the groundwater quality parameters pH, temperature, conductivity and turbidity were evaluated using a field meter prior to sampling All purge water generated via sampling was contained in drums that were stored in a 90 day (maximum) storage area pending transport to an approved offsite treatment and disposal facility

4.4 QA/QC

Quality assurance/quality control (QA/QC) samples were collected at the frequency prescribed by the Quality Assurance Plan Addendum (QAPA) All samples were analyzed by Empirical Laboratory, Knoxville, TN QA/QC samples included field duplicates, field blanks, and trip blanks Data was validated and found to be usable in all cases The laboratory analytical reports and associated data validation reports are provided as Appendix B

5. Results

A total of 6 soil and 18 groundwater samples were collected during the two phases of field investigation in 2008 for analysis of VOCs Summaries of detected constituents in soil and groundwater are provided in Tables 2 and 3, respectively Figure 5 depicts TCE concentrations detected in soil and includes the results of previous investigations (Alliant, 2003) Figure 6 depicts TCE concentrations detected in groundwater and also integrates results from previous investigations (Draper-Aden, 2007, and 2008)

5.1 Soil

Neither TCE nor any other analytes were detected in soil in excess of their industrial Regional Screening Level (RSL) (USEPA, 2008) However, TCE was detected in saturated soil samples from two borings located on the northeast perimeter of Unit 5 (5GP-12A and 5GP-28) Both samples were collected beneath the water table at a depth of 23 to 24 ft and 27 to 28 ft, respectively TCE concentrations in the 23 to 24 foot sample were 0 0019 milligrams per Kilogram (mg/kg) and were 0 0057 mg/kg in the 27 to 28 ft sample relative to a residential soil RSL of 2 8 mg/kg The soil analytical results for the samples collected show decreasing TCE concentrations with depth Previous investigations (Draper-Aden, 2007) also reported TCE detections in saturated soil along the eastern edge of Unit 5 at a depth of 14 feet bgs and a concentration range of 0 011 to 0 120 mg/kg The presence of TCE in saturated soils is consistent with the presence of TCE in groundwater in the same vicinity

5.2 Groundwater

Groundwater monitoring has been ongoing since 1996 at Unit 5 and these data have been previously reported to the USEPA and VADEQ Long term data trends are provided as Figures A-1 through A-4 of Appendix A The results of the work reported herein are generally consistent with the long-term groundwater monitoring, and have also been used to determine the extent of the TCE plume in the vicinity of Unit 5

TCE was detected in groundwater samples at 6 of the 18 boring locations all of which were located east and northeast of the Unit 5 Concentrations of TCE were greater than the GPS (5 µg/L) at just one location, 5GP-28 TCE concentrations in groundwater samples collected from two intervals at 5GP-28 (27 to 30 ft, and 36 5 to 39 5 ft) were both greater than the GPS, at 11 and 5 7 µg/L, respectively TCE concentrations in the remaining five direct push borings ranged from non-detect to 11µg/L and defined the vertical and horizontal extent of the TCE in groundwater northeast of the Unit

TCE was also detected in one of the permanent monitoring wells (5W5B) above the GPS at a concentration of 8 9 µg/L in December 2007 Concentrations in the remaining wells ranged between 2 3 µg/L to 3 4 µg/L There was no evidence of TCE in any of the vertical aquifer profile samples collected upgradient of Unit 5 (Figure 6) No reductive dechlorination daughter products of TCE (cis-1,2 dichloroethene and vinyl chloride) were detected

6. Nature and Extent of Plume

Recent and historical analytical results indicate that TCE is present within saturated soils just beneath Unit 5 at one location, and at two locations under the access road located to the northeast of Unit 5 (Figure 5) The highest concentration of TCE detected in soil was 120 µg/kg, collected beneath Unit 5 at a depth of 14 ft bgs at boring 5GP-21

The current horizontal extent of the TCE plume in groundwater above the GPS of 5 µg/L is approximately 160 feet long and 40 feet wide (Figure 6) The maximum detection of TCE in 2008 was 11 µg/L TCE has not been detected in the Plume

Monitoring Wells located 500 ft to 700 ft downgradient of the Unit since 1999, and prior 1999 only very low level and sporadic detects were noted in these wells Though historically TCE concentrations at wells 5WC21, 5WC22, and 5WC23 were slightly greater than the GPS, however the 2007 data suggests that the downgradient extent of the plume has dissipated

Vertically oriented samples have been collected in the vicinity of Unit 5 and TCE concentrations have been documented to decrease with depth in the surficial aquifer, which extends to an approximate depth of 50 feet below ground surface The TCE plume is limited in vertical extent to shallow groundwater in the interbedded zone Concentrations of TCE in groundwater were observed to decrease with depth at each Vertical Aquifer Profile sample location where TCE was detected (Table 3 & Appendix A) This decreasing trend trends is also apparent at the 5WC2 well cluster, where the shallowest well, 5WC21, has historically had higher concentrations than the adjacent deeper wells These data illustrate the limited vertical extent of the plume

Figure A-5 (Appendix A) depicts the relationship between aqueous TCE concentrations and downgradient (northeast) distance from Unit 5 for both the most recent groundwater data set and the previous eight quarters These data clearly indicate a stable relationship and decreasing concentration trend with distance from Unit 5 TCE concentrations are less than the GPS approximately 160 feet from the location of the initial detection (GP-021) below Unit 5 The relationship between distance and concentration, as shown by the trend line on Figure A-5, suggests that the concentrations in the range of the TCE GPS could be expected at a distance of 175 to 225 feet from Unit 5 Because of the distance between the current extent of the TCE plume and the location of the existing downgradient Plume Monitoring Wells (S5W5, S5W7, 5W9A, 5W10A and 5W11A), a more proximal downgradient Plume Monitoring Well would enhance the level of confidence in the continued definition of the plume extent As discussed in Module VI of the Class 3 Permit Modification, and in Section 7, below, a replacement Plume Monitoring Well is proposed approximately 200 ft downgradient (northeast) of Point of Compliance Well 5WC21 (Figure 2) This well will enhance the level of confidence in the limits of the plume extent and is recommended within Module VI of the Class 3 Permit Modification

7. Recommended Corrective Action

At Unit 5, a well defined stable or decreasing plume has been identified The current maximum TCE concentration in groundwater is 11 µg/L, and extends downgradient less than 200 feet from the Unit As stated in Section 2 3, the average solute transport velocity has been estimated at less than 15 feet per year The TCE source has been remediated (through capping) and no receptors are being affected As such, MNA is recommended as the remedy for Unit 5 groundwater Natural attenuation is defined as "naturally occurring processes in the environment that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (USEPA, 2000) These natural processes include dispersion and diffusion, which may be the primary mechanisms at this site The site conditions at Unit 5 are conducive to and align closely with the governing principles of selecting MNA as a remedial strategy

7.1 Basis for MNA recommendation

The principal data objectives for selecting MNA are reviewed below

1 Affected media/phases of constituents are known

TCE at Unit 5 is present in the dissolved-phase in groundwater and likely sorbed to soils The presence of separate phase product is not supported directly or implicitly by the data and the plume area is well defined

2 Concentration levels are not significantly greater than the GPS

The current maximum TCE concentration observed in groundwater near Unit 5 is 11 µg/L relative to a GPS of 5 µg/L The maximum TCE concentration currently observed in the permanent groundwater monitoring network is 8 9 µg/L, at well 5W5B Currently, concentrations at no other permanent monitoring locations are greater than the GPS Groundwater concentrations at two of the four affected wells (5WC22 and 5WC23) have been less than the GPS for least eight quarters and concentrations at all four affected wells have exhibited decreasing trends over the past 10 quarterly events The historical maximum concentration is 26 µg/L

3 Delineation of plume extent

As indicated in Section 6 of this report, the extent of the TCE plume is fully

delineated The plume (Figure 6) is approximately 40 feet wide and extends from the east side of Unit 5 approximately 160 feet toward the northeast TCE has not been detected above the laboratory detection limit in any downgradient Plume Monitoring Well since 1999 The vertical extent of the plume is delineated The presence of TCE in groundwater at concentrations greater than the GPS is limited to the interbedded soil zone, at depths ranging from approximately 15 to 50 feet bgs TCE concentrations in groundwater at depths greater than 40 feet bgs are less than the GPS In addition, concentrations of TCE in groundwater decrease with depth

4 Groundwater data show natural attenuation is occurring

Concentrations of TCE at all locations are below their historical maximums, and show clear downward trends (Figures A1-A4) The TCE concentration at well 5W5B is currently 8 9 µg/L, down from a maximum concentration of 20 5 µg/L in 1999 Farther downgradient, TCE concentrations at the wells of the 5WC21, 5WC22, and 5WC23 cluster are each now between 2 5 and 3 5 µg/L, down from their historical maximum of 26 µg/L (at 5WC21) in 2003

The Mann-Kendall and Senn-slope statistical tests were performed on the historical data sets for each of the affected wells These analyses indicate statistically significant decreasing trends over the last 10 quarters at each of the four Point of Compliance Wells exhibiting detections (Appendix A, Figures A-1 through A-4) The confidence levels in these trends are greater than 95% for all four data sets This is of particular significance because while the individual wells have each historically demonstrated decreasing trends from time to time, in no other period have all affected wells demonstrated a contemporaneous decreasing trend

Additionally a spatial analysis was conducted for the most recent data set to verify the plume stability and attenuation of dissolved phase concentrations with distance from Unit 5 Figure A-5 (Appendix A) provides this summary plot clearly demonstrating the decreasing TCE concentrations with distance from Unit 5 Additionally, for reference, the prior eight quarters of data are shown for wells 5W5B and 5WC21 These data indicate that a stable relationship exists between these wells and that concentrations have been declining with both time and distance

Because detectable concentrations of TCE daughter products are not present

(Draper Aden, 2008), reductive dechlorination is not held to be the dominant attenuation process Observed decreasing groundwater trends are inferred to reflect diminishing source concentrations, dispersion and diffusion

5 Temporal variability is understood

Groundwater flow direction does not change significantly throughout the period of record A consistent northeastward flow direction from Unit 5 is consistent the narrow dimension of the plume A review of historical data indicates that seasonal variations in precipitation and recharge may cause minor TCE concentration fluctuations

6 No potential receptors

The TCE is contained within the area of the Unit and is not affecting either surface water receptors or drinking water sources

7 Source remediation

The Unit has been closed under RCRA in 1989 and is lined, stabilized, and has an impermeable cover system

7 2 CAP Implementation

Implementation of MNA for TCE in groundwater at Unit 5 would include several components detailed in Permit Module VI The components are as follows

- VADEQ approval of this CAP and the Permit Amendment
- Installation of a Plume Monitoring Well (5W12A) to replace the existing downgradient Plume Monitoring Wells S5W5, S5W7, 5W9A, 5W10A and 5W11A

as shown on Figure 2 This new well will be located approximately 200 feet downgradient of Point of Compliance Well 5WC21 and screened at approximately the same interval targeted by well 5WC21 and hydropunch location GP025 (20 to 30 bgs, contingent upon field conditions) The proposed location of the new Plume Monitoring Well will monitor the plume extent and stability more effectively than the current, more distal Compliance Monitoring Program Plume Monitoring Wells The existing Plume Monitoring Wells, S5W5, S5W7, 5W9A, 5W10A and 5W11A, have not exhibited detections since 1999 and are located either side gradient or are too distant (500-700 feet downgradient) to effectively monitor the present extent of the plume Because of the nature and extent of the plume are clearly defined, a single, more proximal Plume Monitoring Well will provide better surety of plume control than a disperse and distal monitoring network The existing wells will be retained as piezometers to monitor the slope and direction of the hydraulic gradient downgradient of the Unit

- A schedule for groundwater monitoring to verify MNA effectiveness and plume stability The site is presently monitored under the RCRA Post Closure Care Permit Appendix J summarizes the proposed Corrective Action Monitoring Program, incorporating proposed Plume Monitoring Well 5W12A (Figure 2) The present monitoring program is defined in Module V of the permit The permit will be amended with Module VI (Groundwater Corrective Action) to include MNA as the remedy A schedule for the shift from the present compliance monitoring program to the MNA remedy monitoring is provided in Permit Condition VI N of the amended permit Approval of the permit will effectively be the required impetus for installation of the new well and the subsequent shift to the Corrective Action Monitoring Program This CAP document will be attached to the permit as Attachment 2, Appendix I A proposed time table for system installation, including the potential addition of one additional monitoring well is provided in the Permit

- A description and schedule for the Corrective Action operation and maintenance The only capital equipment associated with the MNA Remedy monitoring network is the wells for which the Operation and Maintenance (O&M) is addressed under Module VI of the permit

- A contingency for the provision of an alternate water supply This is addressed in the Permit, but is not applicable The plume extent is entirely contained within the

RFAAP, approximately ½ mile from the nearest surface water discharge, with no current or potential groundwater use downgradient

- A schedule for the submission of status reports Reporting of the results of the MNA Remedy data will continue the present Annual reporting frequency presently

used for the Compliance Monitoring Program Details are contained in Module VI of the Permit

- A recommended public notice procedure The public is routinely updated as to the status of the various investigations and remediations being conducted at the site through the restoration advisory board (RAB) This procedure will continue through the MNA remedy In addition the required public notifications and comment periods for a corrective action will be provided

7.3 Development of MNA Remedial Timeframe

Based on the MNA remedy selected for Unit 5, the predicted timeframe to achieve GPSs is 12 years (i e , October 2019) Hereafter this date is referred to as the MNA projected remedial timeframe During this period, semi-annual groundwater monitoring and annual data reporting will be performed, as required, to ensure compliance with the MNA remedy

For clarity, it is noted that the predicted 2019 MNA remedial timeframe coincides with the end date of the Post-Closure Care Period (October 26, 2019) as specified in the Post-Closure Care Permit This permit, issued on September 28, 2001, requires compliance monitoring until October 28, 2020 The current MNA remedial timeframe predicts that concentrations will be less than the GPSs within the compliance period

The 2019 MNA remedial timeframe was calculated based on pore-volume flushing calculations These calculations are summarized below Additional supporting information is provided in Appendix C First, a composite retardation coefficient was calculated based on the sorption coefficient, soil bulk density and aquifer porosity Second, the number of pore-volume flushes was calculated to attenuate TCE concentrations to the GPS by multiplying the composite retardation coefficient by the natural log of TCE concentrations (current detection/divided by TCE GPS) Third, the solute travel time across the plume was calculated by dividing the average solute transport velocity by the distance between sample location of the current maximum detection and first downgradient location with concentrations less than the GPS Finally, the remedial timeframe was calculated by multiplying the number of pore-volume flushes by the solute travel time These calculations predicted a range of MNA remedial timeframes with a maximum at 11 5 years The final remedial timeframe, derived from the upper limit of this range, is considered to be conservative These calculations assume the average TCE transport velocity at Unit 5 is approximately 15 ft per year One environmental condition not directly factored into these calculations is the potential for seasonal variations in precipitation and recharge to cause concentration fluctuations

7.4 Annual Evaluation Methodology (Calculation of MNA Timeframe)

The technical approach and methodology used for the data evaluation will be based on USEPA guidance for MNA studies (Newell et al , 2002) This approach involves the calculation of point attenuation rates and comparison of updated predicted timeframes to the 2019 MNA remedial timeframe The point attenuation rate represents the cumulative effects of all natural attenuation processes at a specific well location and thus is likely to be more representative of actual conditions than the conservative pore-volume flushing calculations The following steps describe the methodology for this evaluation

- Construction of graphs of natural log concentrations versus time for monitoring wells (5W5B, 5WC21, 5WC22, 5WC23, and 5W12A) exhibiting current detections of TCE and degradation products at concentrations greater than GPS values Non-detect values will be plotted at half the detection limit

- Calculation of the point attenuation rate constant for each constituent based on a linear regression whereas the slope of the regression represents the attenuation rate constant The dataset used to calculate the rate constant will encompass at least eight monitoring events

- Updated MNA compliance predictions using the following equation

$$t = \frac{-\text{Ln}\left[\frac{C_{goal}}{C_{start}}\right]}{k_{point}}$$

Whereas

t = predicted GPS remedial timeframe
C_{goal} = GPS concentration
C_{start} = current constituent concentration
K_{point} = point attenuation rate

- Provide an updated MNA remedial timeframe prediction with the additional data in each annual report using the methods described above An example calculation is provided in Appendix C

7.5 Contingency Measures

Recent field investigations and data analysis indicate that the residual TCE source area is defined, the TCE plume is stable or shrinking, and only one monitoring well (5W5B) and hydro-punch sample location exhibit TCE detections at concentrations greater than the GPS While existing monitoring data indicate that TCE will attenuate within a reasonable timeframe, it should be noted that short-term concentration increases due to seasonal or other factors (such as variations with sampling technique or laboratory analysis) are possible If the predicted MNA timeframe based on future monitoring data exceeds 12 years (2019) for three successive monitoring years , then contingency activities will be implemented Three successive monitoring years was selected as a trigger for contingency measures to account for scatter associated with long-term monitoring data related to seasonal or other factors If concentrations decrease to less than the GPS, contingency measures will be discontinued Contingency activities may include the following

- Increased sampling frequency to quarterly and/or additional monitoring parameters/analysis to evaluate seasonal effects or other factors that may be affecting the data trends

- Evaluation of concentration changes along the plume transect and/or changes in plume geometry and contaminant mass estimates based on isocontour maps

- Provide an updated MNA remedial timeframe prediction upon completion of 7 quarterly events using the methods described in Section 7 4

- Additional data collection and technical evaluation performed for these contingency activities will be documented in the Annual Monitoring reports, as appropriate

- Design and implementation of an alternate remedial approach using enhanced in-situ anaerobic degradation or similar in-situ technology, if the predicted MNA timeframe exceeds 19 years (2026) for three consecutive years, which is the time predicted for one additional pore flush, or an additional 7 years

8. Conclusions

MNA is recommended as a remedial approach for TCE in groundwater at Unit 5 The basis for selecting MNA is

- The recently observed concentrations of TCE in monitoring wells are not significantly above GPS and have shown a declining trend in the past 10 quarters

- The TCE groundwater plume is contained within the facility site

- No surface water bodies have been, or will be, affected by the plume

- There is no current or planned future use of the groundwater at the facility

- The plume of TCE in groundwater is small, stable, declining, and clearly defined

- The potential source of TCE (Unit 5) has been stabilized and capped

- Historical data collected in the past 10 quarterly monitoring events show that the plume is currently stable and concentrations of TCE in groundwater attenuate below the GPS as groundwater moves away from the Unit There is no known existing source of TCE Unit 5 has been lined and capped

- Statistical analyses show decreasing trends for TCE concentrations at all affected monitoring wells over the previous 10 quarterly sampling events

9. References

ARCADIS-US, Inc 2008 Final Work Plan Addendum 25 RCRA Facility Investigation Work Plan TCE Plume at Bldgs 1549, 1041, 1034 (RAAP-047) May

Alliant Ammunition and Powder Company LLC (Alliant) 2003 Field Investigation Report and Risk Assessment, Hazardous Waste Management Units, 5 and 7 Radford Army Ammunition Plant, Radford Virginia March

Draper Aden 2007 Draft Alternate Source Designation Report for Hazardous Waste Management Unit 5, Radford Army Ammunition Plant, Radford Virginia

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Newell, C , H Rifai, J Wilson, J Connor, J Azia, M Suarez (Newell et al , 2002) Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies USEPA Position Paper

USEPA 2000 Region 5 Framework for Monitored Natural Attenuation Decisions for Groundwater, September

USEPA 2004 Summary of the Triad Approach Office of Superfund Remediation Technology Innovation March 25

Corrective Action Plan
Hazardous Waste
Management Unit 5

Radford Army Ammunition
Plant, Virginia

Appendix A

Appendix A - Supporting Information From Investigational Activites (Historic and Present)

1 Historical Potentiometric Surface Maps [Not included in Permit Attachment]

2 Historical Investigation Data [Not included in Permit Attachment]

3 Historical TCE Concentrations in Groundwater

4 Boring Logs (2008)

5 Fate and Transport Plots

6 Historical Investigation Boring Logs [Not included in Permit Attachment]

Appendix B

Appendix B - Analytical Laboratory Data and Data Validation Reports [Not included in Permit Attachment]

Appendix C

This appendix discusses the development of the Monitored Natural Attenuation (MNA) remedial timeframe predictions presented in the Corrective Action Plan (CAP) and the approach and methodology for future annual MNA timeframe evaluations

Development of Remedial Timeframe Predictions

The MNA remedial timeframe for trichloroethene (TCE) to attenuate to less than the Groundwater Protection Standard (GPS) was predicted using a conservative pore-volume flushing calculation, which assumes that no degradation is occurring, and a series of pore flushes is the primary attenuation process to attenuate TCE These calculations were performed based on the following steps First, a composite retardation coefficient was calculated using the following equation (Payne et al 2008)

$$R_{composite} = 1 + (\frac{K_d \times \rho_{BD}}{\theta_{total}}) \qquad \text{Eq 1}$$

ρ_{BD} = bulk density of the soil A value of 1 85 g/cm^3 was used assuming the total porosity of 30 percent

Θ_{total} = total porosity The porosity for aquifer materials found at the site (clay with sand and fine gravel) ranges from 25 to 60 percent (Fetter, 2002) A value 30 percent was assumed for the purpose of estimating the remedial timeframe

K_d = TCE partition coefficient in soil determined as follows

$$K_d = K_{oc} \times f_{oc} \qquad \text{Eq 2}$$

Where

K_{oc} = organic-carbon partition coefficient The calculated value of 166 Liters per kilogram (L/kg) as reported in Table 39 of U S States Environmental Protection Agency (USEPA) (1996) was used, and

f_{oc} = fraction organic carbon in the aquifer material A value of 0 001 or 0 1 percent organic carbon which is the default value recommended by USEPA (1996) for subsurface aquifer materials was used

Using Equation 1, the composite retardation coefficient was calculated as 2 02 The analytical model selected to evaluate the pore volume flushing is the mixed linear reservoir model (Zheng and Bennett, 2002) This model determines the number of pore volumes (N_{PV}) required to reduce the starting dissolved concentration (C_{start}) to a target concentration (C_{goal}) using the following equation

$$N_{PV} = -R_{composite} \ln\left(\frac{C_{goal}}{C_{start}}\right) \qquad \text{Eq 3}$$

Where

N_{pv} = number of pore volume flushes
$R_{composite}$ = composite retardation coefficient (calculated as 2 02 for TCE)
C_{goal} = the MCL for TCL of 5 ug/L
C_{start} = current maximum TCE concentration (11 ug/L – 5GP-028)

Using Equation 3, the number of pore-volume flushes was 1 60

Last, the predicted MNA remedial timeframe was calculated by multiplying the required number of pore volume flushes to adequately attenuate TCE contamination by the travel time across the plume (groundwater velocity divided by the distance between monitoring wells)

$$T = (N_{PV}*L)/V_S \qquad \text{Eq 4}$$

Where

T = predicted MNA timeframe
N_{pv} = number of pore volume flushes (1 6)
L = Length along the flow path between monitoring locations (108 ft)
V_S = Groundwater velocity across the plume (15 ft/year)

Using Equation 4, the predicted MNA timeframe for TCE to attenuate to the GPS based on pore-volume flushing is 11 5 years An example of this pore-volume flushing calculation is provided as Appendix C-1 The final remedial timeframe of 12 years (2019) was derived from the upper limit of this range

The time required for TCE to attenuate based on one additional pore flush was used to develop the timeframe for when contingency measures will be implemented, if required Using Equation 4, the predicted MNA timeframe for TCE to attenuate to the GPS based on 2 6 pore flushes is 18 7 years

Methodology for Annual MNA Evaluation

The pore-volume flushing calculations, which were used to develop the predicted MNA remedial timeframe only account for dilution and dispersion as the primary attenuation mechanisms and thus are very conservative in nature EPA guidance for MNA studies recommends that MNA predictions be based on attenuation rates derived from long-term monitoring data (Newell et al , 2002) These data represent the cumulative effects of all natural attenuation processes at a specific well location and thus are likely to be more representative of actual conditions than the conservative pore-volume flushing calculations For the annual MNA Evaluation at Unit 5, the technical approach and methodology will be based on point attenuation rate calculations as described in Newell et al (2002) This approach involves the calculation of point attenuation rates and comparison of updated predicted timeframes to the 2019 MNA remedial timeframe The following steps describe the methodology for this evaluation

- Construction of graphs of natural log concentrations versus time for monitoring wells (5W5B, 5WC21, 5WC22, 5WC23, and 5W12A) exhibiting current detections of TCE and degradation products at concentrations greater than GPS values Non-detect values will be plotted at half the detection limit

- Calculation of the point attenuation rate constant for each constituent based on a linear regression analysis whereas the slope of the regression represents the attenuation rate constant The dataset used to calculate the rate constant will encompass at least eight monitoring events

- Updated MNA compliance predictions using the following equation

$$t = \frac{-\ln\left[\frac{C_{goal}}{C_{start}}\right]}{k_{point}} \qquad \text{Eq 5}$$

Where

t = predicted GPS remedial timeframe
C_{goal} = GPS (ug/L)
C_{start} = current constituent concentration (ug/L)
K_{point} = point attenuation rate

- Comparison of updated MNA predictions to the 2019 MNA remedial timeframe

An example calculation for TCE at well 5W5B is provided as Appendix C-2 Using Equation 5, the predicted remedial timeframe for the current TCE concentration (7 8 ug/L) at 5W5B to attenuate to the GPS (5 ug/L) is 2 4 years Since this predicted timeframe (October 2010) is less than the 2019 MNA remedial goal, then the MNA remedy is considered effective Similar calculations will be performed on an annual basis for any constituents in the monitoring program that exhibit concentrations above the GPS

References

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Appendix C-1

Predicted MNA Remedial Timeframe per CAP

Total Porosity =	30%	%	Estimated
log(Koc) =	2.22	--	USEPA 1996
f_{OC} =	0.001	--	USEPA 1996
Bulk Density =	1.85	g/cm^3	assumed value based on 30% total porosity
K_d =	0.17		Calculated, $K_{oc}*f_{oc}$
Retardation Coefficient =	***2.02***	--	***Calculated; 1+((Kd*Bulk Density)/total porosity)***

Groundwater Velocity =	15	ft/yr	Estimated
Spacing Between 5GP-028 and 5CW21 =	108	ft	Calculated from Scale on Figure 1 (1"=80')
Travel Time Between Wells =	7.2	yr	Calculated
Retardation Coefficient for TCE =	2.02		Calculated
Current TCE Concentration in 5GP-028 =	11	ug/L	Given
Current TCE Concentration in 5CW21 =	2.5	ug/L	Given
End Concentration =	5	ug/L	TCE GW standard
Number of Pore Flushes =	***1.60***		***Calculated***
Predicted MNA Remedial Timeframe	***11.5***	***yr***	***Calculated***

PORE FLUSHES + 1			
Number of Pore Flushes =	***2.60***		***Calculated***
Predicted MNA Remedial Timeframe	***18.7***	***yr***	***Calculated***

Appe C-2
Point Attenuation Rate Calculation Example

Sample Date	TCE (ug/L)	ln TCE (ug/L)
4/18/2005	13.00	2.56
8/15/2005	12.00	2.48
11/18/2005	12.00	2.48
2/14/2006	8.50	2.14
4/18/2006	17.00	2.83
8/18/2006	11.00	2.40
11/18/2006	9.40	2.24
2/14/2007	9.00	2.20
4/18/2007	10.00	2.30
10/30/2007	8.90	2.19
4/28/2008	7.80	2.05
		#NUM!
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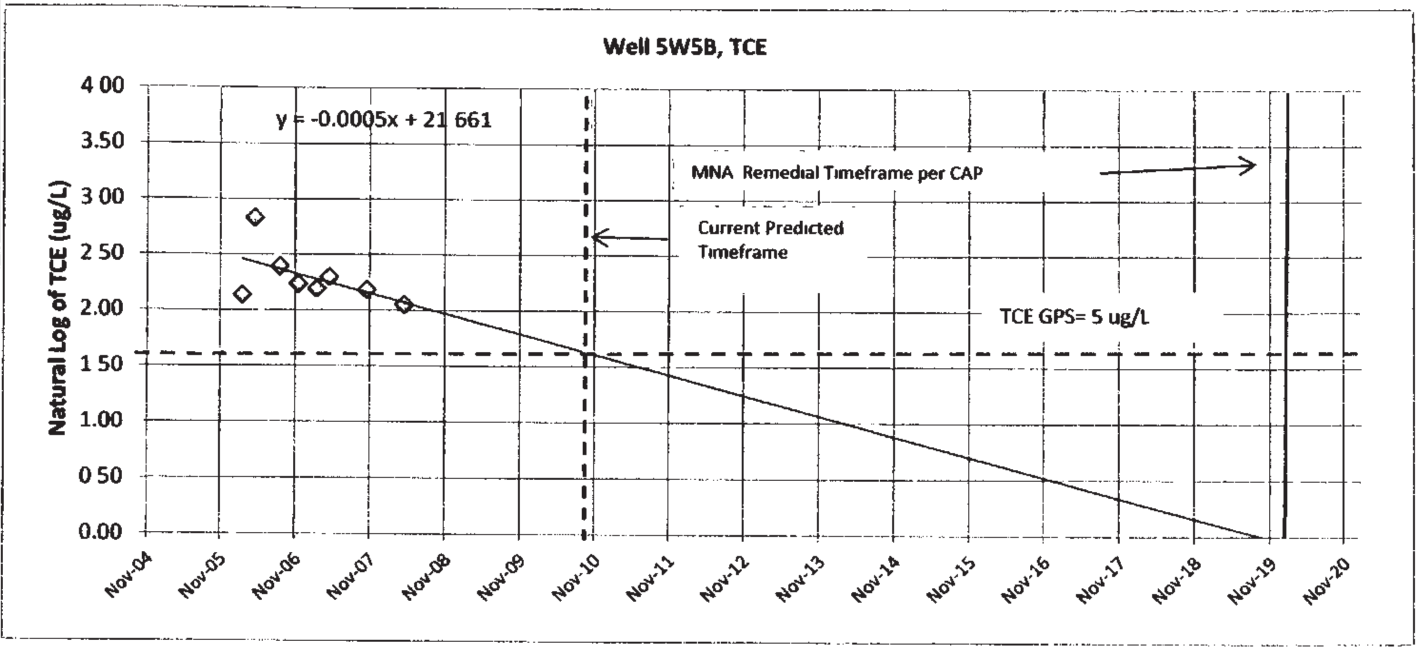


Last 8 rounds		TCE MCL	Estimated Rate and Time Required			Current MNA Timeframe Prediction	MNA Goal (per CAP)	MNA Ineffective Date (per CAP)
First Event	Last Event	ug/L	Rate (per day)	Rate (per year)	Time (years)			
2/14/2006	4/28/2008	5.000	0.0005	0.183	2.44	October-2010	October-2019	December-2026

Effectiveness Evaluation for MNA Remedy	Status	Condition
1) Is the current MNA remedial timeframe prediction less than the 2019 MNA Goal?	yes	If 'yes', then the remedy is considered effective and no additional action is required. If 'no' for three consecutive years, then contingency measures will be implemented as defined in the CAP.
2) Is the current MNA remedial timeframe prediction less than the 2026 MNA ineffective date?	yes	If 'yes', the remedy will be considered effective. If 'no' for three consecutive monitoring years, then an alternate remedial approach will be implemetned as defined in the CAP

Appendix J
Groundwater Corrective Action Targeted Contaminants - GPSs and Semiannual Monitoring List for Unit 5

Targeted CA Contaminants (Concentration Unit: µg/l)									
CONSTITUENTS	**Cas RN#**	**SW-846 Method**	**MDL**	**PQL**	**Back-ground**	**EPA MCL**	**VA DEQ ACL**	**EPA RSL**	**GPS**
Trichloroethene (TCE)	79-01-6	8260B	0.177	1	0.8	5	0.44	2	5
1,1-Dichloroethene (1,1-DCE, $H_2C{=}CCl_2$)	75-35-4	8260B	0.44	1		7	260	340	7
cis-1,2-Dichloroethene (**cDCE**)	156-59-2	8260B	0.1	1		70	28	73	70
trans-1,2-Dichloroethene (***t*DCE**)	156-60-5	8260B	0.8	1		100	86	110	100
Vinyl chloride (Chloroethene, VC, $H_2C{=}CHCl$)	75-01-4	8260B	0.1	1		2	0.015	0.016	2
Cobalt, total	7440-48-4	6010/6020	1	5	7		4.7	11	7
See the note in Appendix K for Column Titles									

MNA Indicators (First year of monitoring only)		
Indicator	**Analytic Method**	
Methane, Ethane & Ethene	RSK 175M	Anaerobic dechlorination
Nitrate/nitrite	9056	**Nitrate**: Electron acceptor by denitrifying bacteria
Sulfate	9056	**Sulfate/Sulfide**: Electron acceptor/Sulfate reduction
Sulfide	9034	
Total Organic Carbon (TOC)	9060B	

Field Parameters	
pH	
Temperature	
Dissolved Oxygen (DO)	DO: aerobic environments; electron acceptor
Oxidation-Reduction Potential (ORP)	Redox Potential: +500mV aerobic to -500mV anaerobic environments
Specific Conductivity	

Appendix K
GROUNDWATER CORRECTIVE ACTION ANNUAL MONITORING LIST

Concentration Unit µg/l

CONSTITUENTS	Cas RN#	SW-846 Method	MDL	PQL	Back-ground	EPA MCL	VA DEQ ACL^	EPA RSL	GPS
Antimony, total	7440-36-0	6010/6020	0.4	1	3	6	6	15	6
Arsenic, total	7440-38-2	6010/6020	2	10	1	10	0.045	0.045	10
Barium, total	7440-39-3	6010/6020	1	10	172.87	2000	2900	7300	2000
Beryllium, total	7440-41-7	6010/6020	0.2	1	0.7	4	16	73	4
Cadmium, total	7440-43-9	6010/6020	0.2	1	1.45	5	6.9	18	5
Chromium, total	7440-47-3	6010/6020	1	5	5	100	--	--	100
Cobalt, total	7440-48-4	6010/6020	1	5	7		4.7	11	7
Copper, total	7440-50-8	6010/6020	1	5	18	1300	620	1500	1300
Lead, total	7439-92-1	6010/6020	0.2	1	10	15	NA	--	15
Mercury, total	7439-97-6	7470A	0.2	2	0.9	2	0.5006	0.63	2
Nickel, total	7440-02-0	6010/6020	2	10	106		300	730	300
Selenium, total	7782-49-2	6010/6020	3	10	1	50	78	180	50
Silver, total	7440-22-4	6010/6020	0.2	2	2.3		71	180	71
Thallium, total	7440-28-0	6010/6020	0.2	1	2	2	0.16	0.37	2
Vanadium, total	7440-62-2	6010/6020	1	10	17		63	180	63
Zinc, total	7440-66-6	6010/6020	3	10	75		4700	11000	4700
Acetone	67-64-1	8260B	3	10	89		12000	22000	12000
Bis (2-ethylhexyl) phthalate (DEHP)	117-81-7	8270C	1.5	6	10	6	4.8	4.8	10
2-Butanone (Methyl ethyl ketone, MEK)	78-93-3	8260B	1	10	21.3		4900	7100	4900
Chloroform	67-66-3	8260B	0.1	1	0.5	80#	0.19	0.19	80
Dichlorodifluoromethane	75-71-8	8260B	0.28	1	1		190	200	190
1,2-Dichloroethane	107-06-2	8260B	0.147	1	0.1	5	0.15	0.15	5
Diethyl ether	60-29-7	8260B	0.39	12	12		--	7300	7300
Diethyl phthalate	84-66-2	8270C	0.5	10	0.2		11000	29000	11000
2,4-Dinitrotoluene	121-14-2	8270C	0.6	10	0.18		0.2	0.22	10

2,6-Dinitrotoluene	606-20-2	8270C	0.7	10	0.08		0.042	37	10
Methylene chloride (Dichloromethane)	75-09-2	8260B	0.182	1	0.7	5	9.9	4.8	5
o-Nitroaniline, 2-	88-74-4	8270C	0.7	10	10		150	370	150
p-Nitroaniline, 4-	100-01-6	8270C	1.3	20	20		3.3	3.4	20
Nitrobenzene	98-95-3	8270C	0.8	10	10		0.12	0.12	10
Toluene	108-88-3	8260B	0.1	1	0.1	1000	860	2300	1000
Xylenes (total)	1330-20-7	8260B	0.208	3	0.1	10000	190.0	200	10000

NOTE:

CAS RN *Chemical Abstracts Service registry number*

SW-846 *Test Methods for Evaluating Solid Waste- Physical/Chemical Methods, SW-846 (as updated)*

MDL *Method Detection Limit,*

PQL *Practical Quantitation Limit,*

Background Values *calculated upgradient background concentrations (Appendix F, Permit Attachment 2)*

MCL *Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water EPA, June, 2008. Subject to change when it is updated*

ACL *the Department's Alternate Concentration Limit, Dec 2013, subject to change when it is updated*

RSL: *developed by Oak Ridge National Laboratory under an Interagency Agreement with EPA (June 2011). Subject to change when it is updated.*

GPS *Groundwater Protection Standard*

For any monitoring event, if a GPS for a constituent in the table above is based on a background concentration derived from a PQL, the Permittee will perform verification of a detection (i.e. value greater than the Detection Limit) of such a constituent using low-level analytical methods, if such methods are standard methods that are routinely available from commercial laboratories. Furthermore, the low-level analytical method will be used only if the PQL achievable by that method is less than, or equal to, the ACL or RBC for the subject constituent. If the verification event confirms a quantifiable detection (i.e. value greater than the PQL) above the applicable ACL or RBC, a revised background concentration will be established using low-level analytical methods, if appropriate, and the GPS will be updated based on the new background concentration if warranted

 # the MCL for total trihalomethanes, including bromodichloromethane, bromoform, dibromochloromethane, and chloroform is 80 µg/l

HAZARDOUS WASTE MANAGEMENT
POST-CLOSURE CARE PERMIT

ATTACHMENT 3

UNIT 16
CLOSED HAZARDOUS WASTE LANDFILL

Radford Army Ammunition Plant

EPA I.D.#:VA1210020730

ATTACHMENT 3
UNIT 16

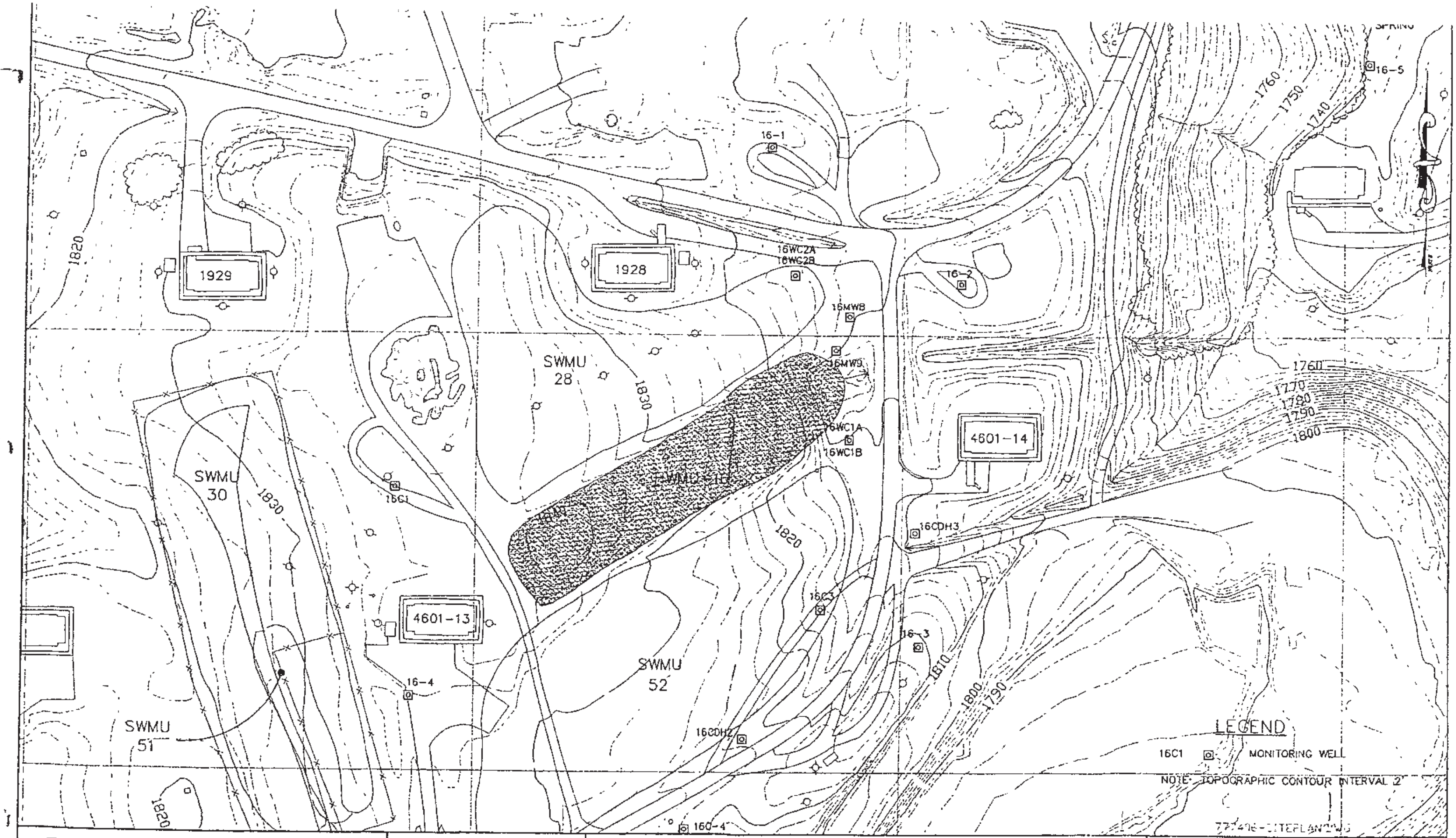
APPENDIX A

HYDROLOGICAL AND GEOLOGICAL INFORMATION

ATTACHMENT 3
UNIT 16

APPENDIX A.1

UNIT TOPOGRAPHIC MAP AND WELL LOCATION MAP



Draper Aden Associates
CONSULTING ENGINEERS
Blacksburg, Virginia – Richmond, Virginia

DESIGNED RGM
DRAWN JFF
CHECKED AEK
DATE 4-8-99

HWMU-16 SITE PLAN
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

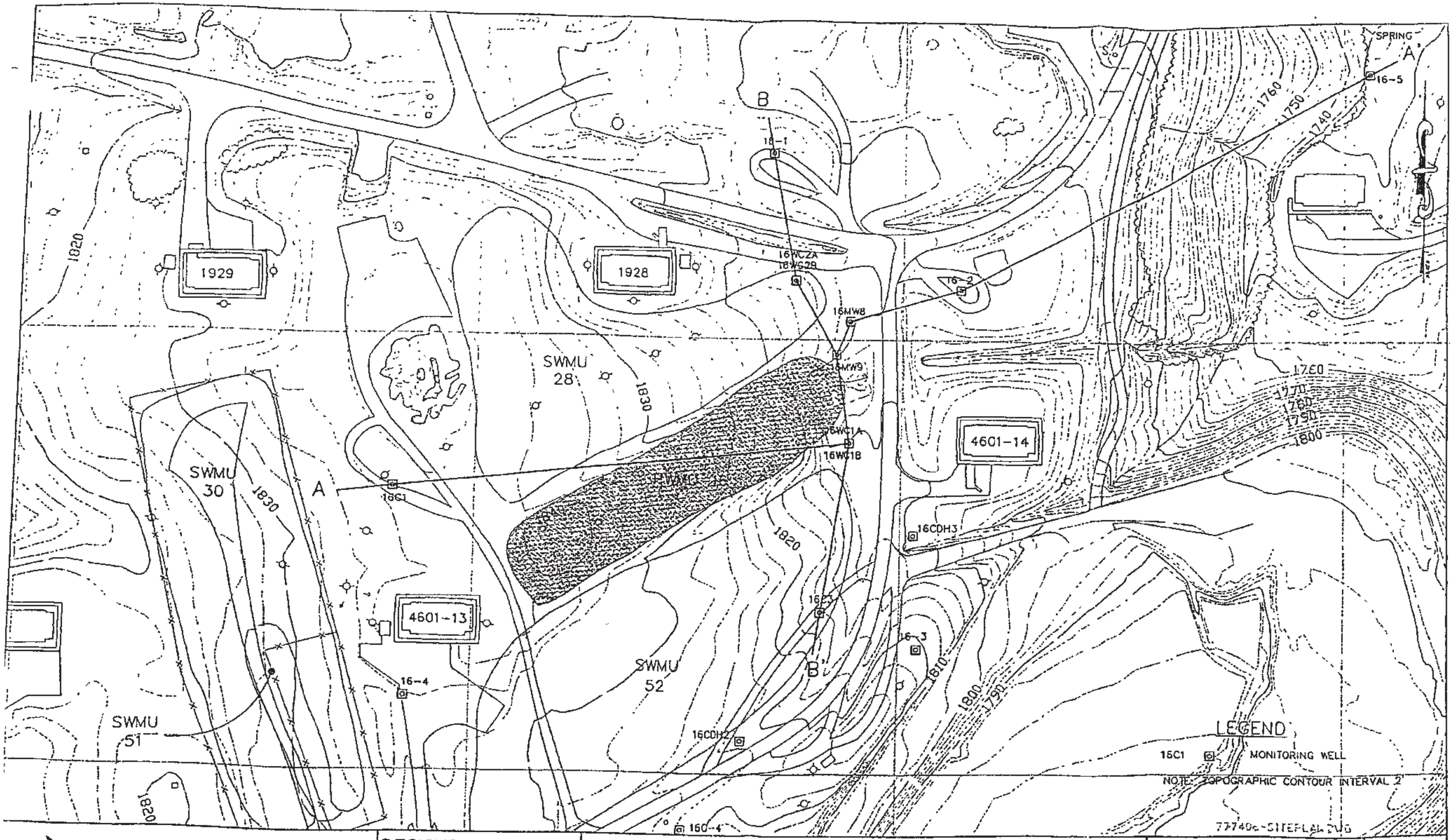
SCALE: 1" = 100'
PLAN NO. 7774-08

FIGURE

ATTACHMENT 3
UNIT 16

APPENDIX A.2

GEOLOGICAL CROSS SECTIONS



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CONSULTING ENGINEERS
Blacksburg, Virginia – Richmond, Virginia

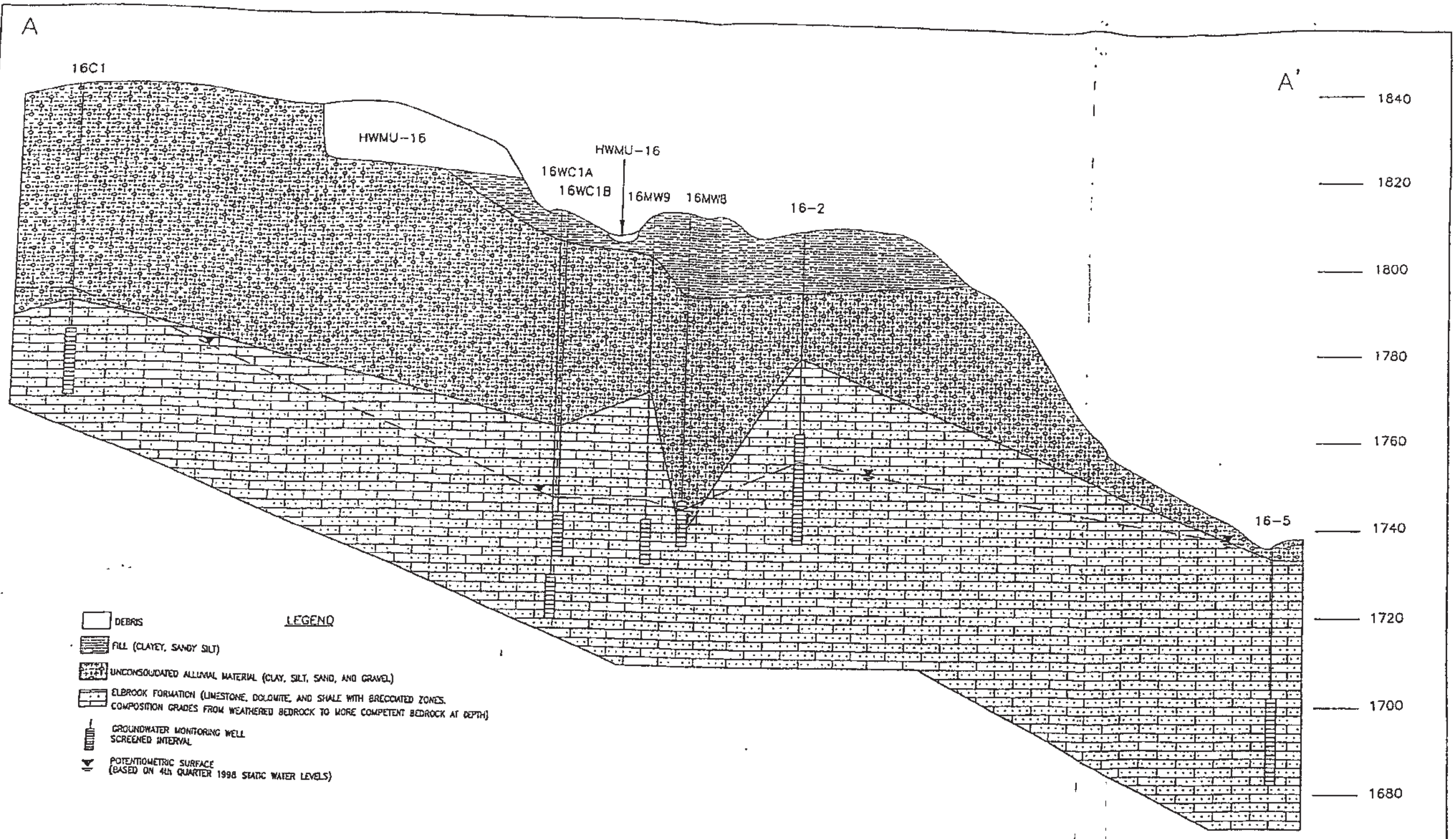
DESIGNED	RGM
DRAWN	BTM
CHECKED	AEK
DATE	4-8-99

HWMU-16 CROSS-SECTION LOCATION MAP
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SCALE: 1" = 100'

PLAN NO.7774-08

FIGURE



Draper Aden Associates
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Blacksburg, Virginia – Richmond, Virginia

DESIGNED RGM
DRAWN BTM
CHECKED VR
DATE 4/29/99

HWMU-16 GEOLOGIC CROSS-SECTION A-A'
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SCALE: V: 1"=20' H: 1"=100'

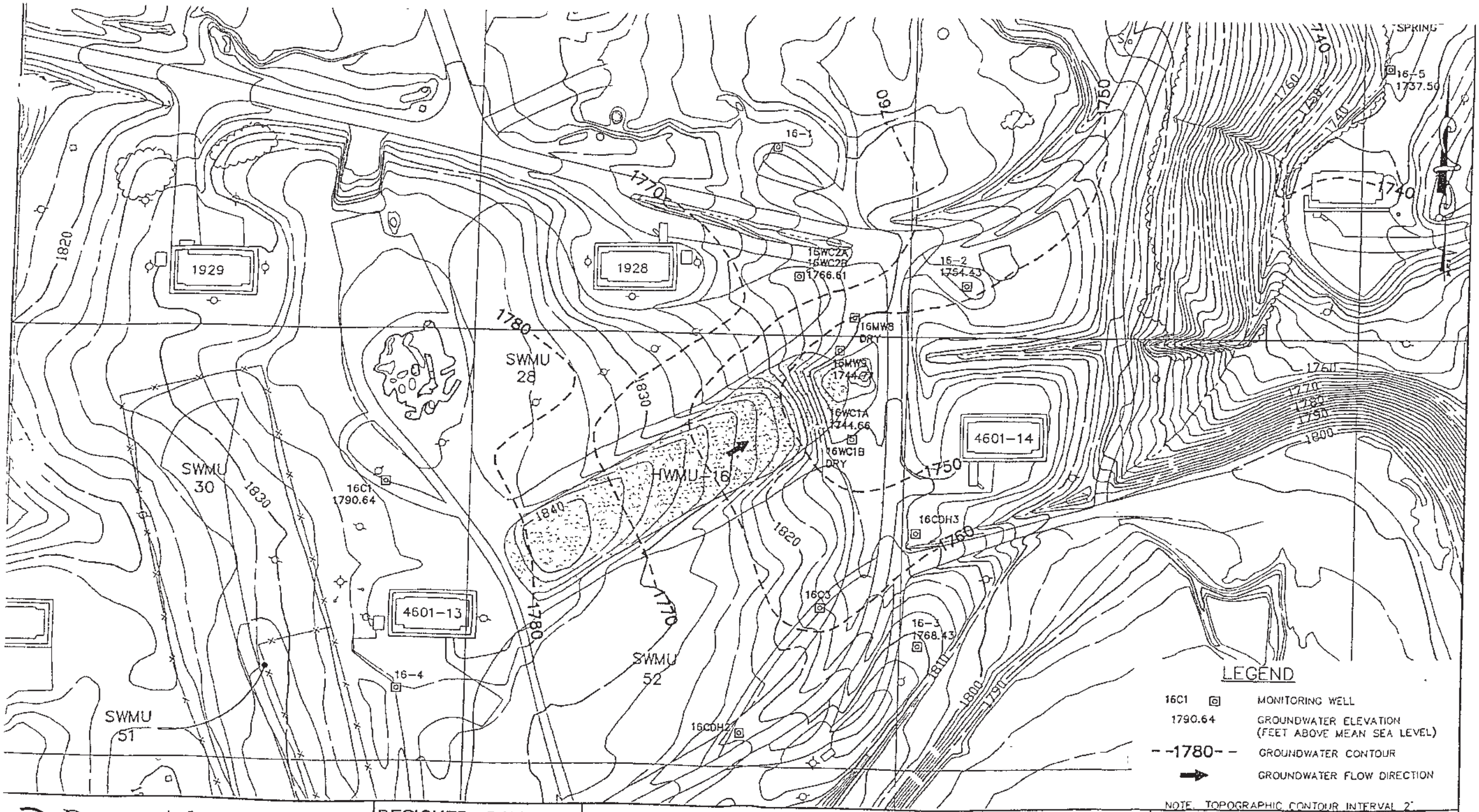
PLAN NO. 7774-08

FIGURE

ATTACHMENT 3
UNIT 16

APPENDIX A.3

POTENTIOMETRIC SURFACE MAPS (GROUNDWATER ELEVATION)



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CHECKED	AEK
DATE	02/13/02

HWMU-16 POTENTIOMETRIC SURFACE MAP (FOURTH QUARTER 2001)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SCALE: 1"=200'

PLAN NO. 7774-22

FIGURE

ATTACHMENT 3
UNIT 16

APPENDIX B

(RESERVED)

ATTACHMENT 3
UNIT 16

APPENDIX C

DESCRIPTION OF WASTES

B. GENERAL INFORMATIONAL REQUIREMENTS

The Radford Army Ammunition Plant (Radford AAP) is submitting this revised RCRA Hazardous Waste Management Part B Permit Application for Hazardous Waste Management Unit Number 16 (HWMU-16) in accordance with Virginia Hazardous Waste Management Regulations 9 VAC 20-60-1010 and in response to the Virginia Department of Environmental Quality's (VDEQ's) review of the *RCRA Part B Permit Application for Radford Army Ammunition Plant (November 1984, revised October 1985)*. For the purposes of this permit, the term "Facility" refers to all contiguous portions of the Radford AAP under the control of either the United States Army or Alliant Ammunition and Powder Company, L.L.C. (Alliant). The Facility specifically includes both the Horseshoe Area and the Main Manufacturing Area. The subject Part B Permit Application will be effective for only a portion of the Facility (i.e., HWMU-16), which will be designated herein as the "Unit." All other HWMUs at the Radford AAP Installation will be, or have been, addressed under separate Permit Documentation. General Information is provided to demonstrate the context of HWMU-16 within the overall history and function of the Radford AAP Installation.

B.1 General Facility Description

Location

The Radford AAP is located in the mountains of southwestern Virginia within Pulaski and Montgomery Counties. The installation consists of two noncontiguous areas - the Radford Unit (or Main Section) and the New River Ammunition Storage Area Unit. The Main Section is located approximately 4 miles northeast of the city of Radford, approximately 10 miles west of Blacksburg, and 47 miles southwest of Roanoke, Virginia. The New River Unit is located approximately 6 miles west of the Main Section, near the town of Dublin, Virginia. All uses of the terms "Radford AAP" or "the Facility" in this document refer to the Main Section only.

The Radford AAP is situated in one of a series of narrow valleys typical of the Valley and Ridge physiographic province of the Appalachian Highland Region of North America. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long. The valley has a width of approximately eight miles at the southwest end and narrows to approximately two miles at the northeast end. The Radford AAP lies along the New River in the relatively narrow northeast corner of the valley. The maximum elevation at Radford AAP is 2,225 feet above mean sea level (MSL) in the southeast corner and the minimum elevation is approximately 1,675 feet above MSL along the New River at the northern property boundary.

The Radford AAP is divided by the New River into two areas (Figure I-1, Section I of this Application). The southern area, which comprises approximately two-thirds of Radford AAP, is called the "Main Plant Area." The remaining northern one-third section is called the "Horseshoe Area," and is located within the meander of the New River. The entire Radford AAP is secured by artificial barriers to prevent unknowing or unauthorized entry. The Facility perimeter is surrounded by a six-foot chain link fence with three-strand barbed wire top guard. The access gates and perimeter fencing at the Radford AAP are posted with no trespassing signs. The signs are posted in sufficient number so as to be seen from any approach to the restricted portions of the property.

Forty three (43) Solid Waste Management Units (SWMUs) and eight (8) HWMUs are located in both the Main Plant Area and the Horseshoe Area (Figure I-2). This Part B Permit Application is specifically for HWMU-16. As shown on Figure I-2, HWMU-16 is located in the Horseshoe Area. HWMU-16 is a closed hazardous waste landfill. Hazardous wastes known to have been disposed of within HWMU-16 included 3,898 tons of ash from the burning of waste explosives and explosives-contaminated material (D008 and D007 waste), 545 tons of wastewater treatment sludges (K044 and K045 waste), 6 tons of asbestos, and various laboratory chemicals. Waste disposal within the Unit began in 1980; the Unit was certified closed in 1993 in accordance with a Commonwealth of Virginia-approved closure plan. No waste has been processed through the Unit since it was closed. As shown on the Site Plan (Figure I-3), a spring and perennial stream are located approximately 730 feet northeast of the Unit. As illustrated on Figure I-2, the New River is located approximately 1,500 feet south of the Unit.

History

The Radford AAP is a government-owned, contractor-operated (GOCO) military industrial installation supplying solvent and solventless propellant grains and trinitrotoluene (TNT) explosives. From its inception as a GOCO installation in 1940 until 1995, the Radford AAP was operated by Hercules Incorporated. On March 6, 1995, Alliant Techsystems, Inc. bought out Hercules Incorporated and took over operation of the Radford AAP. On April 1, 1999, the division of Alliant Techsystems, Inc. which operates the Radford AAP became a limited liability corporation under the name of Alliant Ammunition and Powder Company, L.L.C.

Construction of the Radford AAP production facility began in 1940 with the impending participation of the United States in World War II, and the determination by Congress of a need for increased ammunition production facilities. Initially, Radford AAP consisted of two distinct areas - a smokeless-powder plant (Radford Ordnance Works [ROW]) and a bag-manufacturing and loading plant for artillery, cannon, and mortar projectiles (New River Ordnance Works [NROW]). These two production facilities were operated separately from 1940 to 1945. Late in 1945, ROW was designated as the Radford Arsenal, and NROW was designated as a subpost. By January 1950, NROW was made an integral part of the Radford Arsenal and no longer considered a subpost. The arsenal was renamed Radford Ordnance Plant in 1961 and was finally redesignated as the Radford AAP in August 1963 (USATHAMA, 1984).

Expansion of both ROW and NROW continued throughout World War II. Late in 1945, the Radford Unit was placed on standby status. The following year, the nitric acid area of the plant was reactivated to produce ammonium nitrate fertilizer, an activity that continued until 1949 under contract with Hercules Powder Company (later Hercules Incorporated). In September 1945, the NROW was declared surplus; but in April 1946, the magazine areas were changed from surplus to standby status. Between December 1946 and January 1948, large parcels of the NROW plant manufacturing area were sold (USATHAMA, 1984). These parcels were excess land holdings that had never been used for production purposes.

Between 1952 and 1958, Goodyear Aircraft Corporation of Akron, Ohio was contracted to manufacture component parts used in missile production at the Radford AAP. The close coordination required between Goodyear and Hercules resulted in Goodyear moving its assembly and coating operations to Radford AAP. In 1958, Hercules took over the Goodyear operations at the Plant (USATHAMA, 1984).

In mid-1968, the continuous TNT plant was put into production and remained in operation until destroyed by an explosion in May 1974. The TNT plant had five main operational areas: the nitration lines, the finishing buildings, the red water concentration facility, the acid neutralization facility, and the spent acid recovery plant. The C-line in the TNT area ran from 1983 to 1986, when the TNT plant was placed on standby. Later, in December 1988, a facility cleanup was conducted and the TNT plant was prepared for long-term standby status. Between 1990 and 1992, two nitroglycerin facilities went on line at Radford AAP. Although there was an explosion at one of these in 1993, they both remain active. A chronological listing of major Radford AAP activities is presented in Table B-1.

Responsibility

Based on discussions with Facility personnel, the general responsibilities assigned to the Radford AAP have not changed from those outlined by USATHAMA (1976), these include:

- Manufacturing of explosives and propellants;
- Handling and storage of strategic and critical materials as directed for other government agencies;
- Operation and maintenance, as directed, of active facilities in support of current operations. Maintenance and/or lay-away, in accordance with Ammunition Procurement and Supply Agency instructions, of standby facilities, including any machinery and packaged lines received from industry, in such conditions as will permit rehabilitation and resumption of production within the time limitations prescribed;
- Receipt, surveillance, maintenance, renovation, demilitarization, salvage, storage, and issue of assigned Field Service Stock and industrial stock as required or directed;
- Procurement, receipt, storage, and issue of necessary supplies, equipment, components, and essential materials;
- Mobilization planning, including review and revision of plant as required;
- Custodial maintenance and administrative functions of subinstallations; and
- Support services for tenants.

These responsibilities are met through the efforts of the operating contractor, Alliant Ammunition and Powder Company, L.L.C. The Administrative Contracting Officer (ACO) and his staff provide technical assistance and administer the contracts with the civilian operating contractors. Radford AAP provides logistics support for tenant activities such as the U.S. Army Research, Development and Acquisition Information Systems Agency, (USARDAISA) which is charged with performing data processing activities during peacetime.

Industrial Operations

From 1941 to the present the principal end products produced at Radford AAP have been TNT, single-base and multi-base propellants, and cast and solventless propellants. Intermediate products produced are oleum (concentrated sulfuric acid), nitric acid, nitroglycerine (NG), and nitrocellulose (NC).

Production at Radford AAP is accomplished at the primary and secondary manufacturing areas. The primary manufacturing processes are the production of single-base and multi-base solvent propellants, cast and solventless propellants, and TNT. Separate process areas are provided for the production of solventless propellant, referred to as rolled powder. The process steps are essentially the same for the production of solvent-type single-, double-, and triple-base propellants; the major differences are in the specific chemical and explosive ingredients added. Single-base and double-base propellants may include one or more of the following chemicals: barium nitrate, potassium nitrate, ethyl centralite, graphite, carbon black, potassium sulfate, lead carbonate, dibutylphthalate, and diphenylamine. Triple-base propellants consist of ethyl centralite and potassium sulfate cryolite, while special high-energy propellants contain high melting point explosives (HMXs). The secondary manufacturing processes include the production of oleum, nitric acid, NG, and NC.

Propellant Production

The separate processes used in the production of the various propellants are discussed below.

Single-base solvent propellant - In this batch process, nitrocellulose is dehydrated and mixed with appropriate chemicals and solvents for the desired blend. The mixture then undergoes a series of operations where it is shaped into a cylindrical block, extruded into strands, and cut to desired size. The solvents ethyl alcohol and ethyl ether are recovered, and the grains are water and air dried. The last major operation includes glazing, blending, and packaging.

Multibase solvent propellant - The manufacture of the multibase solvent propellant is similar to the single base except for the addition of nitroglycerin, nitroguanidine, and other chemicals for the formulation desired. The ethyl alcohol and acetone solvents are recovered, and the mix is forced-air dried.

Cast propellant - The manufacturing of cast propellants for rocket grains requires the mixing of nitroglycerin with triacetin, diethyl phthalate, ethyl centralite and 2-nitrodiphenylamine (2-NDPA) (depending on formulation), and a casting solvent, followed by the addition of the base grain. The rocket grain is then cast, cured, machined, assembled, and packaged.

Solventless propellant (rolled powder) - The solventless propellant is prepared by a batch process in which nitrocellulose, nitroglycerin, and other chemicals are slurried in water, wrung to a wet cake, and dried to a paste. After the paste is blended, the mixture is rolled into sheets. The propellant is then wound into a carpet roll for extrusion into small rocket grains. The propellant is also rolled and finished for mortar increments.

TNT Production

Before its destruction in May 1974, the TNT plant consisted of three manufacturing lines (A, B, and C), each with a rated capacity of 50 tons/day using the modern Canadian Industries, Limited (CIL), continuous nitration and purification process and an advanced drying, solidifying, and packaging operation. When the TNT plant reopened in 1983, the B and C lines were restored, and improved safety equipment, process equipment, and a TNT wastewater treatment facility were added. The overall volume of TNT production was reduced. Operations for fume recovery, red water concentration and destruction, waste neutralization, and spent acid recovery were located in the TNT plant area. These operations directly support the manufacture of TNT.

Secondary Manufacturing Operations

The secondary manufacturing operations at Radford AAP are the production of oleum, sulfuric and nitric acids, nitroglycerin, and nitrocellulose, as described below:

- Oleum 40 percent is manufactured by absorbing sulfur trioxide (SO3) in 100 percent sulfuric acid. A new plant, constructed in 1970, uses a sulfur acid regeneration (SAR) process.
- The ammonia oxidation process (AOP) is used to make weak, 60 percent nitric acid. A new plant was constructed in 1970.
- The sulfuric acid concentration (SAC) process produces 93 percent sulfuric acid, and concentrates the sulfuric acid residue from the nitric acid concentration (NAC) and TNT processes. This process was replaced by the SAR process in 1970.
- The NAC process is used to concentrate the weak nitric acid produced in the AOP plant and to recover the spent acids from the manufacture of NC and NG. This was replaced by a new facility constructed in 1970.

NG was manufactured at Radford AAP by both the batch and continuous (Biazzi) processes. The batch process employed three steps: nitration of glycerin to produce NG, separation, and neutralization of the NG charge. The continuous process is a fully automated controlled method in which the NG is produced by reactions similar to the batch process. In 1984, the batch process became inoperative and was replaced by a continuous process. Since 1984, only the continuous process has been operating.

The manufacture of NC starts with the preparation and air drying of cotton linters and wood pulp fibers and the preparation of mixed acid (nitric/sulfuric acid). The remaining major steps consist of nitration and purification. A dry charge of cotton linters or wood pulp fibers, depending on the type and grade of NC desired, is agitated with the mixed acid in a dipping pot. After nitration, the spent acid is separated from the NC. The raw NC from the nitration operation is stabilized by a stabilization acid boil and two neutral boils in the boiling tub house. It is then transferred to the beater house, where it is cut to suitable size and partially neutralized. Next, in the poacher house, a series of NC boils are performed; first, a soda boil neutralizes any remaining acid, then neutral boils and washes are performed to remove the soda. The NC is then screened, filtered, and washed. In the blender house, NC of various classes is mixed to produce the mixture or blend desired. The mixture is then wrung through centrifugal wringers in the final wringer house to obtain a product containing a small and uniform amount of moisture. The NC is then shipped to the green powder lines for processing into single-base solvent propellant and to the NG premix area for processing into multibase solvent and solventless propellant.

B.2 Chemical And Physical Analyses of the Hazardous Waste Handled at the Unit

Hazardous wastes known to have been disposed of within HWMU-16 included 3,898 tons of ash from the burning of waste explosives and explosives-contaminated material (D008 and D007 waste), 545 tons of wastewater treatment sludges (K044 and K045 waste), 6 tons of asbestos, and various laboratory chemicals. A complete listing of the wastes contained in HWMU-16 is presented in the Hazardous Waste Permit Application Part A for Radford AAP (revised July 1999). According to EP toxicity analyses conducted on ash residues disposed in HWMU-16, several heavy metals were detected. With the exception of lead concentrations detected in the propellant burning ground ash, the metals detected exhibited low (i.e., nonhazardous) concentrations. The results of the analyses conducted on the ash residues are presented in Table B-2 at the end of this section.

TABLE 1

SUMMARY DESCRIPTION OF WASTES DISPOSED IN HWM 16

Waste	Rate Of Generation (tons/yr)	Physical Form	Hazard Description	EPA Hazard Number
Ash from waste propellant incineration	unknown	solid	reactive, non-EP toxic	D003
Residue from waste propellant burning	unknown	solid	reactive, EP toxic	D003, D008
Residue from explosive contaminated waste burning	200	solid	reactive	D003
SAR area fume burner ash	0.1	solid	EP toxic	D006, D007
Sludge from neut. of SAR process water		sludge	nonhazardous	—
Sludge from neut. of nitrocellulose mfg acid process water			hazardous	—
Sludges from Bioplant, Building 470, and NG 2 Pretreatment Building 9410			- ardous	—

(Source: Engineering-Science)

TABLE B-2

EP TOXICITY RESULTS FOR WASTES DISPOSED IN HWMU-16

PARAMETER	Incinerator Ash from Waste Propellant Incinerator	Contaminated Burning Ground Ash	Propellant Burning Ground Ash
Arsenic	ND	ND	ND
Barium	ND	0.64 mg/l	0.76 mg/l
Cadmium	0.092 mg/l	0.032 mg/l	0.012 mg/l
Chromium	0.148 mg/l	0.026 mg/l	0.031 mg/l
Lead	3.4 mg/l	ND	51 mg/l
Mercury	ND	0.029 mg/l	ND
Selenium	ND	ND	ND
Silver	0.037 mg/l	ND	ND

ND = Not Detected

Source: USAEHA (December 1981)

P. O. No.	Date	Quantity	Material
80-83	9-19-80	58 lbs.	Lead Salicylate
80-100	11-3-80	550 lbs.	Sulfur
80-108	11-18-80	500 lbs.	Sulfur
81-3	1-7-81	250 lbs.	Nitrodiphenylamine
81-7	2-2-81	76 lbs.	Carbolac
81-7	2-2-81	25 lbs.	Alum. Powder
81-8	2-2-81	100 lbs.	Potassium Nitrate
81-14	2-11-81	400 lbs.	Cryolite
81-34	4-2-81	650 lbs.	Diphenylamine
81-43	4-27-81	15 lbs.	Chromium Nitrate Crystals
81-57	5-27-81	500 lbs.	Sulfur
81-74	7-8-81	450 lbs.	Cryolite, Synthetic
83-07	1-10-83	100 lbs.	Magnesium Oxide
83-10	1-19-83	200 lbs.	Charcoal
83-15	2-3-83	1.1 lbs.	Ferrous Ammonium Sulfate
83-25	2-14-83	1 lb.	Phenolphthalein Powder
		3 Bottles	Ferrous Ammonium Sulfate
83-48	4-15-83	150 lbs.	Ethyl Cellulose Flake
83-72	6-6-83	1.1 lbs.	Ferrous Ammonium Sulfate
83-76	6-13-83	3.0 lbs.	Barium Perchlorate
		0.5 lb.	Lead Dioxide
		0.5 lb.	Lead Nitrate
83-89	7-5-83	21 lbs.	Carbon Black
83-119	9-27-83	220 lbs.	Potassium Sulfate
82-67	8-10-82	3 Bottles	Tetra Bromethane
		17 Bottles	Stabilizer Sol. Ph 4
		11 Bottles	Sodium Methoxide
		9 Bottles	Chlorobenzene ←
82-77	8-26-82	120 Bottles	Yellow Ink
82-86	10-1-82	1095 Each	Combat Meals
82-107	12-8-82	2 Bottles	Alkalinity #1, Reagent #1
"	"	2 Bottles	Alkalinity, #2, Reagent #2
"	"	2 Bottles	Buffer Salt pH 7.2 Mixture
"	"	2 Rolls	Cotton, Aseptic, Absorbent
"	"	54 Gals.	Diubutyl Phthalate ←
"	"	2 Bottles	1, 3-Diphenylguanidine
"	"	2 Each	Mannitol - MP 166-167
"	"	2 Bottles	Mercuric Chloride
"	"	1 Bottle	Morpholine
"	"	2 Bottles	No. 2 Absorbing Reagent
"	"	2 Bottles	Nitrilotriethanol MP 20-22 DEG
"	"	2 Bottles	Sodium Sulfate Anhydrous
"	"	1 Lot	Perchloric Acid 70-72 PC
"	"	3 Pks.	Perfluoroelastomer
"	"	2 Bottles	Phosphorus Pentoxide Powder
"	"	1 lb.	Potassium Sulfate Powder
"	"	3 lbs.	Sodium Acetate, Crystals

P. O. No.	Date	Quantity	Material
82-107	12-8-82	3 Bottles	Sodium Citrate, Crystal
"	"	1 lb.	Sodium Cobaltinitrate Powder ←
"	"	1 Bottle	Sodium Methoxide
"	"	2 Bottles	Sodium Oxalate Standard
"	"	6 lbs.	Stearic Acid
"	"	1 Lot	Sucrose Rea Cry
"	"	4 Gals.	Tetrahydrofuran ←
"	"	1 Lot	Thymol Blue B Indicator Solution
"	"	9 Bottles	Triphenyl Phosphate
"	"	1 lb.	Uranyl Acetate
"	"	1 Bottle	Zinc Metal Dust
"	"	4 Pks.	Total Count Millipore Filters

0713b

Additional Materials Placed in Site 16 Hazardous Waste Trench Since 1980

a. 2168 tons of residues from burning explosives and explosives - contaminated wastes

b. 545 tons of wastewater treatment sludges

c. 165 tons of flashed spent activated carbon

ATTACHMENT 5
UNIT 16

APPENDIX D

CONTINGENCY PLAN

Please refer to Appendix B to Permit Attachment 1

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rev 1 - class I permit mod 9-2014 (JCF/DAA)

ATTACHMENT 3
UNIT 16

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING (SEMIANNUAL) CONSTITUENT LIST

ATTACHMENT 3, UNIT 16

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING (SEMIANNUAL) CONSTITUENT AND REQUIRED ANALYTICAL METHOD LIST

Analyte	METHOD	PQL (ug/l)
Arsenic, total	6010/6020	10
Barium, total	6010/6020	10
Beryllium, total	6010/6020	1
Cadmium, total	6010/6020	1
Chromium, total	6010/6020	5
Cobalt, total	6010/6020	5
Copper, total	6010/6020	5
Lead, total	6010/6020	1
Mercury, total	7470	2
Nickel, total	6010/6020	10
Vanadium, total	6010/6020	10
Zinc, total	6010/6020	10
Benzene	8260	1
2-Butanone	8260	10
Carbon tetrachloride	8260	1
Chloroethane	8260	1
Dichlorodifluoromethane	8260	1
1,1-Dichloroethane	8260	1
1,1-Dichloroethene	8260	1
Diethyl ether	8260	12.5
Dimethyl ether;	8260	12.5
Ethylbenzene	8260	1
Methylene chloride	8260	1
Tetrachloroethene; PCE	8260	1
Chloromethane	8260	1
Toluene	8260	1

Modified: 9-12-2014 - Class 1

1,1,1-Trichloroethane	8260	1
Trichloroethene	8260	1
1,1,2-Trichloro-1,2,2-Trifluoroethane	8260	1
Trichlorofluoromethane	8260	1
Xylenes, total	8260	3
Diethyl phthalate	8270	5
2,4-Dinitrotoluene	8270	10
2,6-Dinitrotoluene	8270	10

Notes:

ug/l = micrograms per liter
PQL = Practical Quantitation Limit

All methods are as described in EPA's SW-846, Test Methods in support of the RCRA program, August 31, 2010. Web site: http://www.epa.gov/epawaste/hazard/testmethods/index.htm. Single samples are required for each parameter and constituent during each sampling event. Alternate SW-846 Methods may be approved by the Department if the request is in writing and submitted at least 30 days prior to the sample collection event. Proposed alternate methods shall achieve the same practical quantitation limit/estimated quantitation limit (or lower) as the specified method.

UPDATED - DO NOT USE

ATTACHMENT 3
UNIT 16

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING (SEMIANNUAL) CONSTITUENT LIST

ATTACHMENT 3, UNIT 16

APPENDIX E

GROUNDWATER COMPLIANCE MONITORING (SEMIANNUAL) CONSTITUENT AND REQUIRED ANALYTICAL METHOD LIST

Analyte	METHOD	PQL (ug/l)
Arsenic, total	6010/6020	10
Barium, total	6010/6020	10
Beryllium, total	6010/6020	1
Cadmium, total	6010/6020	1
Chromium, total	6010/6020	5
Cobalt, total	6010/6020	5
Copper, total	6010/6020	5
Lead, total	6010/6020	1
Mercury, total	7470	2
Nickel, total	6010/6020	10
Vanadium, total	6010/6020	10
Zinc, total	6010/6020	10
Benzene	8260	1
2-Butanone	8260	10
Carbon tetrachloride	8260	1
Chloroethane	8260	1
Dichlorodifluoromethane	8260	1
1,1-Dichloroethane	8260	1
Diethyl ether	8260	12.5
Dimethyl ether;	8260	12.5
Ethylbenzene	8260	1
Methylene chloride	8260	1
Tetrachloroethene; PCE	8260	1
Chloromethane	8260	1
Toluene	8260	1
1,1,1-Trichloroethane	8260	1

Trichloroethene	8260	1
1,1,2-Trichloro-1,2,2-Trifluoroethane	8260	1
Trichlorofluoromethane	8260	1
Xylenes, total	8260	3
Diethyl phthalate	8270	5
2,4-Dinitrotoluene	8270	10
2,6-Dinitrotoluene	8270	10

Notes

ug/l = micrograms per liter
PQL = Practical Quantitation Limit

All methods are as described in EPA's SW-846, Test Methods in support of the RCRA program, August 31, 2010 Web site http //www epa gov/epawaste/hazard/testmethods/index htm Single samples are required for each parameter and constituent during each sampling event Alternate SW-846 Methods may be approved by the Department if the request is in writing and submitted at least 30 days prior to the sample collection event Proposed alternate methods shall achieve the same practical quantitation limit/estimated quantitation limit (or lower) as the specified method

updated -do not use -JCFSee class 1 permit mod 9- 2014

ATTACHMENT 3
UNIT 16

APPENDIX F

GROUNDWATER
INITIAL BACKGROUND DATA

TABLE 2
HWMU-16
Calculated Background Values

Constituent	Background Concentration (µg/l unless otherwise noted)
Antimony	3
Arsenic	1
Barium	175.4
Beryllium	0.7
Cadmium	0.2
Chromium	6.2
Cobalt	5
Copper	13
Lead	10
Mercury	0.2
Nickel	16
Selenium	1
Silver	0.5
Thallium	6
Vanadium	151
Zinc	51
Bromoform	0.3
Carbon Tetrachloride	0.2
Chlorobenzene	0.1
Chloromethane	0.3
1,4-Dichlorobenzene	0.1
Dichlorodifluoromethane	46.5
1,1-Dichloroethane	9.5
1,2-Dichloroethane	0.1
trans-1,2-Dichloroethene	0.1
Ethylbenzene	0.1
Methyl Ethyl Ketone	1.1
1,1,2,2-Tetrachloroethane	0.3
Tetrachloroethene	0.7
Toluene	0.1
1,1,1-Trichloroethane	9.2
1,1,2-Trichloroethane	0.5
Trichloroethene	0.1
Trichlorofluoromethane	11.3
Vinyl Chloride	0.1
Xylenes (total)	0.2

TABLE 2
HWMU-16
Calculated Background Values

Constituent	Background Concentration (µg/l unless otherwise noted)
Di-n-butylphthalate	5
2,4-Dinitrotoluene	0.10
2,6-Dinitrotoluene	0.11
2378-TCDF	0.0485 ppt
12378-PECDF	0.0439 ppt
23478-PECDF	0.0417 ppt
123478-HXCDF	0.0390 ppt
123678-HXCDF	0.0377 ppt
234678-HXCDF	0.0428 ppt
123789-HXCDF	0.0415 ppt
1234678-HPCDF	0.0615 ppt
1234789-HPCDF	0.0709 ppt
OCDF	0.1307 ppt
Cyanide	10
Total Organic Carbon (x4)	7000
Total Organic Halides (x4)	42.2
Specific Conductivity	672 µS/cm
pH	5.7 to 7.9 pH units

Statistical Computations – RAAP HWMU-16 – 1,1,2-Trichloro-1,2,2-Trifluoroethane

In accordance with the facility permit and VHWMR, statistical background concentration is being established for 1,1,1-Trichloro-1,2,2-Trifluoroethane. Inter-well upper prediction limits (UPL) were calculated on the background data for this target parameter in accordance with the facility permit and VHWMR (40 CFR 264.97(h)). Background data for this target parameter consisted of all data for the background well 16C1 collected from 2nd quarter 2004 through 3rd quarter 2006.

Discussion of Tests for Normality

The power of a statistical tool to account for false positive and false negative results, while accurately detecting true statistical variations for a facility under scrutiny depends on numerous factors, one of which is the distribution of the data. A great number of statistical tools are based on the assumption that data are normally distributed. Hence the distribution of the sample population for parameters evaluated under this statistical analysis is first determined. Sample populations are tested for normal distribution using several normality tests. "Groundwater Information Tracking System with Statistical Analysis Capability" (GRITS/STAT) v5.0 was the software used to run these statistical tests. GRITS/STAT is an analytical software package provided by the USEPA. The distributions of the data sets were verified in the original mode as well as in log-transformed mode. The normality of the data set was evaluated using the Shapiro-Wilk test for normality.

Discussion of Prediction Interval Tests

Normality tests are performed prior to running parametric tests (tests that require that the data be normal). Results of the normality tests show that the background data for 1,1,2-Trichloro-1,2,2-Trifluoroethane is non-normally distributed. Non-parametric UPL (NUPL) was constructed on the background data for this parameter. The confidence levels of NUPLs are typically approximate and estimated to be around 91%.

Summary of UPL

Parameter	Background Data Distribution	Type of UPL	Multiple Comparisons/year	UPL (µg/l)
1,1,2-Trichloro-1,2,2-Trifluoroethane	Non-Normal	NUPL	N/A	1.2

Statistical Computations – RAAP HWMU-16

In accordance with the facility permit and VHWMR, statistical background concentrations are being established for the four new target parameters chloroethane, diethyl ether, dimethyl ether and methylene chloride. These four target parameters were added to the facility monitoring program during the 3rd quarter 2003 monitoring event. Inter-well upper prediction limits (UPL) were calculated on the background data for the target parameters in accordance with the facility permit and VHWMR (40 CFR 264.97(h)). Background data for these target parameters consisted of all data for the background well 16C1 collected from 3rd quarter 2003 through 3rd quarter 2004.

Discussion of Tests for Normality

The power of a statistical tool to account for false positive and false negative results, while accurately detecting true statistical variations for a facility under scrutiny depends on numerous factors, one of which is the distribution of the data. A great number of statistical tools are based on the assumption that data are normally distributed. Hence the distribution of the sample population for parameters evaluated under this statistical analysis is first determined. Sample populations were tested for normal distribution using several normality tests. "Groundwater Information Tracking System with Statistical Analysis Capability" (GRITS/STAT) v5.0 was the software used to run these statistical tests. GRITS/STAT is an analytical software package provided by the USEPA. The distributions of the data sets were verified in the original mode as well as in log-transformed mode. The normality of the data sets was evaluated using the Shapiro-Wilk test for normality.

Discussion of Prediction Interval Tests

Normality tests are performed prior to running parametric tests (tests that require that the data be normal). A 99% confidence parametric inter-well UPL was computed for each of the four target parameters that showed normally distributed background data. Results of the normality tests show that the background data for chloroethane, diethyl ether and methylene chloride are normally distributed, and the background data for dimethyl ether is non-normally distributed. Non-parametric UPL (NUPL) was constructed on the background data for dimethyl ether, and parametric UPLs (PUPL) were constructed on the background data for chloroethane, diethyl ether and methylene chloride. No adjustments to the error rates were made to the NUPLs for multiple comparisons. Adjustment for 10 comparisons per year (considering 10 compliance monitoring wells at the facility and 4 quarters of data for each year, and considering historic detects, 10 is considered a representative number for multiple comparisons per year) was made to the PUPLs. The confidence levels of NUPLs are well less than 95%. Any statistically significant increase (SSI) must be confirmed by verification sampling.

Summary of UPLs

Parameter	Background Data Distribution	Type of UPL	Multiple Comparisons/year	UPL (µg/l)
Chloroethane	Normal	PUPL	10	20.7
Diethyl ether	Normal	NUPL	10	75 5
Dimethyl ether	Non-normal	PUPL	N/A	17.0
Methylene Chloride	Normal	PUPL	10	13.95

RAAP-HWMU-16 - Statistical Analysis - Notes

1) Y2K Correction dates are as shown in table below

Actual Event	Date Used in Stat Software
2000-Qtr1	12/13/1999
2000-Qtr2	12/14/1999
2000-Qtr3	12/15/1999
2000-Qtr4	12/16/1999
2001-Qtr1	12/17/1999
2003-Qtr3	12/18/1999
2003-Qtr4	12/19/1999
2004-Qtr1	12/20/1999
2004-Qtr2	12/21/1999
2004-Qtr3	12/22/1999

Interwell Tests:

2) Background data for target parameters chloroethane, diethyl ether, dimethyl ether and methylene chloride were evaluated using Shapiro-Wilk test Background data showed normal distribution for chloroethane, diethyl ether and methylene chloride Parametric interwell 99% confidence upper prediction limits were computed for parameters with normally distributed background data. Dimethyl ether background data was non-normally distributed. Therefore non-parametric Upper Prediction Limit (UPL) was computed for dimethyl ether

3) No adjustments for multiple comparisons could be made for non-parametric UPLs Adjustments were made to the parametric UPLs for 10 future comparisons per year to account for multiple compliance monitoring wells and quarterly event data.
Any Statistically significant increase (SSI) must be confirmed by verification sampling

ormality Tests

Report Printed: 02-02-2005 13:49

Facility:RAAPHWMU16 Haz. Waste Unit 16 - RAAP

Address:

City:Radford ST:VA Zip:24141
County:PULASKI

Contact:
Phone:( ) -

Permit Type:Detection

Constituent:ClEthane Chloroethane

CAS Number: 75-00-3
MCL: 0.000 ppb
ACL: 0.000 ppb
Detect Limit: 2.000 ppb

Start Date:Mar 31 1996
End Date:Dec 22 1999

Normality Test on Observations for wells listed below:

Well:16C1 Position:Upgradient Observations:5

Scale	Minimum	Maximum	Mean	Std Dev
Original:	1.000	6.400	4.340	2.078
Log:	0.000	1.856	1.303	0.749

Pooled Statistics
Observations: 5

Statistic	Original Scale	Log Scale
Mean:	4.340	1.303
Std Dev:	2.078	0.749
Skewness:	-0.810	-1.296*
Kurtosis:	-0.555	-0.011
Minimum:	1.000	0.000
Maximum:	6.400	1.856
CV:	0.479	0.575

piro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.9037	0.7620	0.6860

Log:	0.7615*	0.7620	0.6860

Indicates statistically significant evidence of non-normality.
RIT/STAT Version 5.0

Parametric Prediction Interval

Report Printed February 2,2005

Facility:Haz. Waste Unit 16 - RAAP
Parameter:Chloroethane(CAS Number:75-00-3)

ONE-TAILED UPPER PARAMETRIC PREDICTION INTERVAL

Observations (n): 5
Shapiro-Wilk (W): 0.9037
Critical W,α=0.01: 0.6860
Mean: 4.340 ppb
Std Dev: 2.078 ppb
DF: 4
Conf. Level (1-α): ~~0.9500~~ 0.99
Future Samples (k): 10
$t_{\left[1-\frac{\alpha}{k}\right]}$: 7.1732
Kappa: 7.8579

UL: 20.669 ppb
LL: $-\infty$

ormality Tests

Report Printed: 02-02-2005 13:49

Facility:RAAPHWMU16 Haz. Waste Unit 16 - RAAP

Address:

City:Radford ST:VA Zip:24141
County:PULASKI

Contact:
Phone:( ) -

Permit Type:Detection

Constituent:DEthEth Diethyl ether

CAS Number: - -
MCL: 0.000 ppb
ACL: 0.000 ppb
Detect Limit: 24.000 ppb

Start Date:Mar 31 1996
End Date:Dec 22 1999

Normality Test on Observations for wells listed below:

Well:16C1 Position:Upgradient Observations:5

Scale	Minimum	Maximum	Mean	Std Dev
Original:	12.000	30.000	21.200	6.907
Log:	2.485	3.401	3.007	0.355

Pooled Statistics
Observations: 5

Statistic	Original Scale	Log Scale
Mean:	21.200	3.007
Std Dev:	6.907	0.355
Skewness:	-0.122	-0.491
Kurtosis:	-1.140	-1.024
Minimum:	12.000	2.485
Maximum:	30.000	3.401
CV:	0.326	0.118

piro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.9768	0.7620	0.6860

```
Log:    0.9507       0.7620       0.6860

Indicates statistically significant evidence of non-normality.
RIT/STAT Version 5.0
```

Parametric Prediction Interval
Report Printed February 2,2005

Facility:Haz. Waste Unit 16 - RAAP
Parameter:Diethyl ether(CAS Number:- -)

ONE-TAILED UPPER PARAMETRIC PREDICTION INTERVAL

Observations (n): 5
Shapiro-Wilk (W): 0.9768
Critical W,α=0.01: 0.6860
Mean: 21.200 ppb
Std Dev: 6.907 ppb
DF: 4
Conf. Level (1-α): ~~0.9500~~ 0.99
Future Samples (k): 10
$t_{\left[1-\frac{\alpha}{k}\right]}$: 7.1732
Kappa: 7.8579

UL: 75.470 ppb
LL: -∞

Normality Tests

Report Printed: 02-02-2005 13:53

Facility:RAAPHWMU16 Haz. Waste Unit 16 - RAAP

Address:

City:Radford ST:VA Zip:24141
County:PULASKI

Contact:
Phone:( ) -

Permit Type:Detection

Constituent:DMethEth Dimethyl ether

CAS Number: - -
MCL: 0.000 ppb
ACL: 0.000 ppb
Detect Limit: 24.000 ppb

Start Date:Mar 31 1996
End Date:Dec 22 1999

Normality Test on Observations for wells listed below:

Well:16C1 Position:Upgradient Observations:5

Scale	Minimum	Maximum	Mean	Std Dev
Original:	12.000	17.000	13.000	2.236
Log:	2.485	2.833	2.555	0.156

Pooled Statistics
Observations: 5

Statistic	Original Scale	Log Scale
Mean:	13.000	2.555
Std Dev:	2.236	0.156
Skewness:	1.500*	1.500*
Kurtosis:	0.250	0.250
Minimum:	12.000	2.485
Maximum:	17.000	2.833
CV:	0.172	0.061

Shapiro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.5521*	0.7620	0.6860

```
Log:    0.5521*     0.7620      0.6860

* Indicates statistically significant evidence of non-normality.
RIT/STAT Version 5.0
```

Nonparametric Prediction Interval

Report Printed February 2,2005

Facility:Haz. Waste Unit 16 - RAAP
Parameter:Dimethyl ether(CAS Number:- -)

ONE-TAILED UPPER PARAMETRIC PREDICTION INTERVAL

Observations (n):	5
Conf. Level (1-α):	33 330%

UL: 17.000 ppb
LL: 0.000

Report Produced by GRITS/STAT 5.01

Normality Tests

Report Printed: 02-02-2005 13:54

Facility:RAAPHWMU16 Haz. Waste Unit 16 - RAAP

Address:

City:Radford ST:VA Zip:24141
County:PULASKI

Contact:
Phone:( ) -

Permit Type:Detection

Constituent:MeCl Dichloromethane (Methylene chloride)

CAS Number: 75-09-2
MCL: 0.000 ppb
ACL: 0.000 ppb
Detect Limit: 2.000 ppb

Start Date:Mar 31 1996
End Date:Dec 22 1999

Normality Test on Observations for wells listed below:

Well:16C1 Position:Upgradient Observations:5

Scale	Minimum	Maximum	Mean	Std Dev
Original:	4.100	6.800	5.800	1.037
Log:	1.411	1.917	1.743	0.197

Pooled Statistics
Observations: 5

Statistic	Original Scale	Log Scale
Mean:	5.800	1.743
Std Dev:	1.037	0.197
Skewness:	-0.925	-1.088*
Kurtosis:	-0.436	-0.263
Minimum:	4.100	1.411
Maximum:	6.800	1.917
CV:	0.179	0.113

Shapiro-Wilk Statistics

Scale	Test Statistic	5% Critical Value	1% Critical Value
Original:	0.8964	0.7620	0.6860

Log: 0.8519 0.7620 0.6860

Indicates statistically significant evidence of non-normality.
RIT/STAT Version 5.0

Parametric Prediction Interval
Report Printed February 2,2005

Facility:Haz. Waste Unit 16 - RAAP
Parameter:Dichloromethane (Methylene chloride(CAS Number:75-09-2)

ONE-TAILED UPPER PARAMETRIC PREDICTION INTERVAL

Observations (n): 5
Shapiro-Wilk (W): 0.8964
Critical W,α=0.01: 0.6860
Mean: 5.800 ppb
Std Dev: 1.037 ppb
DF: 4
Conf. Level (1-α): ~~0.9500~~ 0.99
Future Samples (k): 10
$t_{\left[\frac{1-\alpha}{k}\right]}$: 7.1732
Kappa: 7.8579

UL: 13.947 ppb
LL: $-\infty$

Target Analyte Monitoring Results - HWMU-16 Point of Compliance Wells
Radford Army Ammunition Plant, Radford, Virginia

Upgradient well = 16C1 *All Results in ug/L.*

Analyte/Quarter	16C1	16MW8	16MW9	16WC1A	16WC1B	QL	GPS	Method
Chloroethane					CAS # 75-00-3			
Third Quarter 2003	6.4	U	4.8	U	U	1	20.7	8260B
Fourth Quarter 2003	5.7	U	2.6	1.1	U	1	20.7	8260B
First Quarter 2004	U J	U J	U J	U J	U J	1	20.7	8260B
Second Quarter 2004	4.4	U	2.4	0.63 J	U	1	20.7	8260B
Third Quarter 2004	4.2	U	2	U	U	1	20.7	8260B
Fourth Quarter 2004	4.9	U	2.5	U	U	1	20.7	8260B
First Quarter 2005	7.6 J	U J	3.7 J	U J	U J	1	20.7	8260B
Second Quarter 2005	U J	U	U J	U	U	1	20.7	8260B
Third Quarter 2005	4.7 J	U J	U	U J	U J	1	20.7	8260B
Fourth Quarter 2005	4.6 J	U	2.6 J	U	U	1	20.7	8260B
First Quarter 2006	5.3	U	U	U	U	1	20.7	8260B
Second Quarter 2006	5 J	U	2 J	U	U	1	20.7	8260B
Third Quarter 2006	5	U	0.7 J	0.7 J	U	1	20.7	8260B
Fourth Quarter 2006	5.8	U	1	U	U	1	20.7	8260B
First Quarter 2007	6.1	U	1	U	U	1	20.7	8260B
Second Quarter 2007	5.2	U	1.4	U	U	1	20.7	8260B
Diethyl ether					CAS # 60-29-7			
Third Quarter 2003	12 J	U	12 J	U	U	12	-	8260B
Fourth Quarter 2003	30	U	14	U	U	12	-	8260B
First Quarter 2004	24	U	U	U	U	12	-	8260B
Second Quarter 2004	23 J	U J	13 J	U J	U J	12	-	8260B
Third Quarter 2004	17	U	U	U	U	12	-	8260B
Fourth Quarter 2004	24	U J	U	U	U J	12	-	8260B
First Quarter 2005	29	U	14	U	U	12	-	8260B
Second Quarter 2005	20	U J	9.2	U J	U J	12	-	8260B
Third Quarter 2005	30	U	15	U	U	12	-	8260B
Fourth Quarter 2005	25	U	18	U	U	12	-	8260B
First Quarter 2006	19	U	U	U	U	12	-	8260B
Second Quarter 2006	17	U	U	U	U	12.5	-	8260B
Third Quarter 2006	33	1.5 J	4.3 J	4.6 J	U	12.5	-	8260B
Fourth Quarter 2006	20	U	U	U	U	12.5	-	8260B
First Quarter 2007	21	U	U	U	U	12.5	-	8260B
Second Quarter 2007	17 J	1.5 J	5.7 J	2.1 J	U J	12.5	-	8260B
Dimethyl ether					CAS # 115-10-6			
Third Quarter 2003	6.6 J	U	9.9 J	U	U	12	-	8260B
Fourth Quarter 2003	U	U	U	U	U	12	-	8260B
First Quarter 2004	17 J	U J	13 J	U J	U J	12	-	8260B
Second Quarter 2004	U J	U J	6.6 J	U J	U J	12	-	8260B
Third Quarter 2004	U J	U J	U J	U J	U J	12	-	8260B
Fourth Quarter 2004	16 J	U J	12 J	U	U J	12	-	8260B
First Quarter 2005	26	U	25	U	U	12	-	8260B
Second Quarter 2005	15	U	14	U	U	12	-	8260B
Third Quarter 2005	13	U	U	U	U	12	-	8260B
Fourth Quarter 2005	U	U	U	U	U	12	-	8260B
First Quarter 2006	U	U	U	U	U	12	-	8260B
Second Quarter 2006	U	U	U	U	U	12.5	-	8260B
Third Quarter 2006	11 J	U J	3.2 J	2.8 J	U J	12.5	-	8260B
Fourth Quarter 2006	U	U	U	U	U	12.5	-	8260B
First Quarter 2007	U	U	U	U	U	12.5	-	8260B
Second Quarter 2007	11 J	U	7 J	2.6 J	1.2 J	12.5	-	8260B

See last page of this report for definitions.

Target Analyte Monitoring Results - HWMU-16 Point of Compliance Wells
Radford Army Ammunition Plant, Radford, Virginia

Upgradient well = 16C1

All Results in ug/L.

Analyte/Quarter	*16C1*	*16MW8*	*16MW9*	*16WC1A*	*16WC1B*	*QL*	*GPS*	*Method*
Methylene chloride					*CAS #*	*75-09-2*		
Third Quarter 2003	4 1	U	U	U	U	1	13 95	8260B
Fourth Quarter 2003	6 8	U	U	U	U	1	13 95	8260B
First Quarter 2004	6 4	U	U	U	U	1	13 95	8260B
Second Quarter 2004	5 7	U	U	U	U	1	13 95	8260B
Third Quarter 2004	6	U A	U A	U A	U A	1	13 95	8260B
Fourth Quarter 2004	6 4	U	U	U	U	1	13 95	8260B
First Quarter 2005	6 8 J	U	U	U	U	1	13 95	8260B
Second Quarter 2005	6 3	U	U	U	U	1	13 95	8260B
Third Quarter 2005	6 2	U	U	U	U	1	13 95	8260B
Fourth Quarter 2005	4 7	U	U	U	U	1	13 95	8260B
First Quarter 2006	4 9	U	U	U	U	1	13 95	8260B
Second Quarter 2006	7	U	U	U	U	1	13 95	8260B
Third Quarter 2006	U N	U N	U N	U N	U N	1	13 95	8260B
Fourth Quarter 2006	U A	U	U	U A	U	1	13 95	8260B
First Quarter 2007	6 3	U	U	U	U	1	13 95	8260B
Second Quarter 2007	3 4	U	U	U	U	1	13 95	8260B
1,1,2-Trichloro-1,2,2-Trifluoroethane					*CAS #*	*76-13-1*		
Third Quarter 2003	U	U	U	U	U	1	-	8260B
Second Quarter 2004	1 2	U J	U J	U J	U J	1	-	8260B
Third Quarter 2004	U	U	U	U	U	1	-	8260B
Fourth Quarter 2004	U	U	U	U	U	1	-	8260B
First Quarter 2005	1	U	U	U	U	1	-	8260B
Second Quarter 2005	U	U	U	U	U	1	-	8260B
Third Quarter 2005	U	U	U	U	U	1	-	8260B
Fourth Quarter 2005	U	U	U	U	U	1	-	8260B
First Quarter 2006	U	U	U	U	U	1	-	8260B
Second Quarter 2006	U	U	U	U	U	1	-	8260B
Third Quarter 2006	U	U	U	U	U	1	-	8260B
Fourth Quarter 2006	U	U	U	U	U	1	-	8260B
First Quarter 2007	U	U	U	U	U	1	-	8260B
Second Quarter 2007	U	U	U	U	U	1	-	8260B

See last page of this report for definitions.

Analyte/Quarter	*16C1*	*16MW8*	*16MW9*	*16WC1A*	*16WC1B*	*QL*	*GPS*	*Method*

Definitions: QL Denotes permit required quantitation limit. U Denotes analyte not detected at or above QL. UA Denotes analyte not detected at or above adjusted sample QL. J Denotes associated result is estimated When used with "U" (i e , "UJ"), denotes analyte not detected at or above QL and QL is estimated When used with "UA" (i.e , "UAJ"), denotes analyte not detected at or above adjusted QL and adjusted QL is estimated UN Denotes analyte concentration is less than the quantiation limit and five times the blank concentration Not reliably detected due to blank contamination This qualifier used only for Appendix IX monitoring event when results are reported to at or above the project detection limit R Denotes result rejected Q Denotes data validation qualifier CAS# Denotes Chemical Abstract Services registration number X Denotes mass spectral confirmation not obtained-result suspect.

GPS Denotes Groundwater Protection Standards listed in Appendix G to Attachment 5 in the Final Hazardous Waste Post-Closure Care Permit for Hazardous Waste Units 5, 7, 10, and 16 (October 4, 2002)
NS denotes not sampled NA denotes not analyzed. "–" denotes not detected (pre-2nd Quarter 2003) or not available / not sampled (beginning 2nd Quarter 2003)

Notes:
-Appendix IX Groundwater Monitoring Events·
Third Quarter 2003, Second Quarter 2004, Second Quarter 2005, Third Quarter 2006, Second Quarter 2007
For Appendix IX monitoring events, all results evaluated to detection limit. See laboratory data deliverable for detection limit.

-9/30/2003 Verification sampling event for 16C1 (heptachlor) and 16C1B (Endrin) Verification results all results reported not detected to detection limit Original results 0 067 µg/l and 0 39 µg/l, respectively Confirmation results reported in this table.
-9/30/2003 Verification sampling event for 16C1 (chloroethane, ethyl ether, methyl ether, methylene chloride) and 16MW9 (chloroethane, ethyl ether, methyl ether) Verification results all results confirmed original analysis. Original results reported in this table.
-June 21, 2004 Verification event for 8260B 16C1 (1,1-dichloroethene and 1,1,2-trichloro-1,2,2-trifluoroethane) Verification results all not detected except 1,1,2-trichloro-1,2,2-trifluoroethane added to quarterly analyte list beginning 3Q 2004
Due to laboratory error, Appendix IX results for semivolatiles (Method 8270C) will be presented in 3Q 2004 Verification event results for 16WC1B and 16C1 (8081A) – all verification results were not confirmed.
-07/27-28/2005 Verification event for 16WC1B (Mercury Method 7470A) Not detected in verification sample
Also, verification event for 16C1, 16WC1B-8081A and 16C1, 16MW9, 16WC1A-ethanol All verification results not detected Verification results used.
-06/19/2007 Verification event for 16WC1B and 16MW9 thallium Not detected in verification sample Verification results used

ATK

ATK Armament Systems
Energetic Systems
Radford Army Ammunition Plant
Route 114, PO Box 1
Radford, VA 24143-0100

www.atk.com

August 1, 2011

Jutta Schneider
Program Manager
Office of Remediation Programs
Virginia Department of Environmental Quality
629 East Main Street
Richmond, Virginia 23219

Subject: Additional Appendix IX Groundwater Monitoring Results - Final Notification
Post-Closure Care Permit HWMUs 5, 7, 10, & 16
Radford Army Ammunition Plant, Radford, Virginia
EPA ID#: VA1210020730

Reference: ATK Letter No 11-815-90 Dated June 23, 2011

Dear Ms. Schneider:

During Second Quarter 2011, Alliant Techsystems Inc. completed semiannual groundwater monitoring for Hazardous Waste Management Units (HWMUs) 5, 7, 10, and 16 located at the Radford Army Ammunition Plant (Radford AAP) in Radford, Virginia. The Second Quarter 2011 groundwater monitoring event also served as annual monitoring under 40 CFR 264 Appendix IX for HWMUs 7, 10, and 16.

Verification samples were collected on June 27, 2011 at HWMUs 7 and 16 to confirm or refute the detection of additional Appendix IX constituents listed in the table below.

Well Location	Constituent(s)	Result
	HWMU-7	
7W11B	Benzene	Not Verified
7MW6	Benzene; Diethyl ether	Not Verified
	HWMU-16	
16WC1B	4,4'-DDD	Not Verified
16WC1A	Benzene	Not Verified
16MW9	Benzene	VERIFIED, Add to List

The verification sample results confirmed only the presence of the additional Appendix IX constituent, benzene, in point of compliance well 16MW9. Benzene was detected below the LOQ in well 16MW9; therefore, benzene will be added to the compliance monitoring list for HWMU-16. No other additional Appendix IX constituents were detected in the verification samples collected at HMWUs 7 and 16.

The permit requires collection of four quarters of monitoring data from a Unit's upgradient well(s) to establish background values for newly detected Appendix IX constituents. However, Alliant Techsystems Inc. has collected benzene data from HWMW-16 upgradient monitoring well 16C1 during the previous nine annual Appendix IX groundwater monitoring events (2003-2011). Benzene has never been detected at or above the LOQ in upgradient well 16C1; therefore, in lieu of quarterly background monitoring, we propose to use these data to set the background value for benzene at the LOQ of 1 μg/l and the groundwater protection standard (GPS) at the USEPA maximum contaminant level (MCL) of 5 μg/l.

Complete details regarding the Second Quarter 2011 monitoring event (field data, laboratory data, and data validation reports) will be forwarded to the VDEQ in the forthcoming *Semiannual Groundwater Monitoring Report for Hazardous Waste Management Units 5, 7, 10, and 16, Second Quarter 2011*, which is due to the VDEQ by August 15, 2011. However, Alliant Techsystems Inc. has submitted a request to the VDEQ for a 60-day extension to the August 15, 2011 reporting deadline; a response to the request is pending.

If you have any questions or concerns, please contact Mr. Jeremy Flint at 540/639-7668 (Jeremy.Flint@ATK.COM).

Sincerely,

Paige Holt

Paige Holt, Environmental Manager
Alliant Techsystems Inc.

c: Aziz Farahmand, VDEQ-BRRO
Fuxing Zhou, VDEQ-Central

11-815-106
JFlint

Coordination: J McKenna
J. McKenna

MMMiano
M. A. Miano

bc: P. W. Holt
J. McKenna, ACO Staff
Jeremy Flint
Mike Lawless, Draper Aden Associates
Env. File

11-815-106
JFlint

Concerning the following:

CY 2011 Second Quarter Semiannual Monitoring Event
Additional Appendix IX Groundwater Monitoring Results - Final Notification
Radford Army Ammunition Plant, Radford, Virginia
EPA ID#: VA1210020730

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 who manage the system, or those 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 fines and imprisonment for knowing violations.

SIGNATURE:
PRINTED NAME: for Wm Byron Penland
TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE:
PRINTED NAME: Kent D. Holiday
TITLE: Vice President and General Manager
ATK Energetics Systems

11-815-106
JFlint

REV 1- class i permit mod 2014

ATTACHMENT 3
UNIT 16

APPENDIX G

GROUNDWATER PROTECTION STANDARDS (GPS)

class 1 permit mod - 9-2014

Appendix G to Attachment 3

GROUNDWATER PROTECTION STANDARDS: UNIT 16

Unit: μg/l Unless Otherwise Noted

Constituents/Parameters	864 Methods	PQL	Back-ground	EPA MCL	ACL RSL	GPS
Arsenic, total	6010/6020	10	1	10		10
Barium, total	6010/6020	10	175.4	2000		2000
Beryllium, total	6010/6020	1	0.7	4		4
Cadmium, total	6010/6020	1	0.2	5		5
Chromium, total	6010/6020	5	6.2	100		100
Cobalt, total	6010/6020	5	5		4.7	5
Copper, total	6010/6020	5	13	1300*		1300*
Lead, total	6010/6020	1	10	15*		15*
Mercury, total	7470	2	0.2	2		2
Nickel, total	6010/6020	10	16		300	300
Vanadium, total	6010/6020	10	151		63	151
Zinc, total	6010/6020	10	51		4700	4700
Benzene	8260	1	1	5		5
2-Butanone; Methyl ethyl ketone (MEK)	8260	10	1.1		4900	4900
Carbon tetrachloride	8260	1	0.2	5		5
Chloroethane	8260	1	20.7		21000	21000
Dichlorodifluoromethane	8260	1	46.5		190	190
1,1-Dichloroethane;	8260	1	9.5		0.15	9.5
1,1-Dichloroethene	8260	1	1	7		7
Diethyl ether	8260	12.5	75.5		7300/RSL	7300
Dimethyl ether;	8260	12.5	17			17
Ethylbenzene; Phenylethane	8260	1	0.1	700		700
Methylene chloride	8260	1	13.95	5		13.95
Tetrachloroethene (PCE)	8260	1	0.7	5		5
Chloromethane	8260	1	0.3		190	190
Toluene	8260	1	0.1	1000		1000
1,1,1-Trichloroethane; Methylchloroform;	8260	1	9.2	200		200
Trichloroethene	8260	1	0.1	5		5

Trichlorofluoromethane	8260	1	11.3		1000	1000
Trifluorotrichloroethane (1,1,2-Trichloro-1,2,2-Trifluoroethane)	8260	1	1.2		59000/RSL	59000
Xylenes (total); 1,3-, 1,2-, & 1,4-Dimethylbenzene	8260	3	0.2	10000		10000
Diethyl phthalate	8270	5	5		11000	11000
2,4-Dinitrotoluene	8270	10	10		0.2	10
2,6-Dinitrotoluene	8270	10	10		0.042	10

NOTES:

EPA MCL: Maximum Contaminant Level of USEPA National Primary Drinking Water Regulations (web: http://water.epa.gov/drink/contaminants/index.cfm#Primary; June 2, 2010). * - Action Level. Subject to change without notice as directed by DEQ.

Background: Calculated using analytical data from 1996 through 1998 for upgradient well 16C1.

DEQ ACL: VA DEQ Alternate Concentration Limit, Dec - 2013. Subject to change without notice as directed by DEQ.

RSL: RSL are developed by Oak Ridge National Laboratory under an Interagency Agreement with EPA (June 2011). See web site "Mid-Atlantic Risk Assessment" at http://www.epa.gov/reg3hwmd/risk/human/index.htm Subject to change without notice as directed by DEQ.

For any monitoring event, if a GPS for a constituent in the table above is based on PQL, the Permittee will perform verification of a detection (i.e. value greater than the Detection Limit) of such a constituent using low-level analytical methods, if such methods are standard methods that are routinely available from commercial laboratories. Furthermore, the low-level analytical method will be used only if the PQL achievable by that method is less than, or equal to, the ACL or RBC for the subject constituent. If the verification event confirms a quantifiable detection (i.e. value greater than the PQL) above the applicable ACL or RBC, a revised background concentration will be established using low-level analytical methods, if appropriate, and the GPS will be updated based on the new background concentration if warranted.

Modified: 9-12-2014 - added 1,1-DCE – Class 1

ATTACHMENT 3
UNIT 16

APPENDIX G

GROUNDWATER PROTECTION STANDARDS (GPS)

do not use. Updated 9-2014 - class 1 permit mod

Appendix G to Attachment 3
GROUNDWATER PROTECTION STANDARDS: UNIT 16

Unit: µg/l Unless Otherwise Noted

Constituents/Parameters	864 Methods	PQL	Back-ground	EPA MCL	ACL RSL	GPS
Arsenic, total	6010/6020	10	1	10		10
Barium, total	6010/6020	10	175.4	2000		2000
Beryllium, total	6010/6020	1	0.7	4		4
Cadmium, total	6010/6020	1	0.2	5		5
Chromium, total	6010/6020	5	6.2	100		100
Cobalt, total	6010/6020	5	5		4.7	5
Copper, total	6010/6020	5	13	1300*		1300*
Lead, total	6010/6020	1	10	15*		15*
Mercury, total	7470	2	0.2	2		2
Nickel, total	6010/6020	10	16		300	300
Vanadium, total	6010/6020	10	151		63	151
Zinc, total	6010/6020	10	51		4700	4700
Benzene	8260	1	1	5		5
2-Butanone; Methyl ethyl ketone (MEK)	8260	10	1.1		4900	4900
Carbon tetrachloride	8260	1	0.2	5		5
Chloroethane	8260	1	20.7		21000	21000
Dichlorodifluoromethane	8260	1	46.5		190	190
1,1-Dichloroethane;	8260	1	9.5		0.15	9.5
Diethyl ether	8260	12.5	75.5		7300/RSL	7300
Dimethyl ether;	8260	12.5	17			17
Ethylbenzene; Phenylethane	8260	1	0.1	700		700
Methylene chloride	8260	1	13.95	5		13.95
Tetrachloroethene (PCE)	8260	1	0.7	5		5
Chloromethane	8260	1	0.3		190	190
Toluene	8260	1	0.1	1000		1000
1,1,1-Trichloroethane; Methylchloroform;	8260	1	9.2	200		200
Trichloroethene	8260	1	0.1	5		5
Trichlorofluoromethane	8260	1	11.3		1000	1000

Trifluorotrichloroethane (1,1,2-Trichloro-1,2,2-Trifluoroethane)	8260	1	1.2		59000/RSL	59000
Xylenes (total): 1,3-, 1,2-, & 1,4-Dimethylbenzene	8260	3	0.2	10000		10000
Diethyl phthalate	8270	5	5		11000	11000
2,4-Dinitrotoluene	8270	10	10		0.2	10
2,6-Dinitrotoluene	8270	10	10		0.042	10

NOTES:

EPA MCL: Maximum Contaminant Level of USEPA National Primary Drinking Water Regulations (web: http://water.epa.gov/drink/contaminants/index.cfm#Primary; June 2, 2010). * - Action Level. Subject to change without notice as directed by DEQ.

Background: Calculated using analytical data from 1996 through 1998 for upgradient well 16C1.

DEQ ACL: VA DEQ Alternate Concentration Limit, Dec - 2013. Subject to change without notice as directed by DEQ.

RSL: RSL are developed by Oak Ridge National Laboratory under an Interagency Agreement with EPA (June 2011). See web site "Mid-Atlantic Risk Assessment" at http://www.epa.gov/reg3hwmd/risk/human/index.htm Subject to change without notice as directed by DEQ.

For any monitoring event, if a GPS for a constituent in the table above is based on PQL, the Permittee will perform verification of a detection (i e value greater than the Detection Limit) of such a constituent using low-level analytical methods, if such methods are standard methods that are routinely available from commercial laboratories. Furthermore, the low-level analytical method will be used only if the PQL achievable by that method is less than, or equal to, the ACL or RBC for the subject constituent If the verification event confirms a quantifiable detection (i e value greater than the PQL) above the applicable ACL or RBC, a revised background concentration will be established using low-level analytical methods, if appropriate, and the GPS will be updated based on the new background concentration if warranted

ATTACHMENT 3
UNIT 16

APPENDIX H

BORING LOGS AND WELL CONSTRUCTION DIAGRAMS

Site 16
Ground Water Monitoring Well Construction Details

Well I.D.	Ground Elevation	UTM Coordinates		Boring Termination Depth	Top of Well Screen	Total Well Depth	Screen Length	Comments
		Northing	Easting					
16C-1	1836.78	3,601,325	10,892,905	70	55	70	15	1
16MW8	1815.82	3,601,520	10,893,440	76	66	76	10	1
16MW9	1808.88	3,601,480	10,893,420	79	69	79	10	1
16WC1B	1812.95	3,601,380	10,893,440	79.3	62	73	11	1
16WC1A	1812.61	3,601,380	10,893,440	100	82.5	93.5	11	1
16-1	1813.88	3,601,720	10,893,340	60	30	60	30	1
16-2	1808.78	3,601,560	10,893,560	77	52	77	25	1
16-3	1823.83	3,601,150	10,893,525	89.5	69.5	89.5	20	1
16-5	1739.50	3,601,830	10,894,020	50.71	35.71	50.71	15	4 6
16WC2B	1818.71	3,601,570	10,893,370	104	91	102.5	11.5	1
SPRING								

Comments:
1) Well construction details obtained from boring log.
2) Well screen length obtained from boring log.
3) Well screen length obtained from other data on file.
4) Well screen length assumed.
5) Total well depth obtained from boring log.
6) Total well depth obtained from field sampling log.

16WC2A

16C3

16CDH3

Attachment P

BORING LOGS AND WELL CONSTRUCTION DIAGRAMS

Appendix 1.	General Information
Appendix 2.	Well 16C1 - Background
Appendix 3.	Well 16MW8 - POC
Appendix 4.	Well 16MW9 – POC
Appendix 5.	Well 16WC1A – POC
Appendix 6.	Well 16WC1B – POC
Appendix 7.	Well 16-1 – Compliance Monitoring Well
Appendix 8.	Well 16-2 – Compliance Monitoring Well
Appendix 9.	Well 16-3 – Compliance Monitoring Well
Appendix 10.	Well 16-5 – Compliance Monitoring Well
Appendix 11.	Well 16WC2B – Compliance Monitoring Well
Appendix 12.	Well 16SPRING - Additional Sampling Point
Appendix 13.	Well 16WC2A – Piezometer
Appendix 14.	Well 16C3 – Piezometer
Appendix 15.	Well 16CDH3 - Piezometer
Appendix 16.	Other Wells

Appendix 1.

General Information

TABLE 3 - GROUND WATER MONITORING SYSTEM SUMMARY TABLE FOR HWMU 16

WELLS	TYPE	STATUS	TD	DATE DRILLED	BORING LOG	COMPLETE DIAGRAM	DATUM		SCREEN						GROUT		ANNULAR SEALANT		FILTER PACK		hydraulic conductivity	
							G.L.	T.O.C.	LENGTH	SIZE	SLOT	TYPE	TOP	BASE	TOP	BASE	TOP	BASE	TOP	BASE	K (ft/sec)	K (cm/sec)
C-1	UP/BG	ACTIVE	70.00	08/01/80	YES	YES	1836.78	1840.10	16.00	2.00	0.01	PVC	56.00	70.00	0.00	39.00	39.00	40.00				
MW-8	POC	ACTIVE	78.00	01/17/88	YES	YES			10.00	2.00	#10	TEFLON	60.00	78.00	0.00	58.00	58.00	60.00	60.00	76.00		
MW-9	POC	ACTIVE	79.00	08/22/88	YES	YES			10.00	2.00	#10	TEFLON			0.00	61.00	61.00	64.00	64.00	79.00		
WC-18	POC	ACTIVE	79.30	10/08/87	YES	YES	1812.04	1813.83	10.00	2.00	0.01	TEFLON	63.00	73.00	0.00	57.00	57.00	62.00	62.00	79.30	3.12E-04	9.52E-03
16-1	ASMT	ACTIVE	60.00	10/26/84	YES	YES	1813.88		30.00				30.00	60.00								
16-2	ASMT	ACTIVE	72.00	10/26/84	YES	YES	1806.78		25.00				47.00	72.00								
16-3	ASMT	ACTIVE	89.60	10/30/84	YES	YES	1823.83		20.00				60.00	80.00								
16-5	ASMT	ACTIVE	64.60	10/23/86	YES		1739.50		20.00			SS										
C-3	ASMT	ACTIVE	70.00	07/29/80	YES	YES	1819.22	1822.16	16.00	2.00	0.01	PVC80	56.00	70.00	0.00	39.00	39.00	40.00				
CDH-3	ASMT	ACTIVE	66.00	07/24/80	YES	YES			16.00	2.00		PVC	61.60	66.60								
WC-1A	ASMT	ACTIVE	93.60	10/06/87	YES	YES	1811.42	1813.61	10.00	2.00	0.01	TEFLON	83.60	93.60	0.00	77.50	77.50	82.50	82.50	100.00	9.14E-06	2.79E-04
WC-2A	ASMT	ACTIVE	89.60	10/31/87	YES	YES	1817.36	1818.97	10.00	2.00	0.01	TEFLON	59.50	69.60	0.00	53.00	53.00	58.00	58.00	82.00	5.02E-06	1.53E-04
WC-2B	ASMT	ACTIVE	102.50	10/19/87	YES	YES	1817.83	1819.64	10.00	2.00	0.01	TEFLON	92.50	102.50	0.00	66.00	66.00	91.00	91.00	104.00	3.37E-07	1.03E-06
SPRING	ASMT																					
16-4	UP	SWL	80.00	11/02/84	YES	YES	1836.03		35.00				45.00	80.00								
C-4	UP	SWL	70.00	07/29/80	YES	YES	1824.61	1827.71	15.00	2.00	0.01	PVC	66.00	70.00	0.00	39.00	39.00	40.00				
CDH-2	UP	SWL	70.60	07/23/80	YES	YES	1824.10	1827.71	20.00	2.00			41.20	61.20	0.00	34.20	34.20	38.20	34.20	61.20		
DH-1	UP	INACTIV	73.00	02/28/80	YES	YES	~1840	~1843.6	10.00	1.50	NS	PVC	62.00	72.00	0.00	46.00	46.00	50.00	60.00	72.00		
DH-1A	COREH	INACTIV	94.00		YES	YES	~1840															
C-2		ABND	70.00	07/30/80	YES	YES	1806.20	1806.18	16.00	2.00	0.01	PVC	65.00	70.00	0.00	39.00	39.00	40.00				

03/24/95

Appendix 2.

Well 16C1 (Background)

UP/BG

SITE 16 / C-1

Geraghty
& Miller, Inc.

WELL LOG

PROJECT RADFORD
CLIENT NUS
Date Prepared 7/31/80 By G.F.S

OWNER	Corps of Engineers
WELL No.	C-1
LOCATION	Site C - Solid Waste Landfill in use
TOPO SETTING	
GROUND ELEV.	1935.79

DRILLING STARTED	7/31/80
DRILLING COMPLETED	8/1/80
DRILLER	R. A. Monroe
TYPE OF RIG	C-40

WELL DATA

HOLE DIAM.	5" to 48 ft; 3" to 70 ft
TOTAL DEPTH	70 ft
CASING DIAM.	2 in Timco PVC
CASING LENGTH	55 ft
SCREEN DIAM.	2 in
SCREEN SETTING	55-70 ft
SCREEN SLOT & TYPE	.010 PVC
WELL STATUS	Completed

GROUT

TYPE OF GROUT	Neat cement
GROUT DEPTH	0-40 ft
VOLUME	2.2 cu ft
TYPE OF PLUG	Bentonite
PLUG DEPTH	38-40 ft
VOLUME	1 lb

DEVELOPMENT

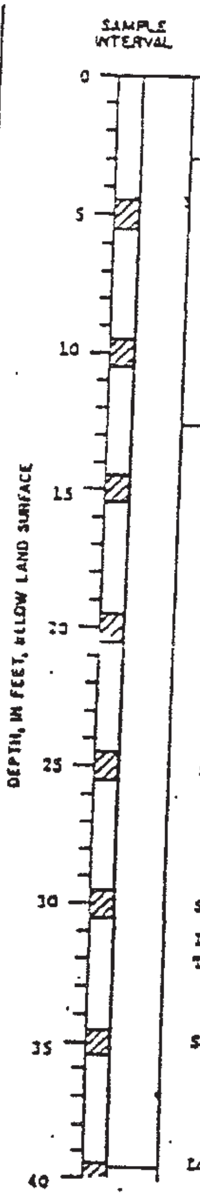
METHOD	Air
RATE	0.5 gpm
LENGTH	60 min

TEST DATA

STATIC DEPTH TO WATER	48.62
DATE MEASURED	8/11/80
PUMPING DEPTH TO WATER	
DURATION OF TEST	
PUMPING RATE	
DATE OF TEST	
TYPE OF TEST	
PUMP SETTING	
SPECIFIC CAPACITY	

FINAL PUMP CAPACITY	
FINAL PUMP SETTING	
AVERAGE PUMPAGE	

WATER QUALITY



Depth, in feet	DESCRIPTION
0	Clay, silty, brown
3	Silty, clayey, some fine sand, brown
10	Same as above
13	Sand, fine, silty, brown
20	Sand grades to medium River Jack
25	Same as above
30	Same as above In and out of River Jack to Top of Rock
35	Same as above
40	Lost circulation (10-15 gpm)

Geraghty
& Miller, Inc.

WELL LOG

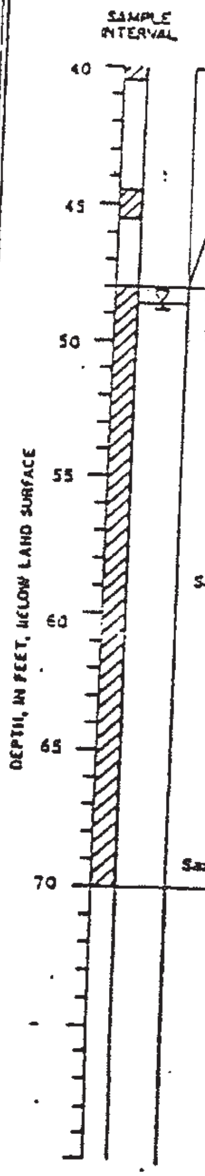
Page 2 of 2

PROJECT RADFORD
CLIENT NUS
Date Prepared 7/31/80 By G.F.S.

OWNER Corps of Engineers
WELL No C-1
LOCATION Site C - Solid Waste Landfill in use
TOPO SETTING
GROUND ELEV. 1936.78

DRILLING STARTED 7/31/80
DRILLING COMPLETED 8/1/80
DRILLER R. A. Monroe
TYPE OF RIG C-40

REMARKS



DESCRIPTION

Changed from 5" fishtail bit to 3" NX core barrel

Top of Rock

Water Table

Limestone, soft, calcite, greenish

Same as above

Same as above

Bottom of Hole

Appendix 3.

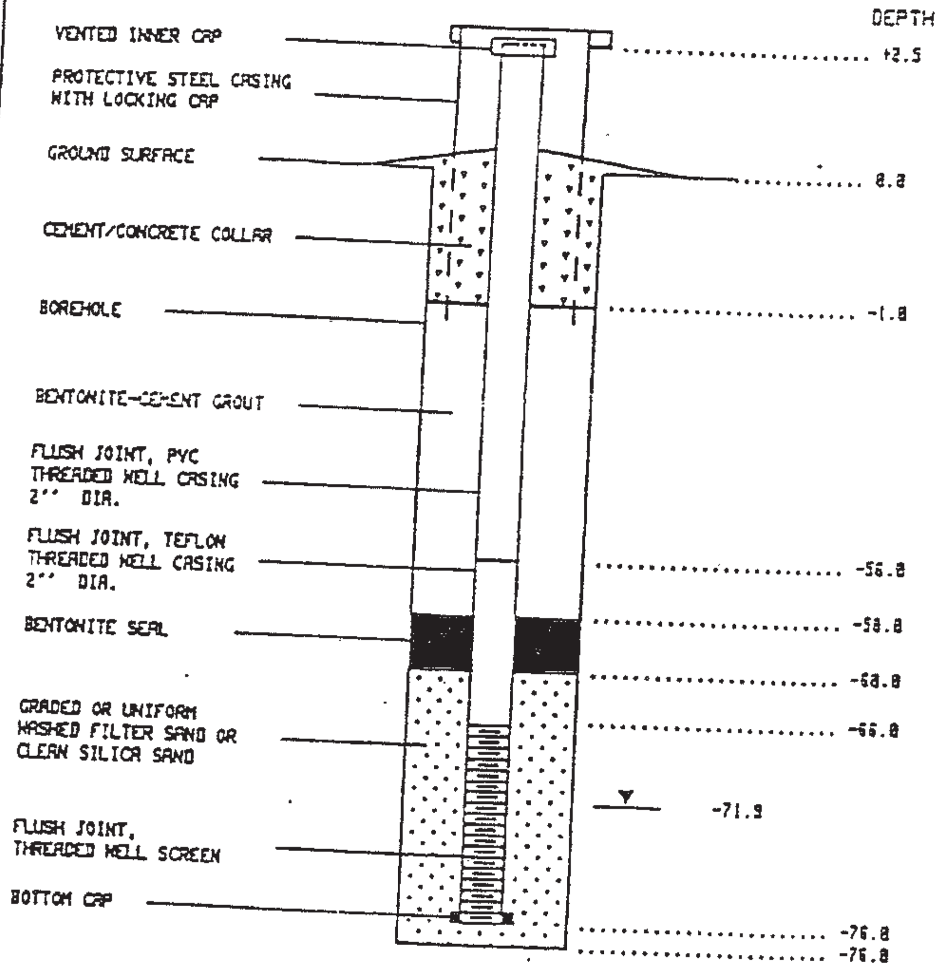
Well 16MW8 (Point of Compliance)

RAAP / SITE 16 / MW-8

WELL CONSTRUCTION DETAILS FOR MW-8 Pec

BORING NUMBER: MW-8
WELL TYPE: 2 in, Sch.40 PVC, Flush Joint
SCREEN TYPE: 2 in, No.10 Slot Teflon
CASING TYPE: 4 in, Sch.80 Steel
DEVELOPMENT: Air Pressure/Surge

Contract No. V801377
Date Water
Level Obtained: 1-24-89



NOT TO SCALE

SCHNABEL ENGINEERING

SCHNABEL ENGINEERING ASSOCIATES
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO.: MW-8
SHEET NO.: 1 OF 2
JOB NO.: V881377
ELEVATION:
CASING SIZE: 3-1/4"
DATE START: 1-16-89
DATE FINISHED: 1-17-89
DRILLER: R. EDWARDS
INSPECTOR: C. HALL

PROJECT: MONITORING WELL INSTALLATION HWM-16, RAAP, RADFORD, VA
CLIENT: HERCULES, INCORPORATED
BORING CONTRACTOR: TERROCK CORPORATION
DRILL: CME-55

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	1-16	2:30	40.0	-
AFTER CASING PULLED	1-17	10:15	68.0	-
___ HR. READING	MONITORING WELL INSTALLED			

DRIVE SAMPLER	
TYPE	S.S.
DIA.	2.00
WT	140#
FALL	30"

STRATUM	DEPTH FT.	ELEV.	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS POC
A	1.0			S	FINE TO COARSE SILTY SAND FILL, WET - BROWN	FILL
A2					REFUSE, CONTAINS SANDY LEAN CLAY, PLASTIC, PAPER AND CINDERS, MOIST - BLACK AND BROWN	REFUSE
			7+11+14	S	do, PERCHED WATER AT 5 FT	
	7.0					
A1			3+4+5	S	FINE TO MEDIUM SANDY LEAN CLAY PROBABLE FILL, MOIST - BROWN	PROBABLE FILL
			4+3+4	S		
	19.0					
			5+5+5	S	FINE TO MEDIUM SANDY LEAN CLAY (CL), MOIST - BROWN AND GRAY	ALLUVIAL
			8+7+9	S		
	27.0					
B			6+8+10	S	FINE TO MEDIUM CLAYEY SAND (SC), CONTAINS IRON OXIDE, MOIST - BROWN AND BLACK	
			3+4+7	S	do, BROWN	
			3+4+5	S	do, WET	
			3+3+4	S		
			4+4+5	S		

SCHNABEL ENGINEERING ASSOCIATES
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO: MW-9

PROJECT: MONITORING WELL INSTALLATION, HWM-16, RAAP, RADFORD, VA
CLIENT: HERCULES, INCORPORATED
BORING CONTRACTOR: TERROCK CORPORATION

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	1-16	-	-	-
AFTER CASING PULLED	1-17	-	-	-
__ HR. READING	MONITORING WELL INSTALLED			

DRILL: CME-55

DRIVE SAMPLER	
TYPE	S.S
DIA.	2.00"
WT.	140#
FALL	30"

SHEET NO: 2 OF 2
JOB NO: V881377
ELEVATION:
CASING SIZE: 3-1/4"
DATE START: 1-16-89
DATE FINISHED: 1-17-89
DRILLER: R. EDWARDS
INSPECTOR: C. HALL

STRATUM	DEPTH FT.	ELEV.	BLOWS ON SAMPLE SPOON PER 6"	SYMBOL	IDENTIFICATION	REMARKS
B					FINE TO MEDIUM CLAYEY SAND (SC), MOIST - BROWN	ALLUVIAL
			2+2+2	S	do, BROWN AND BLACK	
			4+6+8	S		
			3+3+3	S	do, TRACE GRAVEL	
			WOR+3+3	S	do, WET	
	72.0					
C						
	76.0		WOH/24"	S	FINE TO MEDIUM CLAYEY SAND (SC), CONTAINS ROCK FRAGMENTS, WET - BROWN	LIMESTONE RESIDUUM
					BORING TERMINATED AT 76.0 FT	

Appendix 4.

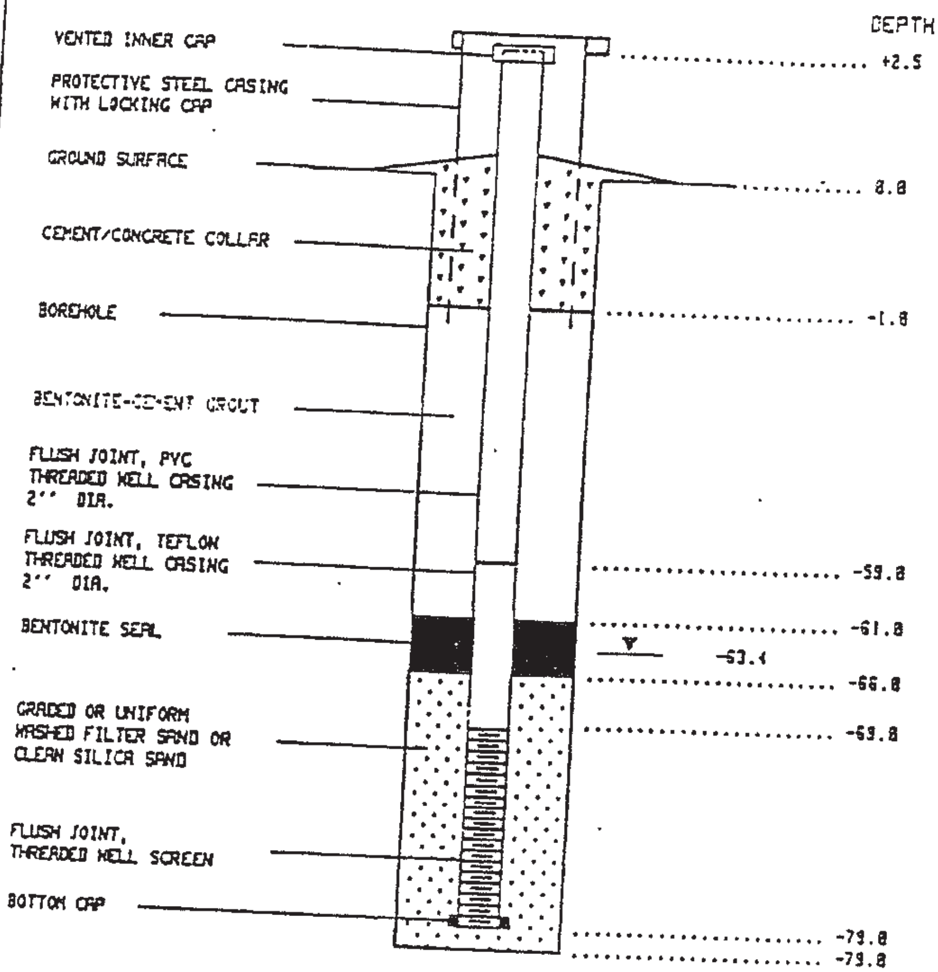
Well 16MW9 (Point of Compliance)

RAAP / SITE 16

WELL CONSTRUCTION DETAILS FOR MW-9 / POC

BORING NUMBER: MW-9
WELL TYPE: 2 in, Sch.40 PVC, Flush Joint
SCREEN TYPE: 2 in, No.10 Slot Teflon
CASING TYPE: 4 in, Sch.80 Steel
DEVELOPMENT: Air Pressure/Surge

Contract No. V851377
Date Water
Level Obtained: 9-25-89



NOT TO SCALE

SCHNABEL ENGINEERING

SCHNABEL ENGINEERING ASSOCIATES
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO: MW-9

PROJECT: MONITORING WELL INSTALLATION, MWH-16, RAAP, RADFORD, VA
CLIENT: HERCULES, INCORPORATED
BORING CONTRACTOR: TERROCK CORPORATION
DRILL: CME - 55

SHEET NO: 1 OF 4
JOB NO: V881377
ELEVATION:
CASING SIZE: 2-1/4
DATE START: 9/20/89
DATE FINISHED: 9/22/89
DRILLER: R. EDWARDS
INSPECTOR: C. HALL

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED
ENCOUNTERED	9/20	4:00	64.0	-
AFTER CASING PULLED	9/21	2:30	62.0	-
__ HR. READING	MONITORING WELL INSTALLED			

DRIVE SAMPLER	
TYPE	S.S.
DIA.	2.00
WT	140#
FALL	30

STRATUM	DEPTH FT.	ELEV.	BLOWS ON SAMPLE SPOON, PER 6"	SYMBOL	IDENTIFICATION	REMARKS POC
A			WOH+3+6	S	FINE TO MEDIUM SANDY LEAN CLAY FILL, CONTAINS ROOT FRAGMENTS AND CRUSHED STONE, MOIST - ORANGE BROWN	FILL
	4.0		2+2+2	S	FINE MEDIUM SANDY SILT FILL, MOIST - BROWN	
B	9.5		2+3+4	S	FINE TO MEDIUM SANDY LEAN CLAY (CL), MOIST - BROWN	ALLUVIAL
			3+5+8	S	do, TRACE GRAVEL	
			3+6+8	S	do, CONTAINS MICA AND LENSES OF SANDY SILT - ORANGE BROWN	
	24.0		3+3+5	S	FINE TO MEDIUM SILTY SAND (SM) MOIST - BROWN	
	29.0		3+4+8	S	FINE TO COARSE CLAYEY SAND (SC) MOIST - BROWN	
			11+16+22	S	do, WITH GRAVEL, MOIST BROWN	
C	39.0		4+4+16	S	SILT (ML) TRACE SAND, CONTAINS LENSES OF LEAN CLAY, MOIST - BROWN	LIMESTONE RESIDUUM
			4+4+6	S		
	49.0		3+4+5	S	ELASTIC SILT (MH) TRACE SAND MOIST - BROWN	

SCHNABEL ENGINEERING ASSOCIATES CONSULTING ENGINEERS	TEST BORING LOG	BORING NO: MW-9
PROJECT: MONITORING WELL INSTALLATION, HWM-16, RAAP, RADFORD, VA		SHEET NO: 2 OF 2
CLIENT: HERCULES, INCORPORATED		JOB NO: V881377
BORING CONTRACTOR: TERROCK CORPORATION	DRILL. CME - 55	ELEVATION.

WATER LEVEL DATA	DATE	TIME	DEPTH	CAVED	DRIVE SAMPLER		
					TYPE	S.S.	CASING SIZE: 2-1/4
ENCOUNTERED	9/20	4:00	64.0	-	DIA.	2" O.D.	DATE START: 9/20/89
AFTER CASING PULLED	9/21	2:30	62.0	-	WT.	140#	DATE FINISHED: 9/22/89
___ HR. READING	MONITORING WELL INSTALLED				FALL	30"	DRILLER: R. EDWARDS
							INSPECTOR: C. HALL

STRATUM	DEPTH FT.	ELEV.	BLOWS ON SAMPLE SPOON, PER 6"	SYMBOL	IDENTIFICATION	REMARKS
C					ELASTIC SILT (MH) TRACE SAND MOIST - BROWN	
	54.0		8+5+7	S	SILT WITH SAND (ML) CONTAINS ROCK FRAGMENTS AND LENSES OF SILTY SAND, MOIST - BROWN	LIMESTONE RESIDUUM
			4+3+3	S	do. CONTAINS LENSES OF FAT CLAY	
			3/12"+ 3/12"	S	do. CONTAINS ROCK FRAGMENTS, WET - BROWN	
D	68.7		35+39+ 26/5"	S	DISINTEGRATED ROCK, WET - GRAY AND BROWN	WASH BORING FROM 69' TO 79'
	79.0				BORING TERMINATED AT 79.0 FT	
					NOTE: MONITORING WELL MW-~~16~~9 INSTALLED AT HWM-16 TO REPLACE OLD WELL C-2 ←	

Appendix 5.

Well 16WC1A (Point of Compliance)

16) WC1-A

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules, Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: W. Simmons
Inspector: Smith
Date Installed: 11/2/87

WELL No.
WC1-A (new)

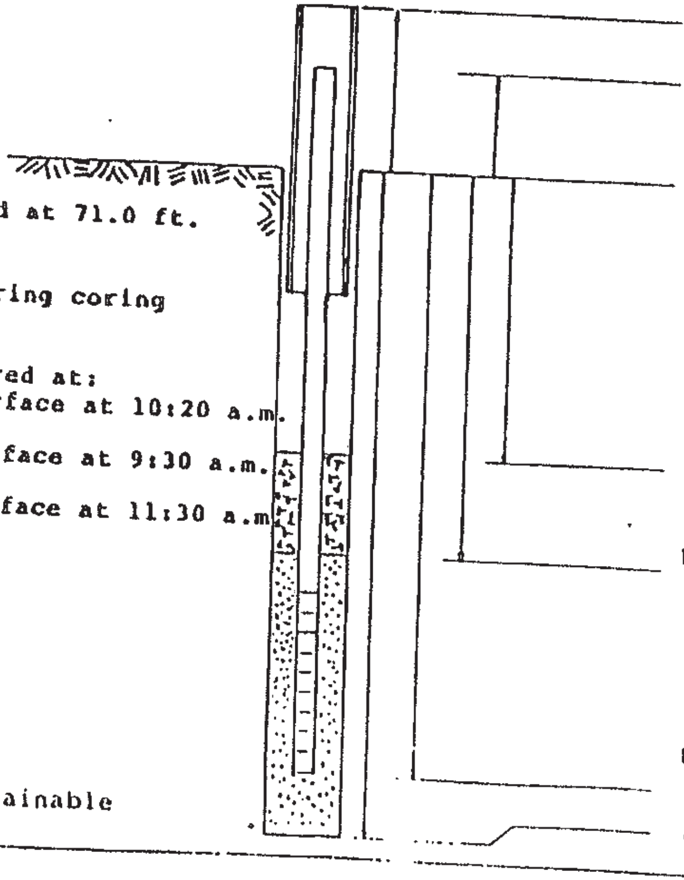
Sand Size: D (10) = 0.45-0.55mm
Bore/ Core Size: 6 inch/NX

Subsurface Conditions Summary

Weathered rock encountered at 71.0 ft. depth.

Large water loss noted during coring operations

Subusrface water encountered at:
-68.7 ft. below ground surface at 10:20 a.m. on 10/23/87
-68.3 ft. below ground surface at 9:30 a.m. on 11/6/87
-68.5 ft. below ground surface at 11:30 a.m. on 11/9/87



Casing Stickup (ft.)= 1.8
Elev. =
Riser Stickup (ft.) = 1.8
Elev. =
Ground Elev.= ----
Depth to Bentonite (ft.)= 77.5*
Elev. =
Depth to Sand Filter(ft.)= 82.5*
Elev. =
Depth to Well Bottom(ft.)= 93.5
Elev. =
Depth of Hole (ft.) = 100.0
Elev. =

*Actual measurement not obtainable

Form No. 303

BORING LOG

HWMU 16\WC1-A

FROEHLING & ROBERTSON, INC.
SINCE 1881
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No. 0-62084

Client: Hercules, Inc.			DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia			
Boring No. WC1-A	Total Depth: 68.2 ft.	Elevation: ----	Location: See Location Plan
Type of Boring: Hollow Stem Auger	Started: 10/5/87	Completed: 10/5/87	Driller: V. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	No sampling conducted see WC1-B (new) for subsurface conditions				GROUNDWATER DATA Subsurface water encountered at: -67.8 ft. below ground surface at 1:50 p.m. on 10/5/87 -62.0 ft. below ground surface at 2:45 p.m. on 10/13/87
	10.0					
	20.0					
	30.0					
		Boring terminated at 68.2 ft.				

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 300

BORING LOG

16 1 of 2 WC1A

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEM
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc.
DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia
Boring No.: WC1-A (new)
Total Depth: 100.0 ft.
Elevation: ----
Location: See Location Plan
Type of Boring: Hollow Stem Auger
Started: 10/20/87
Completed: 11/2/87
Driller: V. Simmons

Elevation	Depth	Description of Materials (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	Remarks
	0.0	No sampling conducted, see WC1-B for subsurface conditions				GROUNDWATER DATA Subsurface water encountered at: -68.7 ft. below ground surface at 10:20 a.m. on 10/23/87 -68.3 ft. below ground surface at 9:30 a.m. on 11/6/87 -68.5 ft. below ground surface at 11:30 a.m. on 11/9/87
	10.0					
	73.0	Auger refusal at 73.0 ft.				
		Highly fractured dolomite with calcite healed joints		73.0	15.0	RQD = 0
				78.0	37.5	RQD = 0
				80.0	22.2	RQD = 0
				83.0	30.9	RQD = 0
				86.5	56.7	RQD = 0
				91.5	24.2	RQD = 0

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise note

Form No. 500

BORING LOG

16\WC1-A

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No. 0-62084

Client: Hercules, Inc.			DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia			
Boring No. WC1-A (new)	Total Depth: 100.0 ft.	Elevation: ----	
Type of Boring: Hollow Stem Auger	Started: 10/20/87	Completed: 11/2/87	Location: See Location Plan
			Driller: W. Simmons

Elevation	Depth 95.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
				96.5		GROUNDWATER DATA
	100.0				29.6	RQD = 0
		Boring terminated at 100.0 ft.		100.0		

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Appendix 6.

Well 16WC1B (Point of Compliance)

HWMU#6-WC1-D

Project: Radford Army Ammunition Plant		WELL No.
Location: Radford, Virginia	Driller: W. Simmons	
Client: Hercules, Inc.	Inspector: Smith	
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen	Date Installed: 10/9/87	WC1-B (new)
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser	Sand Size: D (10) = 0.45-0.55mm	
	Bore/ Core Size: 6 inch/NX	

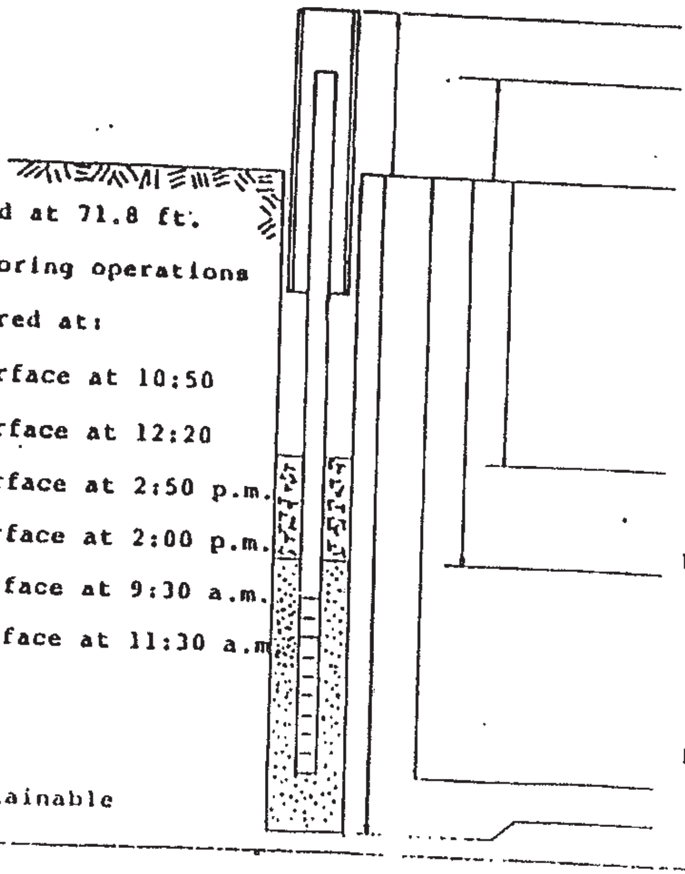
Subsurface Conditions Summary

Weathered rock encountered at 71.8 ft.

Water loss noted during coring operations

Subsurface water encountered at:

-71.4 ft. below ground surface at 10:50 a.m. on 10/8/87
-66.8 ft. below ground surface at 12:20 a.m. on 10/8/87
-68.0 ft. below ground surface at 2:50 p.m. on 10/13/87
-64.3 ft. below ground surface at 2:00 p.m. on 10/30/87
-68.5 ft. below ground surface at 9:30 a.m. on 11/6/87
-68.6 ft. below ground surface at 11:30 a.m. on 11/9/87



Casing Stickup (ft.)= 2.1
Elev. =
Riser Stickup (ft.) = 2.1
Elev. =
Ground Elev.= ----
Depth to Bentonite (ft.)= 57.0*
Elev. =
Depth to Sand Filter(ft.)= 62.0*
Elev. =
Depth to Well Bottom(ft.)= 73.0
Elev. =
Depth of Hole (ft.) = 79.1
Elev. =

*Actual measurement not obtainable

Form No. 500

BORING LOG

HWMU 16\WC1-B

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No 0-62084

Client: Hercules, Inc.			DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia			
Boring No WC1-8	Total Depth: 86.0 ft.	Elevation: ----	
Type of Boring: Hollow Stem Auger	Started: 10/5/87	Completed: 10/7/87	Location See Location Plan
			Driller V. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	Loose orange to green brown medium to fine sandy SILT, trace clay, debris (ML)				GROUNDWATER DATA
			$^{3}3_{3}$	1.5		
				3.0		Subsurface water encountered at: -68.5 ft. below ground surface at 1:20 p.m. on 10/6/87
			$^{2}6_{8}$	4.5		
		-FILL		6.0		
	7.0	Medium-stiff red brown silty CLAY some fine sand (CL)				
			$^{3}3_{4}$	8.5		
				10.0		
		to				
			$^{5}5_{12}$	13.5		
				15.0		
		Medium dense orange brown silty medium to fine SAND, manganese stains.				
			$^{4}7_{11}$	18.5		
				20.0		
			$^{5}8_{13}$	23.5		
				25.0		
			$^{5}9_{12}$	28.5		
				30.0		
		to				
			$^{4}6_{8}$	33.5		
				35.0		
			$^{6}8_{8}$	38.5		
				40.0		

*No. of blows req'd for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 100

BORING LOG

16\WC1-B

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc.			DATE November, 1987
Project Radford Army Ammunition Plant, Radford, Virginia			
Boring No. WC1-B	Total Depth: 86.0 ft.	Elevation: ----	Location See Location Plan
Type of Boring: Hollow Stem Auger	Started: 10/5/87	Completed: 10/7/87	Driller W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	40.0	Medium dense brown coarse to fine SAND				GROUNDWATER DATA
			$^{7}8_{9}$	43.5 45.0		
		to				
		Medium dense yellow brown to tan SILT, some coarse to fine sand, trace shale fragments (ML)	$^{4}6_{9}$	48.5 50.0		
			[illegible] 13_{11}	53.5 55.0		
			$^{4}5_{5}$	58.5 60.0		
		-ALLUVIUM-				
	61.5	Medium stiff tan to brown SILT, trace medium to fine sand (ML)	$^{*}2_{4}$	63.5 65.0		*Weight of Hammer
		-RESIDUUM-				
	69.2	Auger refusal at 69.2 ft.	*	68.5 68.6		*30/1 inch
		Highly fractured dolomite with calcity healed joints		69.2 74.2	**	** No Recovery
				74.2 79.2	6.6	RQD = 0

*No. of blows req'd. for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 500

BORING LOG

H6:WC1-B

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMI
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc. DATE November, 1987

Project: Radford Army Ammunition Plant, Radford, Virginia

Boring No.: WC1-B Total Depth: 86.0 ft. Elevation: ----

Type of Boring: Hollow Stem Auger Started: 10/5/87 Completed: 10/7/87 Location: See Location Plan

Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	80.0				*	
				81.0	**	GROUNDWATER DATA *50% Recovery RQD = 0 **No Recovery
	86.0	Boring terminated at 86.0 ft.				

*No. of blows req'd for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise note

Form No 500

BORING LOG

16\WC1-B

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMI
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No 0-62084
Client. Hercules, Inc.
DATE November, 1987
Project. Radford Army Ammunition Plant, Radford, Virginia
Boring No WC1 8 (new)
Total Depth: 79.3 ft.
Elevation: ----
Type of Boring: Hollow Stem Auger
Started: 10/7/87
Completed: 10/9/87
Location See Location Plan
Driller W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	No sampling conducted see WC1-8 for subsurface conditions				GROUNDWATER DATA Subsurface water encountered at: -71.4 ft. below ground surface at 10:50 a.m. on 10/8/87 -66.3 ft. below ground surface at 12:20 p.m. on 10/8/87 -68.0 ft. below ground surface at 2:50 p.m. on 10/13/87 -64.3 ft. below ground surface at 2:00 p.m. on 10/30/87 -68.5 ft. below ground surface at 9:30 a.m. on 11/6/87 -68.6 ft. below ground surface at 11:30 a.m. on 11/9/87
	10.0					
	20.0					
	71.8	Highly fractured dolomite with calcite healed joints		71.8	25.0	RQD = 0
				75.8	54.8	RQD = 0
	79.3	Boring terminated at 79.3		79.3		

*No of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Appendix 7.

Well 16-1 (Compliance Monitoring)

BORING LOG Site 16 / 16-1

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMIC
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-52188

Client: Hercules, Inc. DATE November, 1984

Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: 16-1 Total Depth: 60.0' Elevation:

Type of Boring: Hollow-stem auger Started: 10-25-84 Completed: 10-25-84 Location: See plan Driller: W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0					
	1.0	Red brown clayey SILT roots, organics				GROUNDWATER DATA
		Red-brown fine sandy SILT trace to little clay -FILL- [Reworked Alluvium] (ML)	3 4 6	4.5 6.0		
	7.0 7.5	Dark brown fine sandy SILT roots, organics				
	10	Medium stiff red-brown fine sandy SILT (ML) -ALLUVIUM-	4 5 5	9.5 11.0		
	15	increase in sand	5 8 9	14.5 16.0		
		grades to				
	20	Orange-brown silty fine SAND, with mica (SM) -ALLUVIUM-	5 5 6	19.5 21.0		
	25		4 6 6	24.5 26.0		
		grades to				
	30	Silty medium to fine SAND (SM)	4 5 6	29.5 31.0		
	35.0		5	34.5		

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

No. ROL-52188
Client: Hercules, Inc.
DATE November, 1984
Project: Radford Army Ammunition Plant: Monitoring Wells. Horseshoe Area Radford, VA
Boring No.: 16-1 cont.
Total Depth:
Elevation:
Location: See plan
Type of Boring: Hollow-stem auger
Started: 10-25-84
Completed: 10-25-84
Driller: V. Simmons, Sr.

Elevation	Depth 35.0	Description of Materials (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Remarks
		Dense orange brown coarse to fine sandy GRAVEL, with silt (GM)	10 26	36.0		GROUNDWATER DATA
		Medium dense red brown coarse to fine sandy SILT, little mica (ML) -ALLUVIUM-		39.5		
			4 5 6	41.0		
	44.0	Yellow tan silty CLAY, trace fine sand relict structure -RESIDUUM- (CL)		44.5		Water level measured @ 43.0' on 11-1-84
	44.7	Auger refusal Gray medium bedded SHALE & siltstone with green glauconitic conglomerate, thin limestone interbeds (ROME FORMATION)		44.7	<20%	* 40/0.2'
	50.0				<20%	50.0
	55.5	Gray and black Fault Breccia (silt matrix, pebble sized clasts) OF WAR ?			73%	55.0
	60.0	Boring terminated @ 60.0'				60.0 30' screen set from bottom

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

Appendix 8.

Well 16-2 (Compliance Monitoring)

Form No. 305

BORING LOG Site 16/16-2

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No. RDL-62188
Date November, 1984
Client: Hercules, Inc.
Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA
Boring No. 16-2
Total Depth: 72.0'
Elevation:
Location: See plan
Type of Boring: Hollow-stem auger
Started: 10-23-84
Completed: 10-25-84
Driller: V. Simmons, Sr.

Elevation	Depth 0.0	Description of Materials (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	Remarks
	0.5	Red brown clayey SILT, trace sand, organics				
		Medium dense red-tan fine sandy SILT, trace clay, small mica flakes (ML) -ALLUVIUM-				GROUNDWATER DATA
			3-6-10	4.5 6.0		
		Grades to	3-5-6	9.5 11.0		
		Medium dense silty fine SAND, slight micaceous (SM)				
			3-4-7	14.5 16.0		
		Grading to				
		Dense red brown silty coarse to fine SAND, few gravel (SM)	12-12-12	19.5 21.0		
		Grading to				
		Dense red coarse to fine sandy GRAVEL, some silt (GM)	14-13-12	24.5 26.0		
	29.0	Medium dense yellow tan SILT trace fine sand & clay -RESIDUUM-	5-7-6	29.5 31.0		
		Auger refusal @ 33.5'; begin coring @ 33.5'		33.5		* 40/0.0' Lost water at 35.0'
	35.0					

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. ROL-62158
Client: Hercules, Inc. DATE November, 1984
Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA
Boring No: 16-2 cont. Total Depth: Elevation: Location: See plan
Type of Boring: Hollow-stem auger Started: 10-23-84 Completed: 10-25-84 Driller: V. Simmons, Sr.

Elevation	Depth	Description of Materials (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Remarks
	35.0	Dove gray vuggy, conglomeratic fractured DOLOMITIC LIMESTONE, thin bedded to shaley in some sections			67%	GROUNDWATER DATA
	38.5	Conglomerate: limestone matrix, quartzite, pebbles, grades back to conglomeratic DOLOMITE with vugs, shaley partings			48%	
	40.5	Void in Rock			VOID	
	43.5	Shows steep (> 45%) dip Black to gray shale & limestone clasts in conglomerate			72%	
					83%	
		Black SHALE fragments in conglomerate			* 62%	53.5 * 3.5' core run 57.0
	57.5	Angular fragments Fault Breccia Limestone matrix (sand-sized limestone particles) with angular fragments of shale and dolomite			98%	
					87%	67.0
	67.0	Mud seam - yellow tan clayey SILT				
	69.0					
	70.0	Black calcareous thin bedded SHALE, highly deformed, steep dip			67%	

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Job No. ROL-62188			DATE November, 1984
Client Hercules, Inc.			
Project Radford Army Ammunition Plant: Monitoring Wells, Horseshoe Area Radford, VA			
Boring No: 16-2 cont.	Total Depth:	Elevation:	Location: See plan
Type of Boring: Hollow-stem auger	Started: 10-23-84	Completed: 10-25-84	Driller V. Simmons, Sr.

Elevation	Depth 70.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
		See description on previous page			95%	GROUNDWATER DATA Water level measured @ 53.7' on 11-1-84
	77.0	Boring terminated @ 77.0'				25' screen set from bottom

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Appendix 9.

Well 16-3 (Compliance Monitoring)

BORING LOG Site 16/16-3

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMIC
"ONE HUNDRED YEARS OF SERVICE"

Report No. 20L-62188

Client: Hercules, Inc.			DATE November, 1984
Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA			
Boring No.: 16-3	Total Depth: 39.5'	Elevation:	Location: See plan
Type of Boring: Hollow-stem auger	Started: 10-26-84	Completed: 10-30-84	Driller: V. Simmons, Jr.

Elevation	Depth	Description of Materials (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	Remarks
	0.0					GROUNDWATER DATA
	1.0	Red brown fine sandy SILT, organics				
		Medium dense orange-brown silty fine SAND, little mica (SM)	6-7-8	4.5 6.0		
		grades to				
		Orange-brown fine sandy SILT, little mica (ML) -ALLUVIUM-	3-4-7	9.5 11.0		
	13.5	Medium dense orange-brown gravelly coarse to fine SAND (SP) -ALLUVIUM-	7-7-7	14.5 16.0		
			12-10-15	19.5 21.0		
	25.0	Stiff tan clayey SILT, shale fragments little fine sand (ML) -RESIDUUM-	9-12-18	24.5 26.0		
			15-19-19	29.5 31.0		
	35.0		12	34.5		

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMISTS
"ONE HUNDRED YEARS OF SERVICE"

Report No. RQL-62188
Client: Hercules, Inc. DATE November, 1984
Project: Radford Army Ammunition Plant; Monitoring Wells, Horseshoe Area Radford, VA
Boring No.: 16-3 cont. Total Depth: Elevation: Location: See plan
Type of Boring: Hollow-stem auger Started: 10-26-84 Completed: 10-30-84 Driller: W. Simmons, Sr.

Elevation	Depth	Description of Materials (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Remarks
	35.0		16 16			GROUNDWATER DATA
			19 21 25	39.5 41.0		
			ND	44.5 46.0		
				49.5 50.0		* 40/0.5'
				54.5 54.8	▽	Water level measured @ 54.8' on 11-1-84 * 40/0.3'
	59.5	Auger refusal @ 59.5' Brown to greenish gray SHALE and SILTSTONE. Highly fractured with layers of soil (ROME FORMATION)			< 20%	Auger refusal @ 59.5'
		Brecciated shale & siltstone, green siltstone matrix with gray and white quartzite and limestone pebble-sized clasts			60%	64.5
	70.0					69.5

*No. of blows req'd. for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Report No. ROL-62188

Client: Hercules, Inc. DATE November, 1984

Project: Radford Army Ammunition Plant: Monitoring Wells, Horseshoe Area Radford, VA

Boring No.: 16-3 cont. Total Depth: Elevation:

Type of Boring: Hollow-stem auger Started: 10-26-84 Completed: 10-30-84 Location: See plan

Driller: V. Simmons, Sr.

Elevation	Depth	Description of Materials (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Remarks
	70.0	Breccia, gray siltstone matrix green shale clasts, gray dolomitic clasts			93%	GROUNDWATER DATA
				74.5	53%	
				79.5	40%	
	86.0	Greenish gray well graded fine to medium SAND. Probable fault plane		84.5	95%	
	88.5	Breccia, gray, SILTSTONE matrix, green shale & gray dolomite clasts				
		Boring terminated @ 89.5'		89.5		20' screen set from 80.0' (Bottom 9.5' collapsed)

*No. of blows req'd for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=4' unless otherwise noted

Appendix 10.

Well 16-5 (Compliance Monitoring)

ASMT /DOW-[illegible]

16-5
HWMU-16

Form No. 100

BORING LOG

FROEHLING & ROBERTSON, INC.
ONE HUNDRED YEARS OF SERVICE

Report No. ROM-62085

DATE November, 1985

Client	Hercules, Inc.
Project	Monitoring Wells Radford Army Ammunition Plant Radford, Virginia
Boring No.	16-5
Total Depth	54.5
Elevation	---
Location	See plan
Type of Boring	Hollow stem auger
Started	10-22-85
Completed	10-23-85
Driller	V. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depths (Feet)	% Core Recovery	RQD %	REMARKS
	0.0	Brown fine sandy SILT					GROUNDWATER DATA
	1.0	Loose brown fine sandy SILT, trace clay, mica flakes -ALLUVIUM-	3 3 4	1.5 3.0			
	4.0	Hard brown clayey SILT -RESIDUUM-		4.5			* 30/0.1'
	5.0	Blue gray dolomite, calcite healed fractures		5.0 10.0	95%	95%	
				15.0	95%	92%	Development Data: Sloshed for 2 hrs. Bailed to 26.0'. Recovered to 16.9' after 24 hrs.
		Yellow-brown to green-gray fault breccia, LIMESTONE, DOLOMITE, and shale clasts		20.0	57%	27%	
				23.0	86%	35%	
				25.0	82%	0%	
				30.0	0%	0%	
				34.5	0%	0%	
	40.0			39.5	97%	33%	

*No. of blows req'd for a 140 lb hammer dropping 30 in to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 inch increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1"=5' unless otherwise noted

Form No. 300

ORING LOG

FROEHLING & ROBERTSON, INC.
ONE HUNDRED YEARS OF SERVICE
SINCE 1881

Report No. RDM-62085

Client Hercules, Inc. DATE November, 1985

Project Monitoring Wells Radford Army Ammunition Plant Radford, Virginia

Boring No. 16-5 cont. Total Depth 54.5' Elevation ---

Type of Boring: Hollow stem auger Started 10-22-85 Completed 10-23-85 Location See plan

Driller W. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	RQD %	REMARKS
	40.0				37%	15%	GROUNDWATER DATA
		Green-gray FAULT BRECCIA, LIMESTONE, DOLOMITE, and shale clasts					
				44.5			
					75%	8%	
				49.5			
					92%	58%	
	54.5			54.5			
		Boring terminated @ 54.5'					
		• 20' 304 SS SCREEN • 35 304 SS RISER					

No. of blows req'd for a 140 lb hammer dropping 30 in to drive 2 in O.D. 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance N.

Scale 1 :5 unless otherwise noted

Appendix 11.

Well 16WC2B (Compliance Monitoring)

HWMU16\WC2-B

Project: Radford Army Ammunition Plant		WELL No.
Location: Radford, Virginia	Driller: W. Simmons	
Client: Hercules, Inc.	Inspector: Smith	
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen	Date Installed: 10/19/87	WC2-B
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser	Sand Size: D (10) = 0.45-0.55mm	
	Bore/ Core Size: 6 inch/NX	

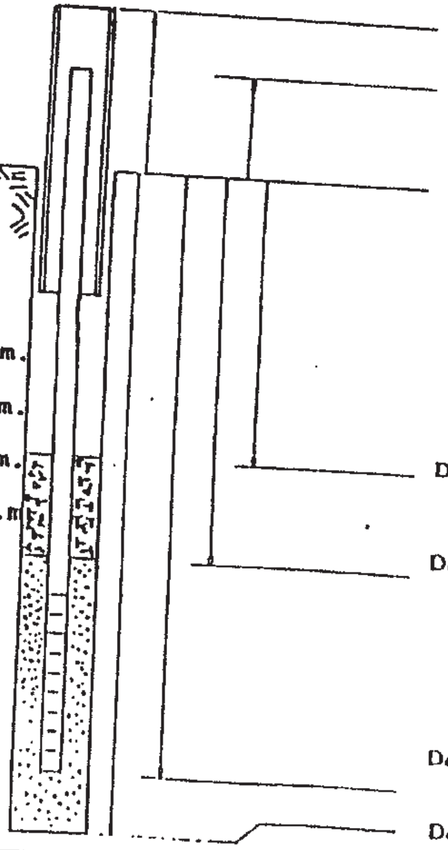
Subsurface Conditions Summary

Weathered rock encountered at 81.0 ft.

Rock lenses encountered at 95.0 ft.

Subsurface water encountered at:

-85.8 ft. below ground surface at 2:14 p.m.
on 10/19/87
-52.2 ft. below ground surface at 2:15 p.m.
on 10/30/87
-51.9 ft. below ground surface at 9:30 a.m.
on 11/6/87
-52.0 ft. below ground surface at 10:00 a.m.
on 11/9/87



Casing Stickup (ft.)= 1.9
Elev. =
Riser Stickup (ft.) = 1.9
Elev. =
Ground Elev.= ----

Depth to Bentonite (ft.)= 86.0*
Elev. =
Depth to Sand Filter(ft.)= 91.0*
Elev. =

Depth to Well Bottom(ft.)= 102.5*
Elev. =
Depth of Hole (ft.) = 104.0*
Elev. =

*Actual measurement not obtainable

Form No. 300

BORING LOG

HWMU16\WC 2-B

SINCE 1881

FROEHLING & ROBERTSON, INC.

FULL SERVICE LABORATORIES • ENGINEERS & CHEM

"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc.
DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia
Boring No: WC2-B
Total Depth: 104.0 ft.
Elevation:
Location: See Location Plan
Type of Boring: Hollow Stem Auger
Started: 10/14/87
Completed: 10/19/87
Driller: W. Simmons

Elevation	Depth 0.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
		Stiff brown clayey SILT, furnace slag and debris (ML)	4 7 7	1.5 3.0		GROUNDWATER DATA Subsurface water encountered at: -85.8 ft. below ground surface at 2:14 p.m. on 10/19/87 -52.2 ft. below ground surface at 2:15 p.m. on 10/30/87 -51.9 ft. below ground surface at 9:30 a.m. on 11/6/87 -52.0 ft. below ground surface at 10:00 a.m. on 11/9/87
			3 3 8	4.5 6.0		
			10 8 9	8.5 10.0		
			5 6 11	13.5 15.0		
		Medium dense orange-brown medium-fine sandy SILT, debris (ML)	7 10 12	18.5 20.0		
			12 11 9	23.5 25.0		
		-FILL-	13 6 7	28.5 30.0		
	31.5	Loose yellow brown silty fine SAND, trace manganese stains (ML)				
			10 10 9	33.5 35.0		
			2 3 3	38.5 40.0		

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise note

Form No. 308

BORING LOG

HWM'12'Hd WC2-B

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"
SINCE 1881

Report No 0-62084

Client: Hercules, Inc.
DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia
Boring No.: WC2-B
Total Depth: 104.0 ft.
Elevation:
Location: See Location Plan
Type of Boring: Hollow Stem Auger
Started: 10/14/87
Completed: 10/19/87
Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	40.0	-to-				GROUNDWATER DATA
		Soft yellow brown to gray SILT, trace clay and coarse to fine sand sized particles	2 2 3	43.5 45.0		
		-ALLUVIUM-	1 1 1	48.5 50.0		
	51.5					
			*	53.5 55.0		*Weight of RODS
		Very dense gray weathered rock		61.0 61.3		*30/3*

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Form No. 100

BORING LOG

Page [illegible] of 3 161\WC2-B

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMIS
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc.

DATE November, 1987

Project: Radford Army Ammunition Plant, Radford, Virginia

Boring No. WC2-8

Total Depth: 104.0 ft.

Elevation: ----

Location: See Location Plan

Type of Boring: Hollow Stem Auger

Started: 11/14/87

Completed: 11/19/87

Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	80.0					GROUNDWATER DATA
		Very dense gray weathered rock		93.5 93.7		*30/2"
	104.0	Boring terminated at 104.0 ft.				

*No. of blows req'd for a 140 lb hammer dropping 30 in. to drive 2 in O.D., 1.375 in I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

Appendix 12.

Well 16Spring (Additional Sampling Point)

Appendix 13

Well 16WC2A (Piezometer)

Form No. 300

BORING LOG

AWMU 16\WC2-A

SINCE 1881

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERS & CHEMI
"OVER ONE HUNDRED YEARS OF SERVICE"

Report No 0-62084

Client: Hercules, Inc.
DATE November, 1987
Project: Radford Army Ammunition Plant, Radford, Virginia
Boring No.: WC2-A
Total Depth: 82.0 ft.
Elevation: -----
Location: See Location Plan
Type of Boring: Hollow Stem Auger
Started: 10/13/87
Completed: 10/13/87
Driller: W. Simmons

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
	0.0	No sampling conducted, see WC2-B for subsurface conditions				GROUNDWATER DATA Subsurface water encountered at: -62.0 ft. below ground surface at 1:50 p.m. on 10/13/87 -60.7 ft. below ground surface at 3:30 p.m. on 10/14/87 -62.5 ft. below ground surface at 2:10 p.m. on 10/30/87 -61.8 ft. below ground surface at 9:30 a.m. on 11/6/87 -61.3 ft. below ground surface at 10:00 a.m. on 11/9/87
	10.0					
	20.0					
	72.0	Auger Refusal		72.0		
		Highly fractured dolomite with calcite healed joints			**	** No Recovery
				77.0		
					10.0	RQD = 0
	82.0			82.0		
		Boring terminated at 82.0 ft.				

*No. of blows req'd for a 140 lb. hammer dropping 30 in. to drive 2 in O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

16\WC2-A

Project: Radford Army Ammunition Plant
Location: Radford, Virginia
Client: Hercules, Inc.
Screen Description: 0.010" slot, 2.0" I.D. Teflon Screen
Riser Description: 2.0" I.D. Teflon Riser and PVC Riser

Driller: W. Simmons
Inspector: Smith
Date Installed: 10/13/87

WELL No.
WC2-A

Sand Size: D (10) = 0.45-0.55mm
Bore/ Core Size: 6 inch/NX

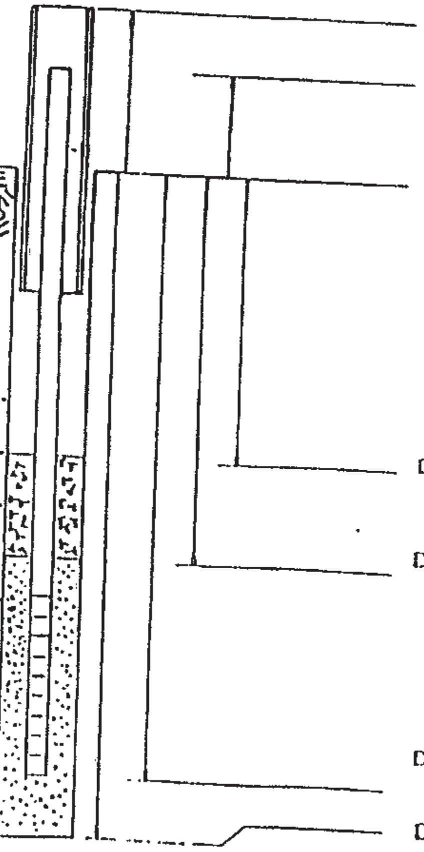
Subsurface Conditions Summary

Cobbles or rock lenses encountered at 40.0 ft. and 70.0 ft.

Weathered rock encountered at 72.0 ft.

Subsurface water encountered at:

-62.0 ft. below ground surface at 1:50 p.m. on 10/13/87
-60.7 ft. below ground surface at 3:20 p.m. on 10/14/87
-62.5 ft. below ground surface at 2:10 p.m. on 10/30/87
-61.8 ft. below ground surface at 9:30 a.m. on 11/6/87
-61.9 ft. below ground surface at 10:00 a.m. on 11/9/87



Casing Stickup (ft.)= 2.0
Elev. =
Riser Stickup (ft.) = 2.0
Elev. =
Ground Elev.= ----

Depth to Bentonite (ft.)= 53.0*
Elev. =
Depth to Sand Filter(ft.)= 58.0*
Elev. =

Depth to Well Bottom(ft.)= 69.5
Elev. =
Depth of Hole (ft.) = 82.0
Elev. =

*Actual measurement not obtainable

Appendix 14

Well 16C3 (Piezometer)

SITE 16 / C-3

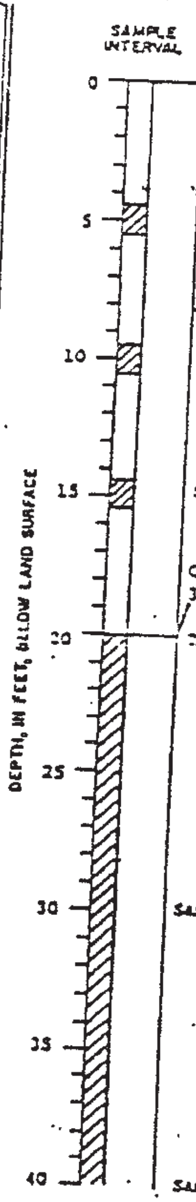
Geraghty
& Miller, Inc.

WELL LOG

PROJECT [illegible]
CLIENT [illegible]
Date Prepared 7/29/80 By [illegible]

SAMPLE INTERVAL

DESCRIPTION



Silt, sandy, pieces of styrofoam, brown

Sand, fine to medium, silty, pieces of styrofoam, brown

Same as above

Changed from 5" fishtail bit to 3" NX core barrel

Trash

Sand grades into coarse

Same as above

OWNER Corps of Engineers
WELL No. C-3
LOCATION Site C - Solid Waste Landfill in use
TOPO SETTING
GROUND ELEV. 1313.73

DRILLING STARTED 7/29/80
DRILLING COMPLETED 7/29/80
DRILLER R. A. Monroe
TYPE OF RIG 40 C

WELL DATA

HOLE DIAM. 5" to 20 ft; 3" to 70 ft
TOTAL DEPTH 70 ft
CASING DIAM. 2 in [illegible] PVC
CASING LENGTH 55 ft
SCREEN DIAM. 2 in
SCREEN SETTING 55-70 ft
SCREEN SLOT & TYPE .010 SCH 80
WELL STATUS Dry

GROUT

TYPE OF GROUT Neat cement
GROUT DEPTH 0-40 ft
VOLUME 1.2 cu ft
TYPE OF PLUG Bentonite
PLUG DEPTH 39-40 ft
VOLUME 1 lb

DEVELOPMENT

METHOD Air
RATE Dry
LENGTH 5 min

TEST DATA

STATIC DEPTH TO WATER Dry
DATE MEASURED 8/12/80
PUMPING DEPTH TO WATER
DURATION OF TEST
PUMPING RATE
DATE OF TEST
TYPE OF TEST
PUMP SETTING
SPECIFIC CAPACITY

FINAL PUMP CAPACITY
FINAL PUMP SETTING
AVERAGE PUMPAGE

WATER QUALITY

Geraghty
& Miller, Inc.

WELL LOG

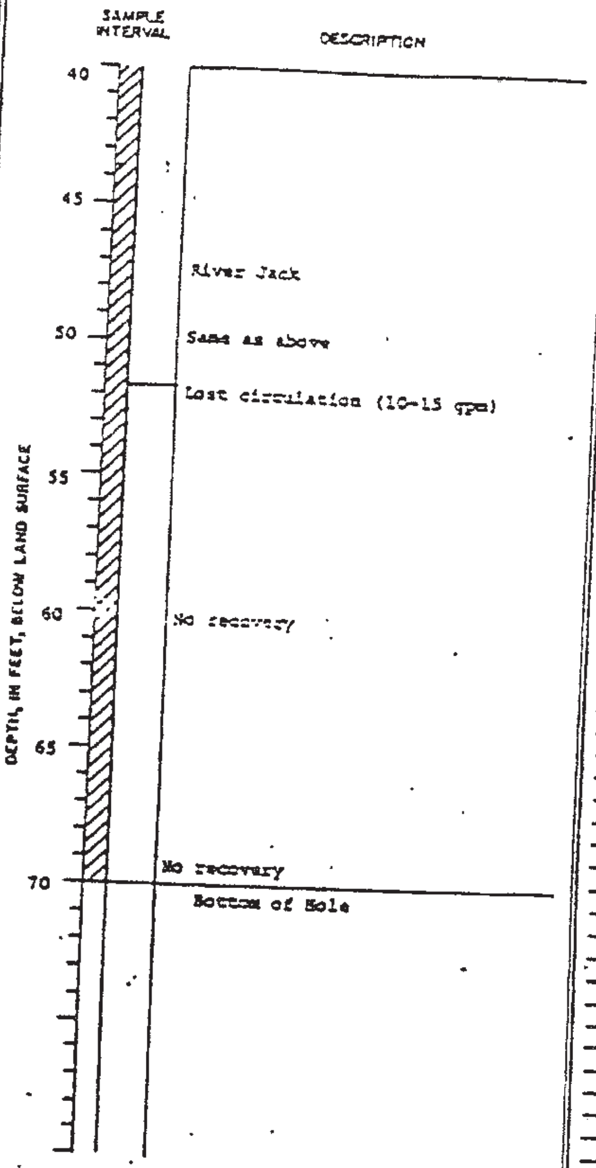
Page 2 of 2

PROJECT RADFORD
CLIENT NUS
Date Prepared 7/30/80 By G.F.S.

OWNER Corps of Engineers
WELL No. C-3
LOCATION Site C - Solid Waste Landfill in use
TOPO SETTING
GROUND ELEV. 1819.77

DRILLING STARTED 7/29/80
DRILLING COMPLETED 7/29/80
DRILLER R. A. [illegible]
TYPE OF RIG C-40

REMARKS



River Jack

Same as above

Lost circulation (10-15 gpm)

No recovery

No recovery

Bottom of Hole

Appendix 15

Well 16CDH3 (Piezometer)

Appendix 16.

Other Wells

Well 16-4
Well 16C-2
Well 16C-4
Well 16DH-2

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICAL
"ONE HUNDRED YEARS OF SERVICE"

Job No. ROL-42188
Client: Hercules, Inc. DATE November, 1984
Project: Radford Army Ammunition Plant: Monitoring Wells, Horseshoe Area Radford, VA
Boring No.: 16-4 cont. Total Depth: Elevation:
Type of Boring: Hollow-stem auger Started: 10-31-84 Completed: 11-2-84 Location: See plan
Driller: V. Simmons, Sr.

Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
	35.0	Hard grey-tan clayey SILT, trace fine sand, relict structure -RESIDUUM- Weathered SHALE	24/30	36.0		GROUNDWATER DATA
			12/14/22	39.5 41.0		
			20/[illegible]	44.5 45.1		* 40/0.1'
						Water level measured @ 48.5' on 11-5-84
	50.0			49.5 50.0		* 50/0.5'
		Auger refusal - coring commenced Highly fractured green and maroon thinly laminated SHALE with calcite-healed fractures and dolomitic laminae (ROME FORMATION)			27%	
				55.0	48%	
				60.0	57%	
				65.0	70%	
				70.0		

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D., 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N.

Scale 1"=5' unless otherwise noted

BORING LOG

FROEHLING & ROBERTSON, INC.
FULL SERVICE LABORATORIES • ENGINEERING CHEMICA
"ONE HUNDRED YEARS OF SERVICE"
1881

Report No. ROL-62188
Client Hercules, Inc.
DATE November, 1984
Project Radford Army Ammunition Plant: Monitoring Wells, Horseshoe Area Radford, VA
Boring No. 16-4 cont.
Total Depth:
Elevation:
Location: See plan
Type of Boring Hollow-stem auger
Started: 10-31-84
Completed: 11-2-84
Driller V. Simmons, Sr.

Elevation	Depth 73.0	DESCRIPTION OF MATERIALS (Classification)	Sample Blows*	Sample Depth (Feet)	% Core Recovery	REMARKS
		Mud seam brown silty CLAY, very wet			40%	GROUNDWATER DATA
	74.0	Greenish gray SHALE, slightly calcareous			75%	
	80.0	Boring terminated @ 80.0'				35' screen set from bottom

*No. of blows req'd. for a 140 lb. hammer dropping 30 in. to drive 2 in. O.D. 1.375 in. I.D. sampler a total of 18 inches in three 6 in. increments. The sum of the last two increments of penetration is termed the standard penetration resistance, N

Scale 1"=5' unless otherwise noted

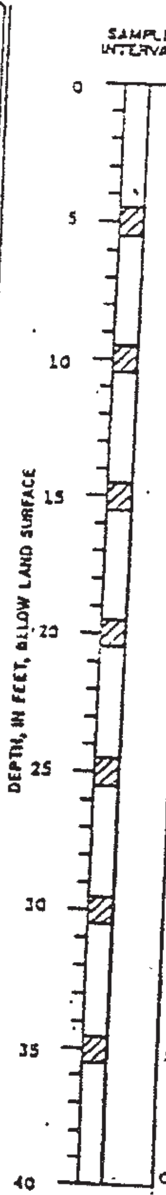
ABANDONED
Ⓐ SITE OF MW-9

SITE 16/ C-2 /MW-9 ?

Geraghty
& Miller, Inc.

WELL LOG

PROJECT RADFORD
CLIENT HUS
Date Prepared 7/10/80 By C. F. C.



Depth	DESCRIPTION
0	Clay, silty, dark brown
	Silt, sandy, brown
	Sand, fine, silty, brown
15	Sand grades into medium
20	Same as above
25	Same as above
30	Sand grades into coarse
	River Jack
35	Same as above
40	Changed from 5" fishtail bit to to 3" NX core barrel

OWNER Corps of Engineers
WELL No. C-2
LOCATION Site C - Solid Waste Landfill in use
TOPO SETTING
GROUND ELEV. 1805.20

DRILLING STARTED 7/30/80
DRILLING COMPLETED 7/30/80
DRILLER R. A. Monroe
TYPE OF RIG C-40

WELL DATA
HOLE DIAM. 5" to 40 ft; 3" to 70 ft
TOTAL DEPTH 70 ft
CASING DIAM. 2 in Timco PVC
CASING LENGTH 55 ft
SCREEN DIAM. 2 in
SCREEN SETTING 55-70 ft
SCREEN SLOT & TYPE .010 PVC
WELL STATUS Completed

GROUT
TYPE OF GROUT Neat cement
GROUT DEPTH 0-40 ft
VOLUME 2 cu ft
TYPE OF PLUG Bentonite
PLUG DEPTH 39-40 ft
VOLUME 1 lb

DEVELOPMENT
METHOD Air
RATE 0.1 gpm
LENGTH 31 min

TEST DATA
STATIC DEPTH TO WATER 61.09
DATE MEASURED 8/12/80
PUMPING DEPTH TO WATER
DURATION OF TEST
PUMPING RATE
DATE OF TEST
TYPE OF TEST
PUMP SETTING
SPECIFIC CAPACITY

FINAL PUMP CAPACITY
FINAL PUMP SETTING
AVERAGE PUMPAGE

WATER QUALITY

Geraghty
& Miller, Inc.

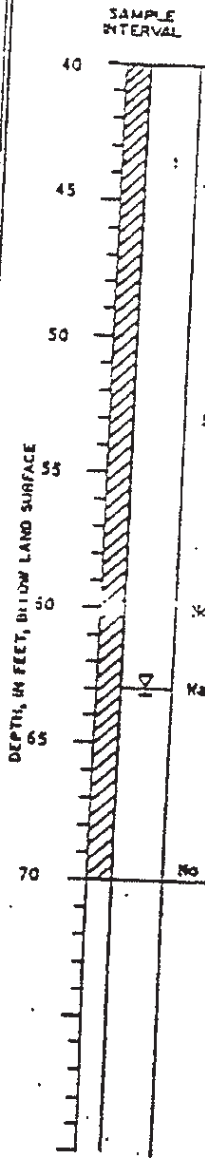
WELL LOG

PROJECT RADFORD
Page 2 of 2
CLIENT NUS
Date Prepared 7/30/90 By [illegible]

OWNER Corps of Engineers
WELL No. C-7
LOCATION Site C - Solid Waste
Landfill in use
TOPO SETTING
GROUND ELEV. 1805.70

DRILLING STARTED 7/30/90
DRILLING COMPLETED 7/30/90
DRILLER R. A. Monroe
TYPE OF RIG C-40

REMARKS



DESCRIPTION

Depth	Description
40	No recovery
50	No recovery
	Lost circulation
60	No recovery
	Water Table
70	No recovery
	Bottom of Hole

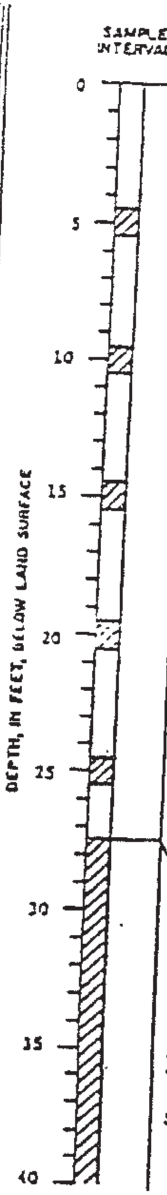
SITE 16 / C-4

Geraghty & Miller, Inc.

WELL LOG

PROJECT RADFORD
CLIENT HUS
Date Prepared 7/29/80 By [illegible]

SAMPLE INTERVAL	DESCRIPTION
0	Silt, clayey, brown
	Sand, fine, very silty, brown
10	Same as above
15	Same as above
20	Same as above.
25	Same as above
	River Jack
	Changed from 5" fishtail bit to 3" NX core barrel
35	In and out of River Jack to Top of Rock
	Same as above



OWNER Corps of Engineers
WELL No. C-4
LOCATION Site C - Solid Waste Landfill
(in use)
TOPO SETTING
GROUND ELEV. [illegible] ft

DRILLING STARTED 7/29/80
DRILLING COMPLETED 7/29/80
DRILLER M. J. Dean
TYPE OF RIG CME-75

WELL DATA
HOLE DIAM. 5" to 27.5 ft; 3" to 70 ft
TOTAL DEPTH 70 ft
CASING DIAM. 2 in [illegible] PVC
CASING LENGTH 55 ft
SCREEN DIAM. 2 in
SCREEN SETTING 55-70 ft
SCREEN SLOT & TYPE .010 PVC
WELL STATUS Completed

GROUT
TYPE OF GROUT Neat cement
GROUT DEPTH 0-40 ft
VOLUME 1.5 cu ft
TYPE OF PLUG Bentonite
PLUG DEPTH 39-40 ft
VOLUME 1 lb

DEVELOPMENT
METHOD Air
RATE [illegible]
LENGTH 15 min

TEST DATA
STATIC DEPTH TO WATER 54.96
DATE MEASURED 8/12/80
PUMPING DEPTH TO WATER
DURATION OF TEST
PUMPING RATE
DATE OF TEST
TYPE OF TEST
PUMP SETTING
SPECIFIC CAPACITY

FINAL PUMP CAPACITY
FINAL PUMP SETTING
AVERAGE PUMPAGE

WATER QUALITY

Geraghty
& Miller, Inc.

WELL LOG

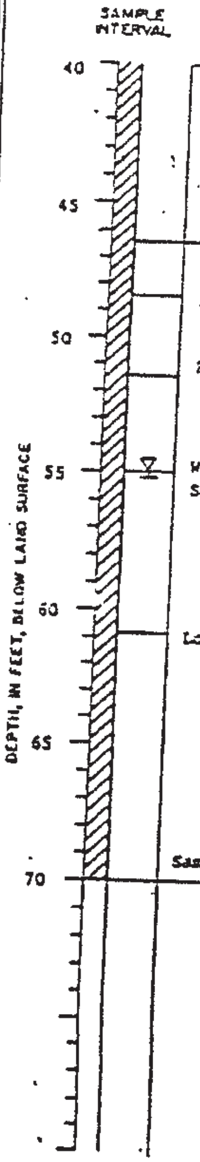
Page 2 of 2

PROJECT RADFORD
CLIENT NUS
Date Prepared 7/29/80 By G.F.S.

OWNER Corps of Engineers
WELL No. C-4
LOCATION Site C - Solid Waste Landfill in use
TOPO SETTING
GROUND ELEV. 1824.61

DRILLING STARTED 7/29/80
DRILLING COMPLETED 7/29/80
DRILLER M. J. Dean
TYPE OF RIG CME-75

REMARKS



DESCRIPTION

Top of Rock
Limestone, brecciated, gray

Lost Circulation (10-15 gpm)

Regained Circulation

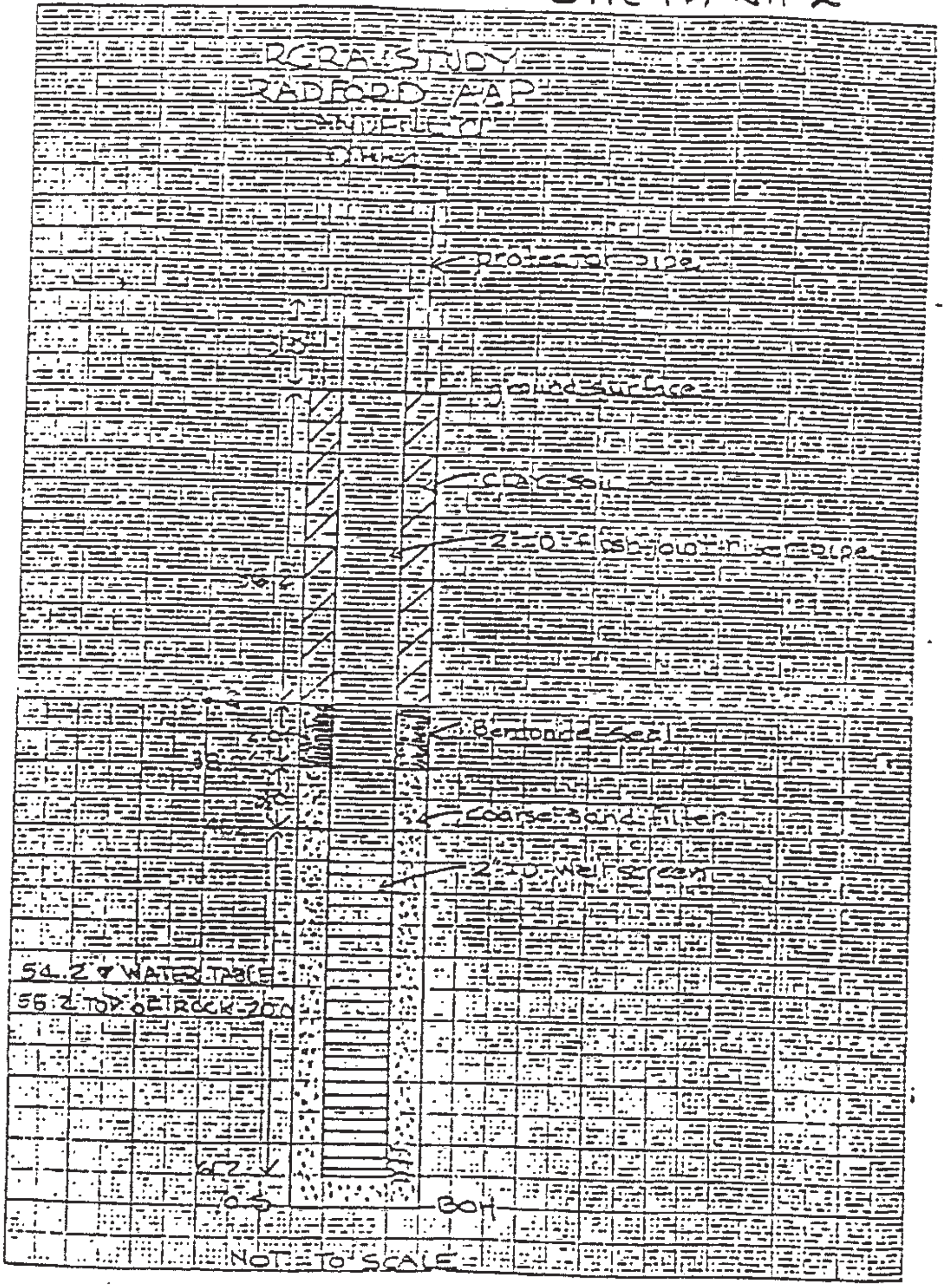
Water Table
Same as above

Lost circulation (10-15 gpm)

Same as above

Bottom of Hole

SITE 16/DH-2



RCRA STUDY
RADFORD AAP
DH-2
protector pipe
ground surface
clay soil
2" ID flush joint riser pipe
Bentonite Seal
Coarse sand filter
2" ID well screen
54.2 ▼ WATER TABLE
56.2 TOP OF ROCK
BOH
NOT TO SCALE

Site 16/DH-2

DRILLING LOG	Division [illegible]	Installation [illegible] — Hole No. DH-2 — Sheet 1 of [illegible] sheets
Project: LANDFILL C - RCRA STUDY		Size and type of bit: 3" OD [illegible]
Location:		Datum for elevation shown: MSL
Drilling agency: [illegible]		Manufacturer's designation of drill: CME - 75
Hole No.: DH-2		Total no. of overburden samples taken: 11 / 3
Name of driller: MARVIN DEAN		Total number core boxes: 1
Direction of hole: ☐ Vertical ☐ Inclined ______ deg. from vert.		Elevation ground water: 34.2 ( )
		Date hole: Started 17 JULY 90 — Completed 23 JULY 90
Thickness of overburden: 55.2		Elevation top of hole:
Depth drilled into rock: 15.3		Total core recovery for boring: 8.3 — 56 %
Total depth of hole: 70.5		Signature of inspector:

Elevation	Depth	Legend	Classification of Materials	% Core Recovery	Box or Sample No.	Remarks	
			2" topsoil		S-1	Split Spoon	3-3-6
			(CL)Clay, some silt & v fn, fn sand, med plast., red brn, moist			K(0-5)=.75 ft./day	
					S-2	Split Spoon	3-4-5
						K(0-13)=.28 ft./day	
					S-3	Split Spoon	4-4-7
						Shelby Tube 11.5-13 K(0-15)=.22 ft./day	
					S-4	Split Spoon	6-8-11
						K(15-20)=.31 ft./day	
					S-5	Split Spoon	[illegible]
						Shelby Tube 21.5-23 K(20-25)=.29 ft./day	
					S-6	Split Spoon	4-5-10
						K(25-31.5) = .17 ft/day	
					S-7	Split Spoon	4-4-7
	32		CL - More Silt and fine sand			K(30-35) = .04 ft/day	
					S-8	Split Spoon	3-3-4
						Shelby Tube 36.5-38	
	38		(SM) SAND, very fine-fine some silt, yellow-brown moist			K(35-40) = .11 ft/day	
					S-9	Split Spoon	6-11-14
						K(40-45) = .69 ft/day	
	44		(SM) Some Gravel (1") below 44'				
					S-10	Split Spoon	11-4-6
						K(45-50) = 16.2 ft/day	

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PROJECT LANDFILL C - RCRA STUDY — HOLE NO. DH-2

DRILLING LOG | DIVISION [illegible] | INSTALLATION [illegible] | Hole No. [illegible]-7 | SHEET 1 OF 1 SHEETS

1. PROJECT LANDFILL C - RCRA STUDY
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY CONTINENTAL CORE DRILLING
4. HOLE NO. (As shown on drawing title and file number) [illegible]-7
5. NAME OF DRILLER [illegible]
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 55.2
8. DEPTH DRILLED INTO ROCK 15.3
9. TOTAL DEPTH OF HOLE 70.5
10. SIZE AND TYPE OF BIT [illegible]
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL CME-75
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 11 | UNDISTURBED [illegible]
14. TOTAL NUMBER CORE BOXES 1
15. ELEVATION GROUND WATER (54.2)
16. DATE HOLE: STARTED 17 JULY 80 | COMPLETED 22 JULY 80
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING 8.3 | 54 %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
					11	Split Spoon 2-2-2
			River Jack 53'-55.2' TOR 55.2'			K(50-55) = 15.6 ft/day
	55.2		Limestone - Lt. Grey - Tan		Run 1 Box 1	NX Core RQD = 0%
	56.3		Clay Seam	28%	2.0	K(55-62.6) = 10.7 ft/day
	62.6		Limestone, Lt. Grey-Tan fine grained, mod to badly weathered, fragmented mod. hard	80%	Run 2 Box 1 4.9	NX Core RQD = 10% K(55-68.8) = 7.5 ft/day
				[illegible] 1.4	Run 3 Box 1	NX Core RQD = [illegible]
	70.5		BOH 70.5 Water at completion-53.1 Water after 24 hrs.-54.2			

50 51 55 62 68 70

8-3-15

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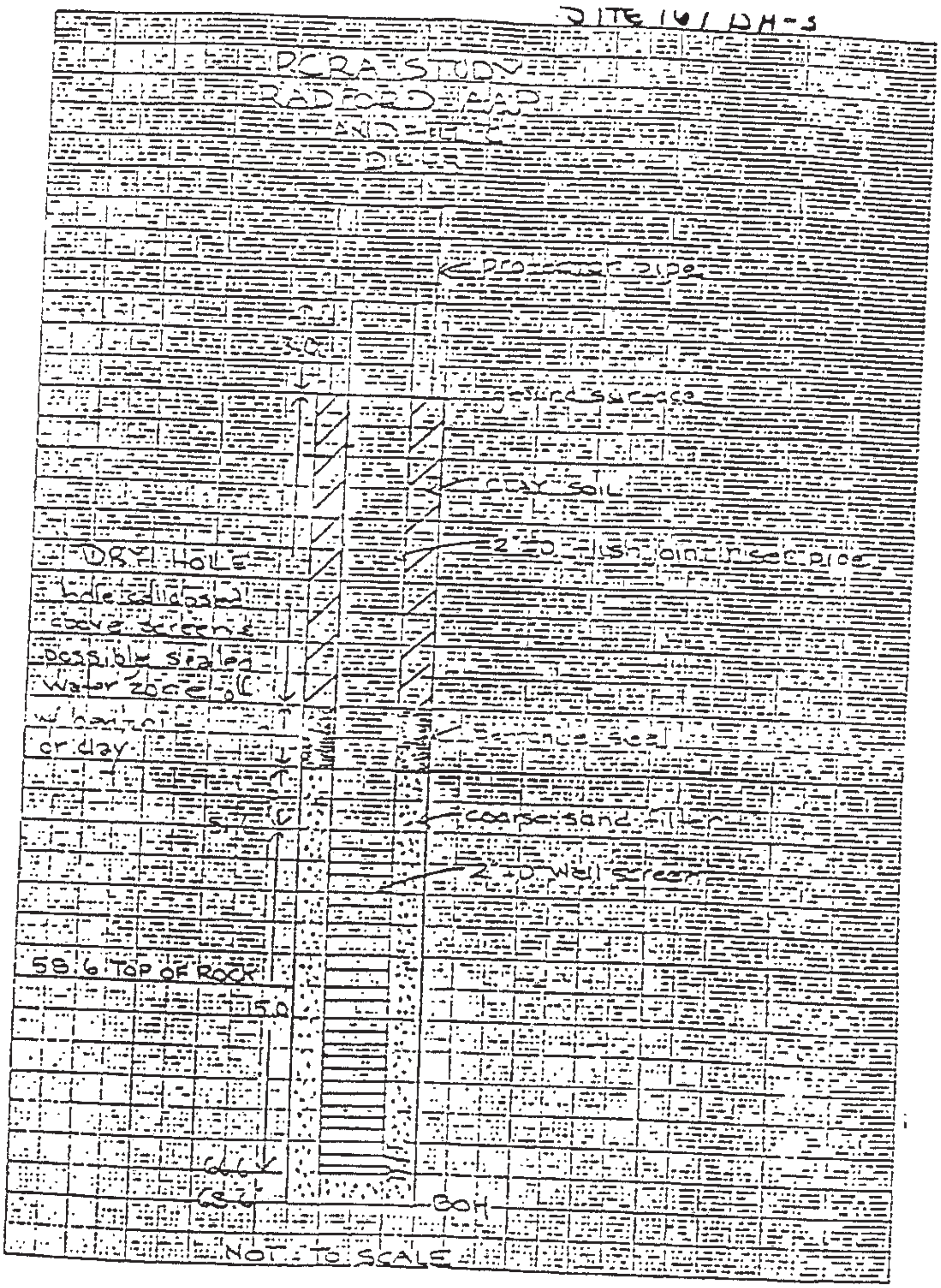
PROJECT LANDFILL C - RCRA STUDY | HOLE NO. [illegible]-7


SITE 16 / DH-3
RCRA STUDY
RADFORD AAP
protective pipe
3.0
ground surface
clay soil
2" I.D. flush joint riser pipe
DRY HOLE
hole sealed above screen
possible sealed water zone off
w/ bentonite
or clay
bentonite seal
5.0
coarse sand filter
2" I.D. well screen
58.6 TOP OF ROCK
15.0
66.6
68.6
BOH
NOT TO SCALE

1 Site 16 / DH-3

DRILLING LOG	DIVISION NAD
INSTALLATION	TAO
SHEET	1 of 2 SHEETS
1. PROJECT	RCRA-RAAP-LANDFILL "C"
2. LOCATION	
3. DRILLING AGENCY	CUNNINGHAM CORE DRILLING
4. HOLE NO.	DH-3
5. NAME OF DRILLER	BOB MONROE
6. DIRECTION OF HOLE	☒ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	58.6
8. DEPTH DRILLED INTO ROCK	10.0
9. TOTAL DEPTH OF HOLE	68.6
10. SIZE AND TYPE OF BIT	3" OD SS NX DIA
11. DATUM FOR ELEVATION SHOWN	MSL
12. MANUFACTURER'S DESIGNATION OF DRILL	SPRAGUE & HENWOOD 40C
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 9 / UNDISTURBED
14. TOTAL NUMBER CORE BOXES	1
15. ELEVATION GROUND WATER	NOT RECORDED
16. DATE HOLE	STARTED 21 JULY 90 / COMPLETED 26 JULY 90
17. ELEVATION TOP OF HOLE	
18. TOTAL CORE RECOVERY FOR BORING	8.7 / 87 %
19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			(CL) CLAY w/some silt and fine sand, red brown, med. plastic moist		S-1	Splitspoon 4-56
						K(0-5)=0
	5.5		(CL) Brown		S-2	Splitspoon 2-4-5
						K(0-10)=0
	9.5		(CL) CLAY w/some silt and fine sand, red brown med. plastic moist			SHELBY TUBE
						K(0-15)=0
					S-3	Splitspoon 7-13-17
						K(0-20)=0
	20.5		(SM) Very fine, w/little silt trace clay, moist yellow brown clay-red brown		S-4	Splitspoon 5-10-14
						K(0-25)=0
					S-5	Splitspoon 7-10-13
						K(0-30)=.07 ft/day
					S-6	Splitspoon 3-4-7
						K(0-35)=.05 ft/day
	35.0		No recovery for S-7 or S-8 probably (CL)		S-7	Splitspoon 3-4-7
						K(35-40)=7.3 ft/day
	41.5		(CH) ("F") Clay contact red brown, very moist		S-8	Splitspoon 14-13-10
						K(40-45)=4.3 ft/day
					S-9	Splitspoon 2-1-2
						K(45-50)=5.8 ft/day

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
MAR 71
(TRANSLUCENT)

PROJECT RCRA-RAAP-LANDFILL "C"
HOLE NO. DH-3

Hole No. 5W-1

DRILLING LOG	NAD	NAD
RCRA-RAAP-LANDFILL "C"		Sheet 1 of 1 sheets
CUNNINGHAM CORE DRILLING	SPRAGUE & HENWOOD 40C	
5W-1		
JOE MONROE	1	
☒ ☐	NOT RECORDED	
58.6	31 JULY 80	31 JULY 80
10.0	5.7	57 %
68.6		

			(CL) CLAY w/silt, sand & gravel v. moist med plastic red brown		S-10	Splitspoon 2-2-3
						K(50-55)=4.5 ft./day
					S-11	Splitspoon 2-2-3
						K(56-58.6)=7.4 ft./day
	58.6		Top 58.6 LIMESTONE - badly fractured lt.-dark grey, calcite healed fractures.	90	Run Box 6.2	HX Core RQD-0% K(58.6-68.6)= ~~[illegible]~~ 2.6 ft/day
				60	Run 2 Box 1 2.?	HX Core RQD-0%
	68.6		BOH 68.6 Water level not recorded dry after installing monitoring well.			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT RCRA-RAAP-LANDFILL "C" HOLE NO. 5W-1

ATTACHMENT 3
UNIT 16

APPENDIX I

GEOPHYSICAL INVESTIGATION AND SURVEY

GEOPHYSICAL INVESTIGATION AT HAZARDOUS WASTE MANAGEMENT SITE 16, RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA

BY

JOSE L. LLOPIS AND KEITH J. SJOSTROM

GEOTECHNICAL LABORATORY

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P.O. BOX 631, VICKSBURG, MISSISSIPPI 39180-0631

SITE 16

JULY 1987

Contents

APPENDIX 2

GEOPHYSICAL INVESTIGATION
AT
HAZARDOUS WASTE MANAGEMENT SITE 16
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

by

JOSE L. LLOPIS and KEITH J. SJOSTROM

GEOPHYSICAL INVESTIGATION AT HAZARDOUS WASTE MANAGEMENT SITE 16, RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA

BY

Jose L. Llopis and Keith J. Sjostrom

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Contents

GEOPHYSICAL INVESTIGATION AT HAZARDOUS WASTE MANAGEMENT SITE 16, RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA

Background

1. At the request of Mr. C. H. Whitten, Engineering Geology and Rock Mechanics Division, Geotechnical Laboratory (GL), personnel of the Earthquake Engineering and Geophysics Division, GL, conducted a geophysical investigation at Hazardous Waste Management Site 16 (HWMS-16), Radford Army Ammunition Plant (RAAP), Radford, Virginia (Figure 1). The investigation was conducted during the period 26 February through 6 March 1987 by Messrs. J. L. Llopis, K. J. Sjostrom, and D. H. Douglas.

Purpose and Scope

2. The objectives of the geophysical field program were to determine any anomalous conditions existing at the site and to determine the elevation of the top of rock near a suspected sink hole. Electromagnetic (EM) and seismic refraction methods were used to meet the above objectives.

Geophysical Methods

Electromagnetic Surveys

3. The EM technique is used to measure differences in terrain conductivity. Like electrical resistivity, conductivity is affected by differences in soil porosity, water content, chemical nature of the ground water and soil, physical nature of the soil, etc. In fact, for a homogeneous earth the true conductivity is the reciprocal of the true resistivity. Some advantages of using the EM over the resistivity technique are (a) less sensitivity to localized resistivity inhomogeneities, (b) no direct contact with the ground required, thus no current injection problems, (c) smaller crew size required, and (d) easy to make, rapid measurements.

4. The EM equipment used at HWMS-16 consists of two coils, connected by a cable. One coil is a transmitter and the other coil is a receiver. The transmitter coil (energized with an alternating current (AC) at an audio frequency)

is placed on the ground surface and the receiver coil placed a small distance away (33, 66, or 132 ft). The transmitter coil creates a time-varying magnetic field which induces small eddy currents in the ground. These currents then generate a secondary magnetic field which is sensed together with the primary field by the receiver coil. The readings in millimhos/ft are then presented in profile fashion or as isoconductivity contours if data is obtained in a grid form.

5. Figure 2 shows the location of the twelve EM survey lines conducted at HWMS-16. All of the EM lines were run using inter-coil separations of 33, 66, and 132 ft. Analogous to resistivity profiling, the greater the coil separation, the greater the depth of investigation. All measurements were taken in the horizontal dipole mode (coils oriented vertically). Readings for each survey line, with the exception of survey line EM-12, were obtained with the coil orientation perpendicular to the survey lines i.e., a coil on either side of the survey line axis. In addition, lines EM-1 through EM-6 were run with the coils oriented parallel to the survey lines (both coils on the survey line). The two different coil orientations (perpendicular and parallel to the survey line) were conducted to asses which orientation would better resolve the individual landfill cell boundaries. Survey lines EM-1 through 11 were spaced 50 ft apart. Readings were taken at 20 ft intervals along each survey line except for line EM-12 which were taken every 25 ft.

Seismic Refraction Surveys

6. The seismic refraction method utilizes the fact that the velocity of a material is dependent on its' elastic properties. It is based on the assumption that materials are locally homogeneous and isotropic. In the seismic refraction method, energy is imparted into the ground usually by means of explosives or by striking a metal plate on the ground with a sledgehammer to produce a seismic disturbance. The location of the seismic disturbance is considered to be a point source and the disturbance is transmitted through the ground as a series of waves. In this investigation the compression-wave (P-wave) will be the elastic wave studied. Geophones are implanted in the ground surface along a straight line spaced at regular intervals. The length of the survey line depends on the depth of the investigation. A common rule of thumb is that the length of the line should be from three to four times the

depth of interest. Interpretation of seismic refraction data consists of plotting the P-wave arrival times for each geophone versus the geophone distances from the seismic source. The slope of the straight line segments drawn through the points correspond to the P-wave velocities of the materials. With further analysis the depths to the horizontal interfaces can be determined.

7. Figure 3 shows the location of refraction lines R-1 through R-7 which were run at HWMS-16. Refraction lines R-2 through R-6 consisted of 24 geophones spaced 50 ft apart with shot points offset 15 ft from the end of each line thus, giving a total line length of 375 ft. This allows a maximum depth of investigation of approximately 90 to 120 ft. Refraction lines R-1 and R-7 consisted of 24 geophones spaced 10 ft apart with shot points offset 10 ft from the end of the lines thus, giving an end-to-end survey line length of 250 ft Hence, the 250-ft refraction lines are useful in determining the velocities to a maximum depth of approximately 60 to 80 ft. The surveys were conducted using a portable 24-channel seismograph and stored on magnetic tape for subsequent processing and interpretation. Energy was imparted into the ground by the use of two-component explosives. A more thorough discussion of seismic refraction field procedures is given in Engineer Manual 1111-1-1802 (Headquarters, Department of the Army, 1979).

Results

Electromagnetic Surveys

8. Results of EM surveys EM-1 through EM-11 are presented in two fashions, two dimensional (2-D) and three dimensional (3-D) views. Figures 4 through 6 present a two dimensional view of the data obtained from conducting EM survey lines EM-1 through EM-11 for intercoil spacings of 33, 66, and 132 ft, respectively. Figures 7 through 9 present a 3-D view of the EM data for lines EM-1 through EM-11 with intercoil spacings of 33, 66, and 132 ft, respectively. Figures 4 through 9 correspond to the case where the coil orientation is perpendicular to the EM survey line. Referring to Figure 4, 33 ft intercoil surveys, three prominent conductivity highs can be seen occurring at the approximate x-y coordinates (450, 625), (325, 375), and (200, 175). Referring to Figure 5 and 6, 66 and 132 ft intercoil surveys, respectively, it

can be seen that the anomalous high conductivity reading at (450, 625) becomes less prominent. The area with the anomalously high conductivity values (450, 625) occurs on the landfill boundary and may be due in part to buried man-placed material and in part to natural conditions, such as higher water content or more clayey material. It is also possible that the conductivity high at (450, 625) may be caused by a septic tank which is buried in the vicinity. It is not known whether the septic tank is made of concrete or steel, therefore; it is difficult to assess its' influence on the conductivity readings. The other two conductivity highs occur in the landfill and are believed to be caused by electrically conductive slag type material used to bury waste at the site or caused by the waste itself. Referring to Figures 7 through 9, 3-D perspectives for EM surveys with intercoil spacings of 33, 66, and 132 ft, respectively, a series of linear northeast-southwest trending features can be discerned. These more conductive linear features correspond with waste trenches known to exist in the area. It is noted that the linear feature with the highest conductivity values corresponds to a landfill trench used for burying hazardous waste. The remaining trenches contain sanitary waste and have relatively lower conductivity readings.

9. Figures 10 through 12 show the interpreted locations of the landfill cells based on the 33, 66, and 132 ft perpendicularly oriented EM survey data, respectively. The "actual" cell locations referred to in Figures 10 through 12 are close approximations of the landfill locations since they were already covered at the time they were surveyed in 1983. The locations of the "actual" landfill cells as shown in Figures 10 through 12 are based on a drawing provided by RAAP personnel. The locations of the landfills were interpreted as areas having a relative high conductivity. Referring to Figures 10 through 12 it can be seen that the interpreted locations of the landfill cells correspond very well in terms of basic width, length, and orientation with the actual locations. Also it will be noted that there is not much difference in the interpretations between the 33, 66, and 132 ft intercoil EM surveys.

10. Figures 13 through 15 show a 2-D view of the EM data obtained with coils oriented parallel to the EM survey lines for intercoil spacings of 33, 66, and 132 ft, respectively. Referring to Figure 13, two conductivity highs are apparent; one is centered at approximate coordinate (290, 350) and the other at (150, 150). Referring to Figure 14 (66 ft intercoil spacing) conduc-

tivity anomalies can also be discerned in the same general locations as for the 33 ft case, however, the anomalies are broader and less distinct. Referring to Figure 15 (132 ft intercoil spacing) it can be seen that there is little variation in conductivity across the site, when compared to the data in Figures 13 and 14, intercoil spacings of 33 and 66 ft, respectively. Referring to Figures 16 through 18, 3-D perspectives for EM surveys with intercoil spacings of 33, 66, and 132 ft, respectively, it can be seen that the 66 ft intercoil spacing survey best defines the landfill cells.

11. Interpreted locations of the landfill cells, based on the results of the EM survey conducted parallel to the EM lines for the 33, 66 and 132 ft intercoil spacings are presented in Figures 19 through 21, respectively. The locations of the landfills were interpreted as being areas having a relatively high conductivity. It can be seen in Figures 19 through 21 that these surveys have less resolving power for delineating the cells than when the survey is conducted perpendicular to the EM lines (parallel to the strike of the cells). The 66 ft intercoil spacing survey (Figure 20) defined the location of the cells better than the 33 or 132 ft surveys (Figures 19 and 21, respectively).

12. The advantage of conducting the EM surveys with the coils oriented vertically and coplanar are that the coils are not as sensitive to misalignment and therefore the survey proceeds more rapidly. However, when the survey is conducted in this manner, readings taken are affected greatly by near-surface materials and changes in conductivity at greater depths can be masked. In order to determine whether conductivity is increasing or decreasing with depth the "two-spacing" technique was used. In this technique intercoil spacings of 33 and 66 ft and/or 66 and 132 ft are used to conduct the survey. For the case where 33 and 66 ft spacings are used, apparent conductivity readings for 33 ft and 66 ft spacings, designated C33 and C66, are taken at each measurement station. Also, at each measurement station a new apparent conductivity, designated Cn, is computed as follows:

$$Cn = 2*C66 - C33$$

The apparent conductivities obtained from performing the above computation are plotted in 2 dimensions. The plot for the 33 ft intercoil spacing (C33) gives the conductivity response of materials for depths of less than approximately

13 ft while the data of 2*C66-C33 gives the conductivity response at depths greater than 13 ft. When the survey is conducted with intercoil spacings of 66 and 132 ft then the plot for C132 gives the conductivity response of materials at depths less than 26 ft while the plot of 2*C132-C66 gives the conductivity response at depths greater than 26 ft.

13. Figures 22 and 23 are plots of the EM two spacing technique, 2*66-33 and 2*132-66, respectively, run with the coils oriented perpendicular to the EM survey lines. Referring to Figure 22 two prominent negative areas can be seen occurring at approximate coordinates (275, 350) and (375, 450). This suggests that in these areas the conductivity of the material is decreasing with depth. Also in this figure, three highly conductive areas can be detected at approximate stations (250, 525), (275, 300), and (350, 400). These areas are indicative of materials increasing in conductivity with depth. Referring to Figure 23, one negative area centered about coordinate (300, 300) can be seen. Three areas with relatively high conductivity values, indicating that conductivity is increasing with depth, can be seen occurring at approximate coordinates (250, 325), (375, 525), and (300, 225).

14. Figures 24 and 25 are plots of the EM two spacing technique, 2*66-33 and 2*132-66, respectively, run with the coils oriented parallel to the EM survey lines. Referring to Figure 24, two prominent negative zones could be discerned at approximate coordinates (220, 180) and (280, 350). No highly positive zones would be defined in this figure. Referring to Figure 25 two negative zones are noted, the first occurs in the lower left-hand portion of the plot and the second occurs about approximate coordinate (280, 340). One prominent positive zone can be seen occurring at approximate coordinate (150, 350) however, this positive peak occurs near the edge of the surveyed area and may not be a reliable data point.

15. Figure 26 presents the results of the EM profile line conducted around the perimeter of HWMS-16, along the road as shown in Figure 2. Referring to Figure 26 an anomalous area is noted at approximately 650 ft. The anomaly is characterized by a peak bounded by a trough on either side. This anomaly occurs on each of the three survey lines and occurs across the road from well CDH2.

Seismic Refraction Surveys

16. Figures 27 through 33 present the time versus distance (TD) information obtained from running seismic refraction surveys R-1 through R-7, respectively. It will be noted that due to the disturbed nature of the site caused by trenching and backfilling, the site is inhomogeneous, in the geologic sense, making depth and velocity determinations questionable. Presented below are interpretations based on geophysical and geologic judgment. Referring to Figure 27, line R-1, two velocity layers are represented. The uppermost layer has a velocity of 2050 fps while the lower velocity layer, occurring at depths ranging between 34 and 54 ft has a velocity of 6910 fps. Referring to Figure 28, line R-2, two layers with velocities of 1550 and 11190 fps can be detected below the southwestern portion of the line while three layers having velocities of 1520, 2510, and 8620 fps are interpreted at the northeastern section of the line. The depth to the 11190 fps layer beneath the southwestern shotpoint is 48 ft while the depths to the 2510 and 8620 fps layers are 16 and 55 ft, respectively. It appears that the 8620 and 11190 fps layers correspond to the same material (bedrock). It also appears that the 2510 fps layer thins out to the southwest. Referring to Figure 29, line R-3, two layers with velocities of 1970 and 8930 fps are discerned at the southwestern end of the line while three layers with velocities of 1650, 4520, and 10710 fps are detected at the northeastern end of the line. The average velocity of the uppermost layer is 1810 fps while the true velocity of the bedrock is 9740 fps and is detected at depths ranging between 54 and 87 ft. The 4520 fps layer which is detected at a depth of 33 ft beneath the northeastern shot point is believed to thin out towards the southwest. Figure 30 presents the TD information obtained from running survey line R-4. Three velocity layers were interpreted from this survey line. The first layer has a velocity of 1580 fps and extends to depths ranging between 29 and 30 ft The second layer has a velocity of 4300 fps and ranges in depth between 66 and 80 ft where the deepest layer (bedrock) having a velocity of 10100 ft is detected. It is noted that the forward traverse indicates an anomalous zone occurring between a distance of 240 and 360 ft relative to the forward shot point. This may be caused by localized doming of the bedrock surface or by a subsurface feature having a greater velocity than the surrounding material. Seismic line R-5 (Figure 31) indicates an unequal number of layers between the forward and reverse traverses. The forward traverse

indicates two velocity zones. The first zone has a velocity of 2220 fps and extends to a depth of 46 ft where the second zone, bedrock, with an apparent velocity of 7500 fps is encountered. The reverse traverse indicates three velocity layers. The first layer with a velocity of 880 fps extends to a depth of 10 ft where the second layer is encountered with a 2010 fps velocity. It appears that layer one of the forward traverse corresponds with layer two of the reverse traverse and that the first layer of the reverse traverse thins out towards the southwest. The bedrock under the northeast shotpoint, with an apparent velocity of 9380 fps, is detected at a depth of 38 ft. The true velocity of the bedrock for line R-5 is 8335 fps. Figure 32 presents the TD information gathered from the conduct of line R-6. Two velocity layers were determined as a result of the testing. The first layer has an average velocity of 1950 fps with a thickness ranging between 33 and 36 ft and is underlain by a second layer, bedrock, which has a true velocity of 7310 fps. An anomalous zone is indicated by the data occurring at distances ranging between 180 and 350 from the southwestern shotpoint. Referring to Figure 33, line R-7, two velocity layers are indicated. The first layer has an average velocity of 2100 fps and extends to depths ranging between 50 and 52 ft where bedrock with a true velocity of 9610 fps exists. An anomalous feature extending between a distance of 190 and 240 ft relative to the northern shotpoint is indicated by the data. Figure 34 presents a summary of the seismic refraction results. Figure 35 presents a contour map of the elevation of the top of rock. The top of rock elevations were obtained by estimating the elevation of the refraction survey shot points and subtracting the calculated overburden thickness. This gave a total of 14 depth data points (one data point under each shot point) to be used as input for a computer contouring program.

Conclusions

17. Two geophysical methods were employed at HWMS-16 in an attempt to delineate zones having anomalous terrain conductivity conditions and to determine the depth to rock. With regard to the surveys performed during the period 26 February through 6 March 1987, the following conclusions are made:

a. The EM surveys delineated several zones having anomalous conductivity values. The method was successful in determining the locations of buried landfill cells. Also, it was determined that cell #4, used for burying hazardous waste material exhibited the highest conductivity values.

b. Although the site was heterogeneous in character, the seismic refraction lines were successful in determining the depth to top of rock and also in determining the P-wave velocities for the various layers at the site.

Figure 1. Site map showing location of Hazardous Waste Management Site 16

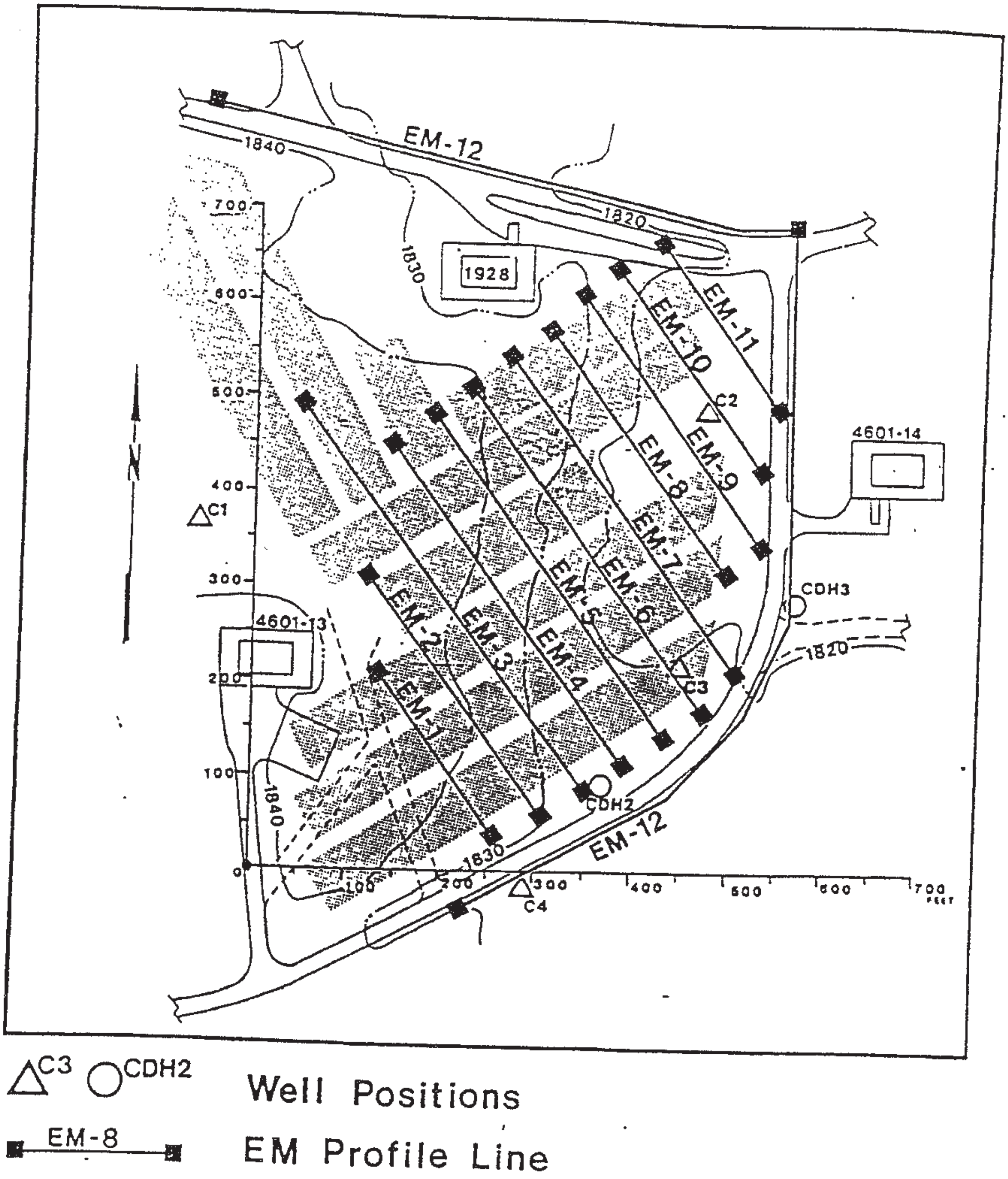


Figure 2. Location and orientation of EM lines

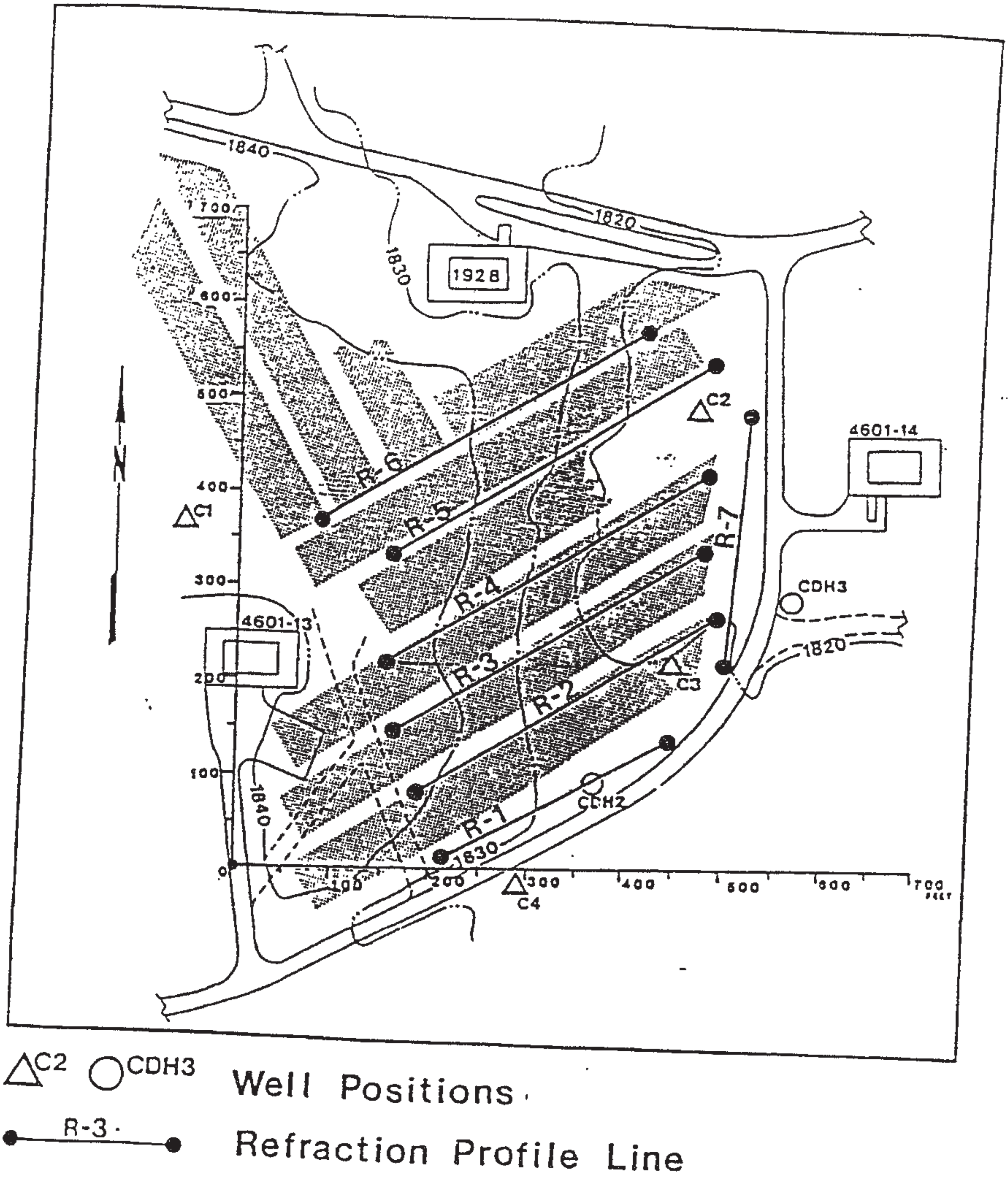
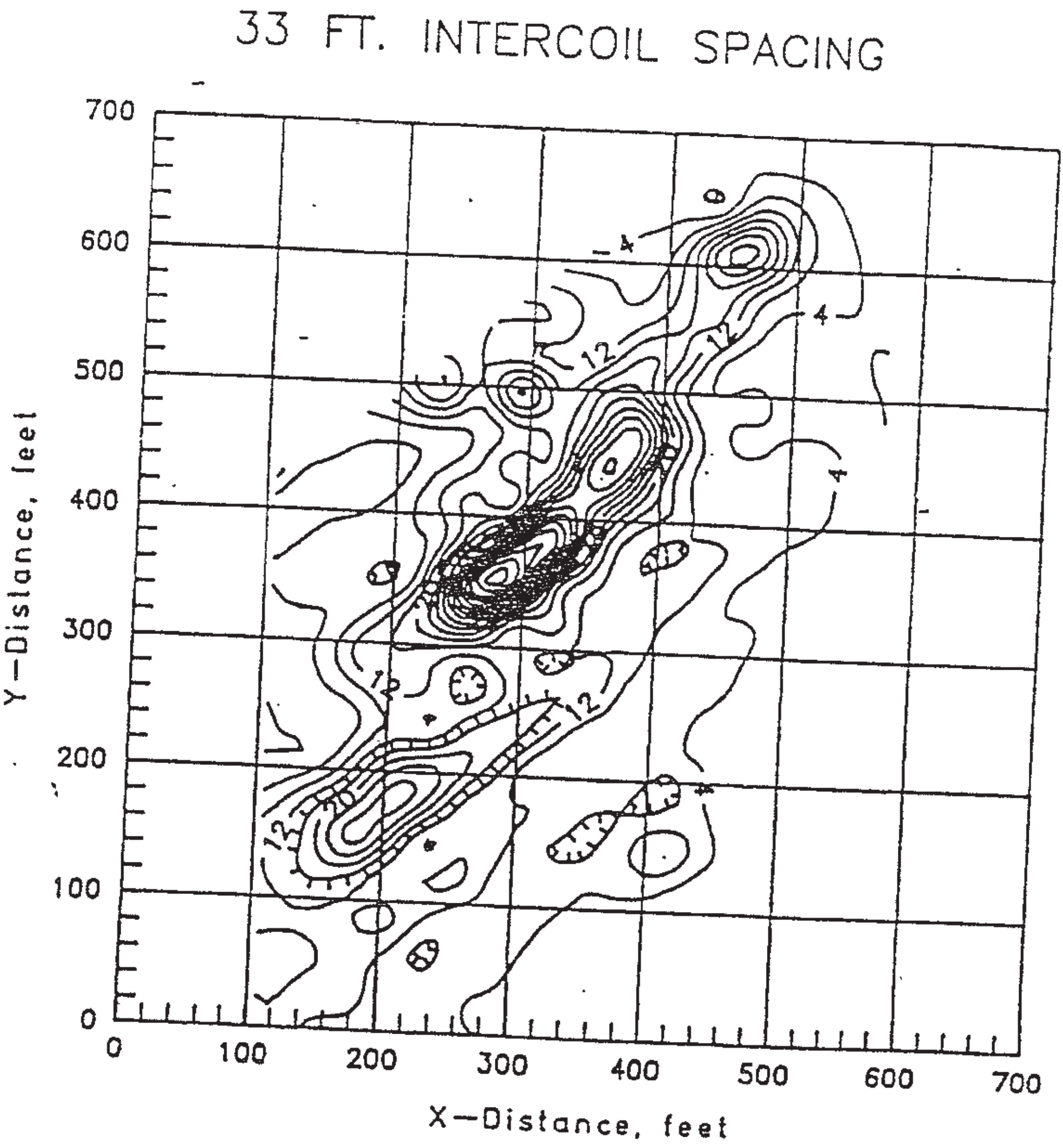


Figure 3. Location and orientation of seismic refraction lines



33 FT. INTERCOIL SPACING

Contour interval=4mmhos/ft

Figure 4. 2-D EM data, 33 ft intercoil spacing, perpendicular orientation

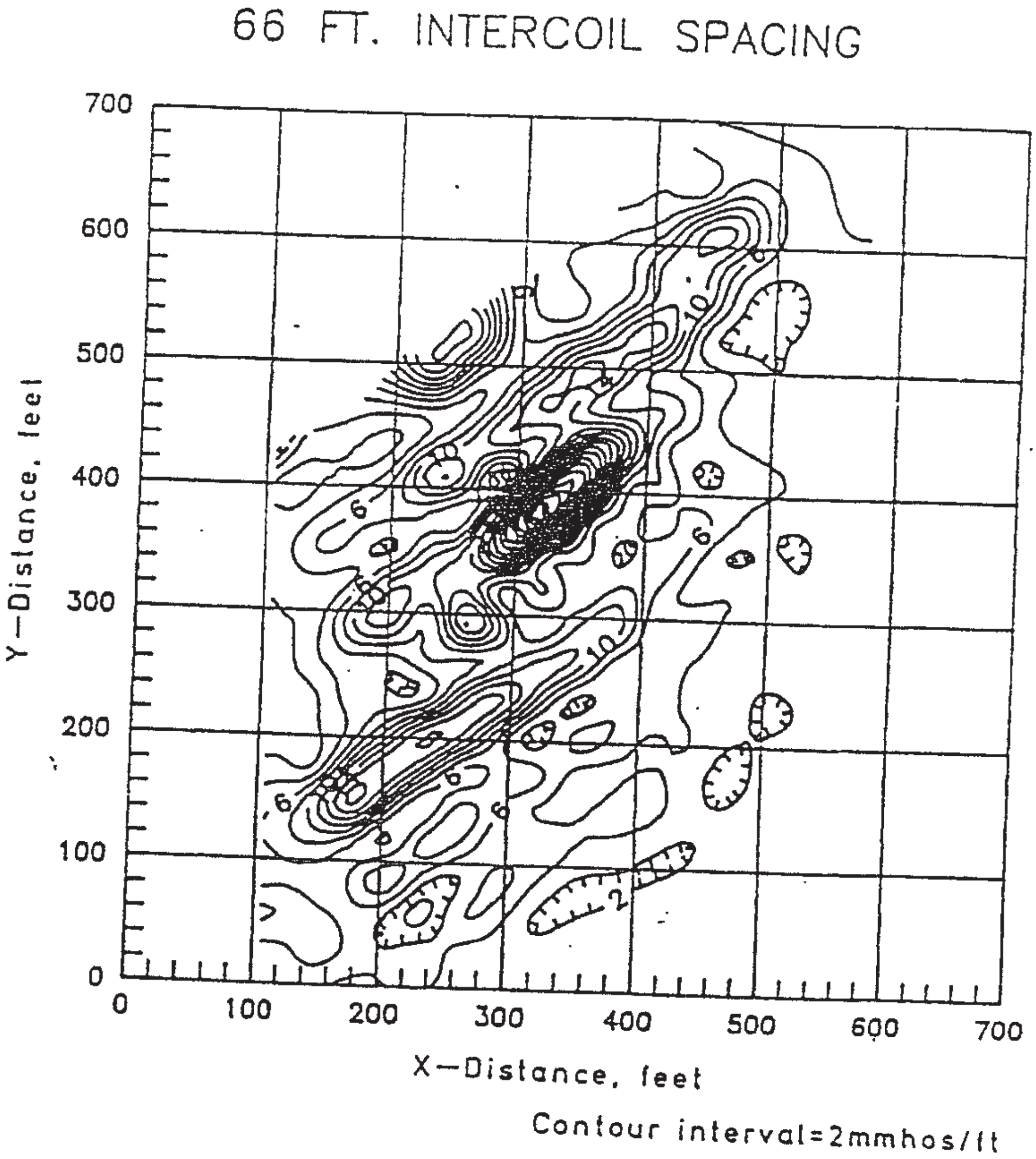
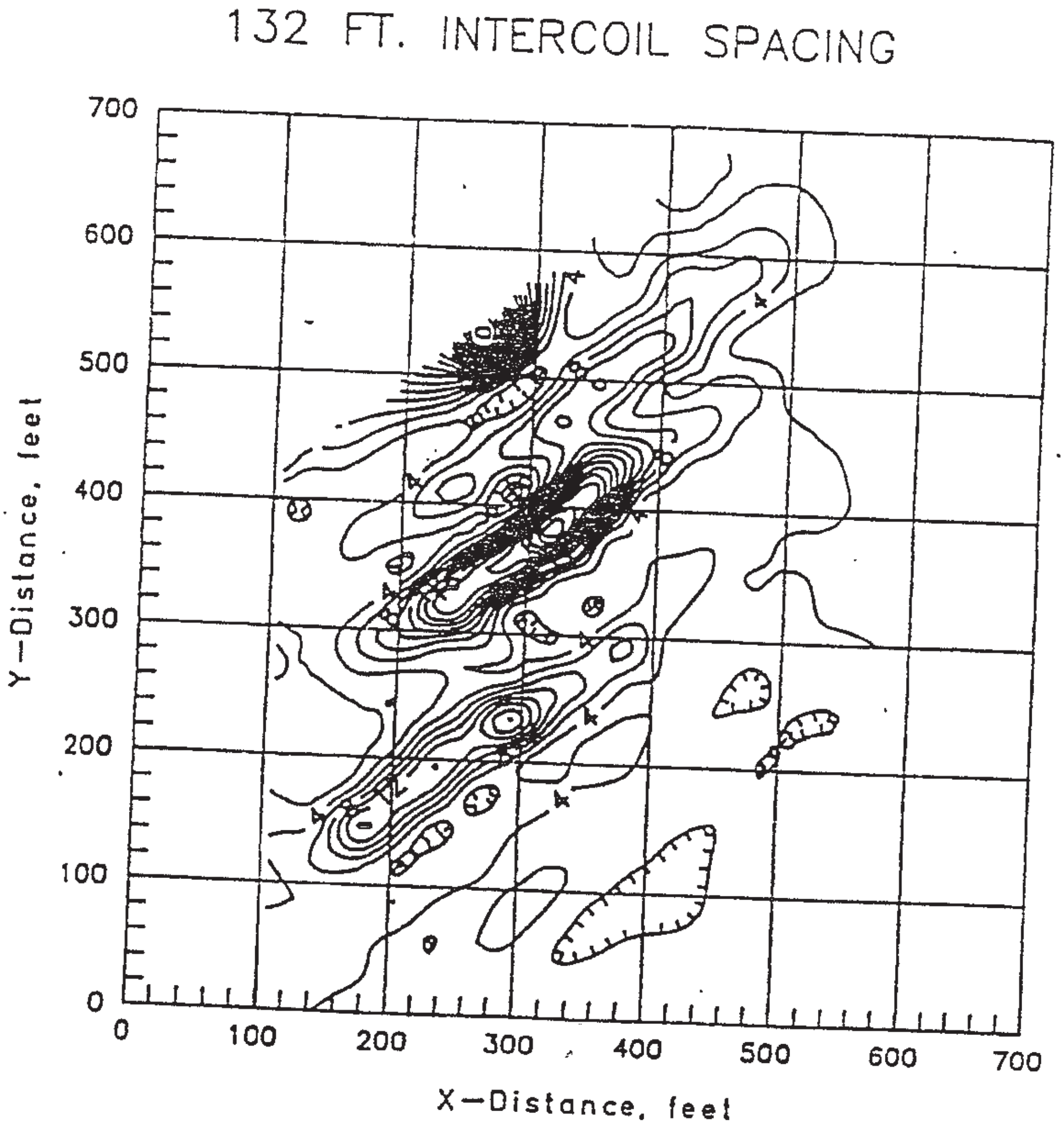


Figure 5. 2-D EM data, 66 ft intercoil spacing, perpendicular orientation



Contour interval=2mmhos/ft

Figure 6. 2-D EM data, 132 ft intercoil spacing, perpendicular orientation

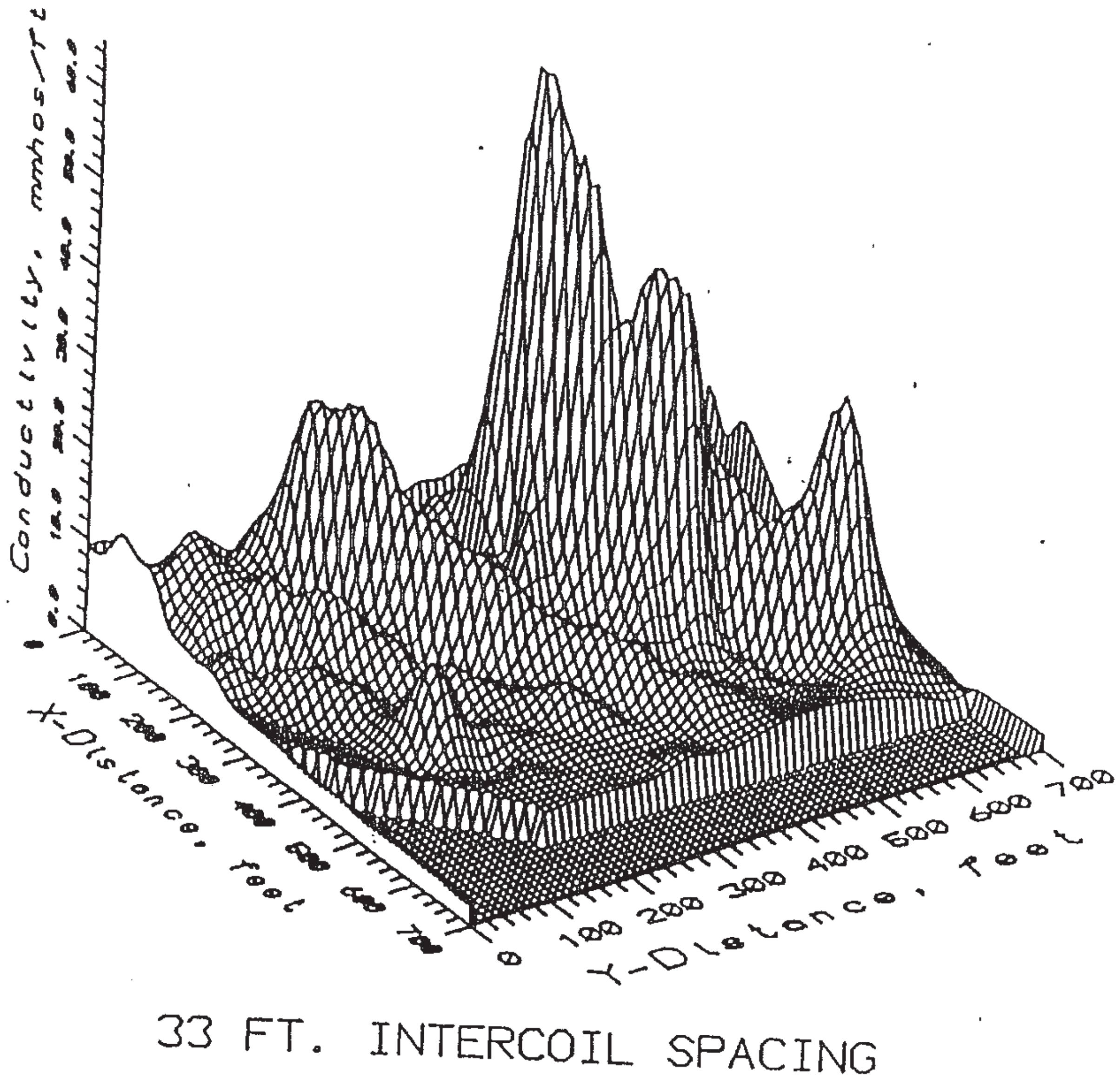
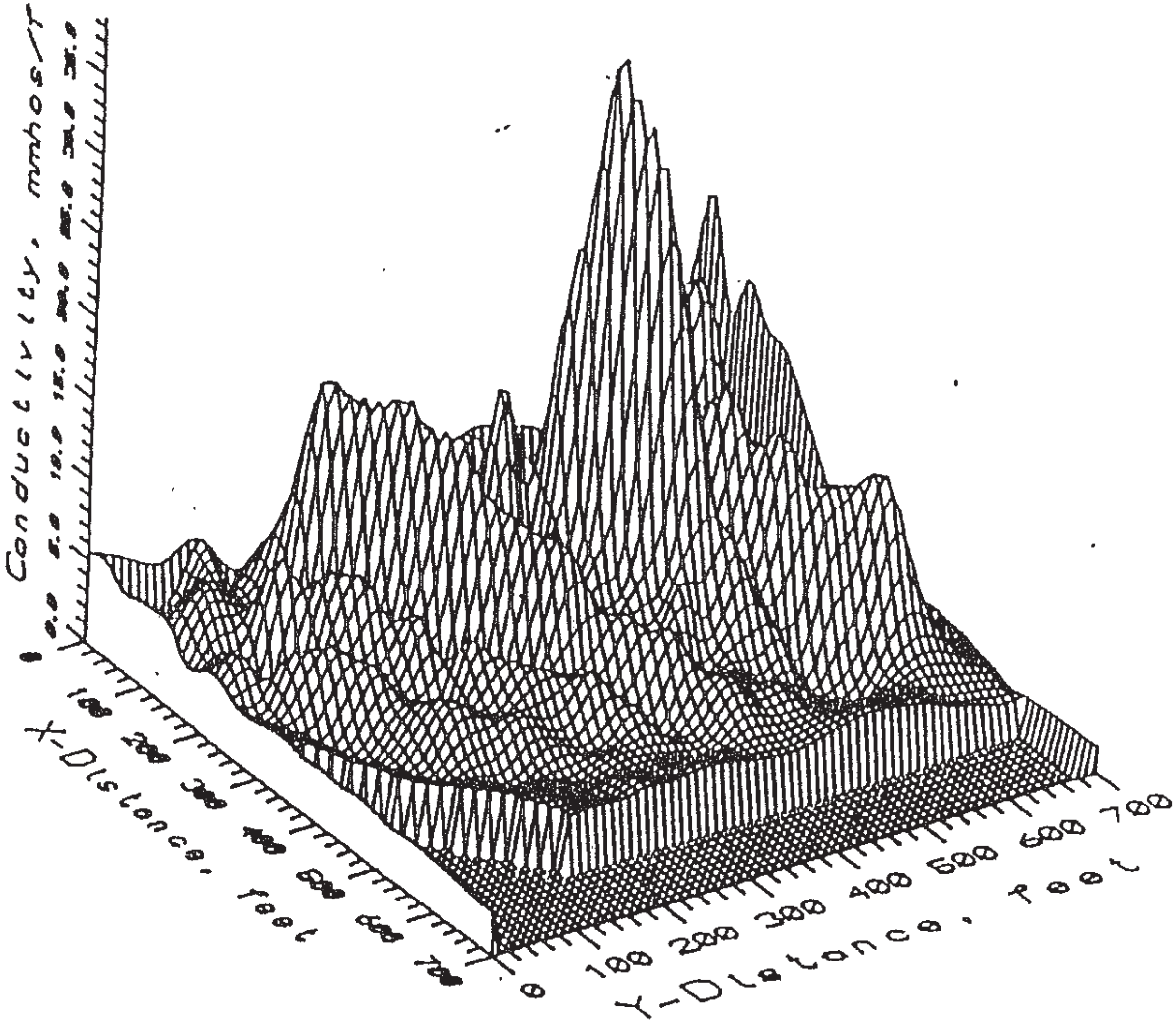
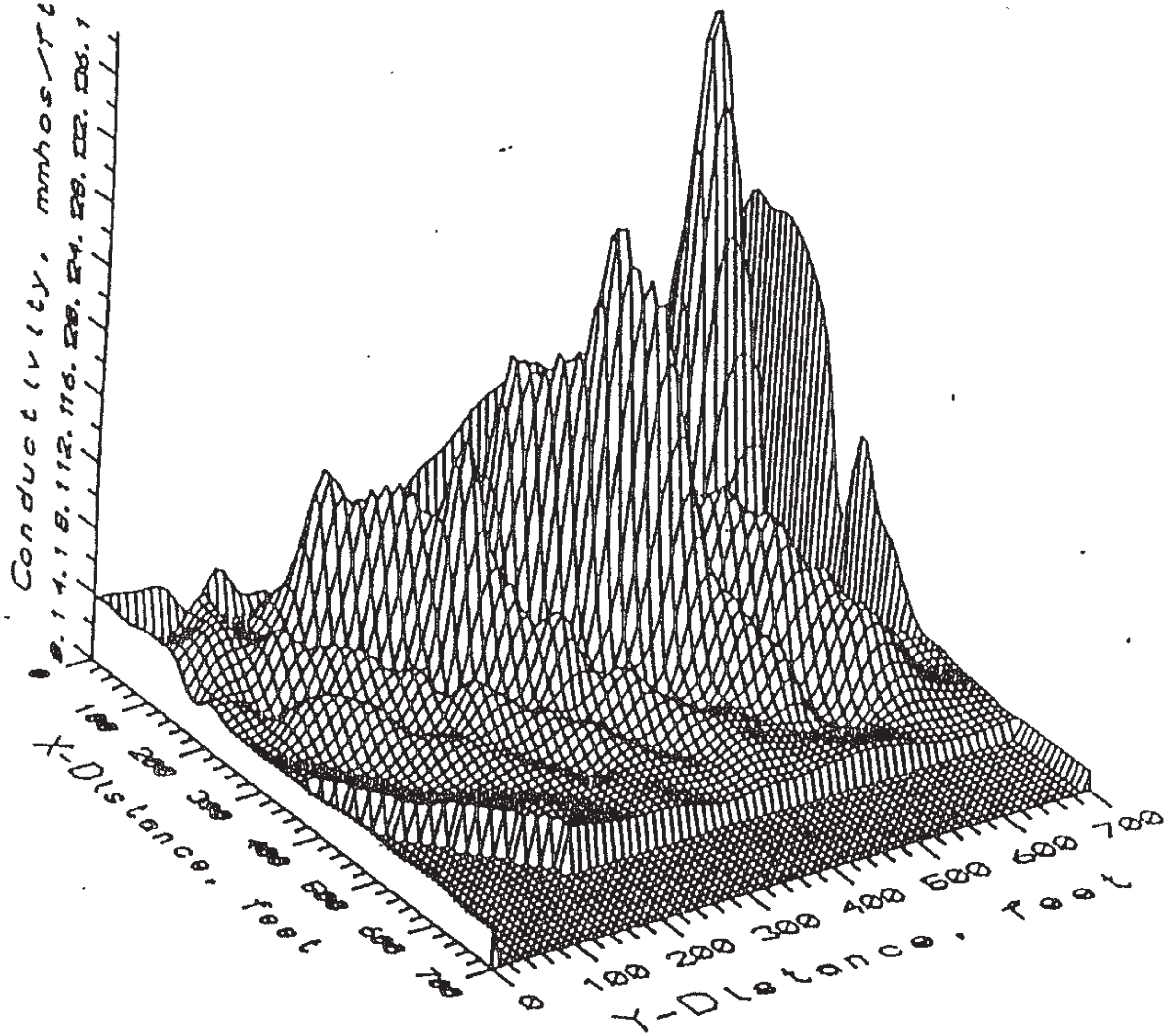


Figure 7. 3-D EM data, 33 ft intercoil spacing, perpendicular orientation



66 FT. INTERCOIL SPACING

Figure 8. 3-D EM data, 66 ft intercoil spacing, perpendicular orientation



132 FT. INTERCOIL SPACING

Figure 9. 3-D EM data, 132 ft intercoil spacing, perpendicular orientation

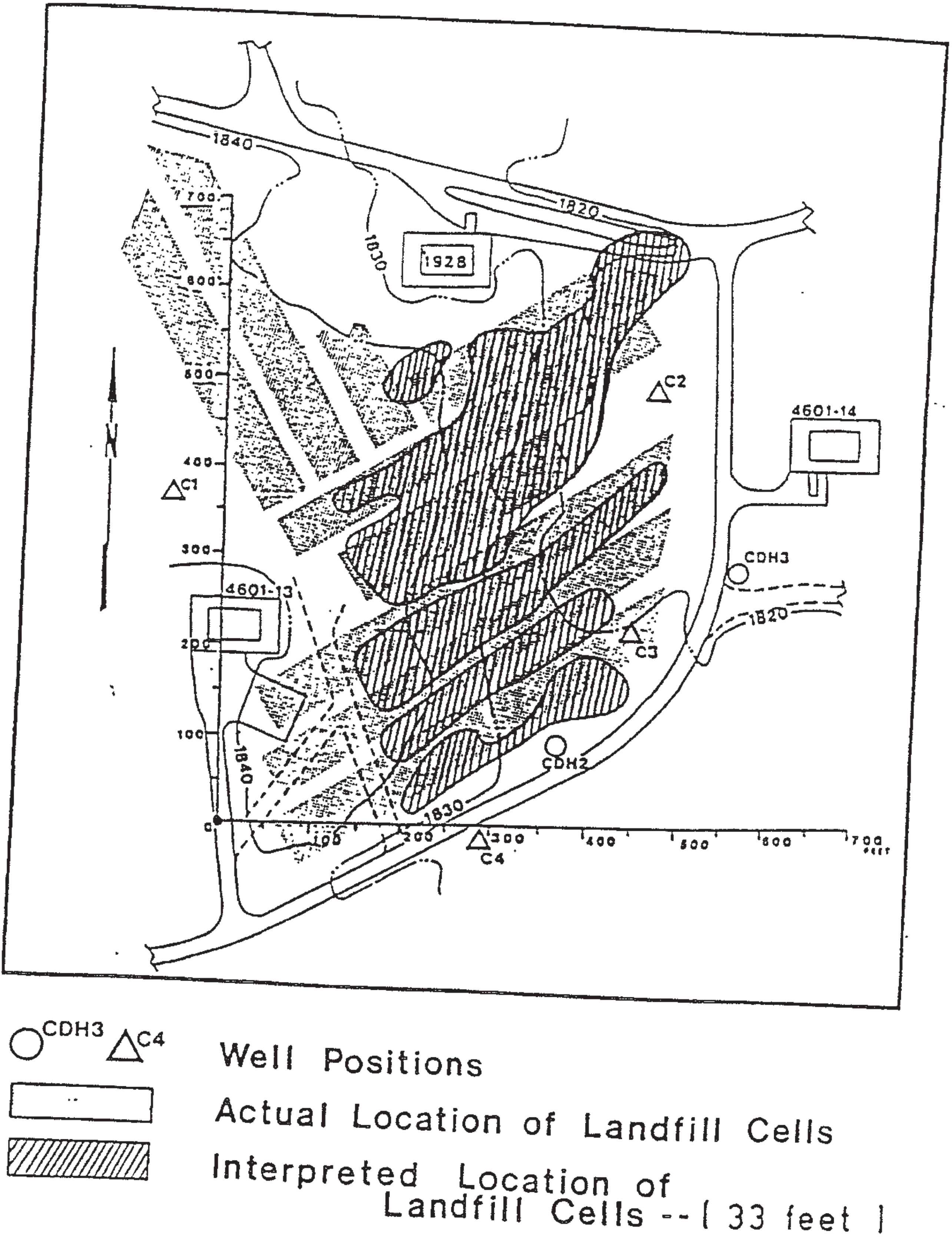


Figure 10. Interpreted location of landfill cells, 33 ft intercoil spacing, perpendicular orientation

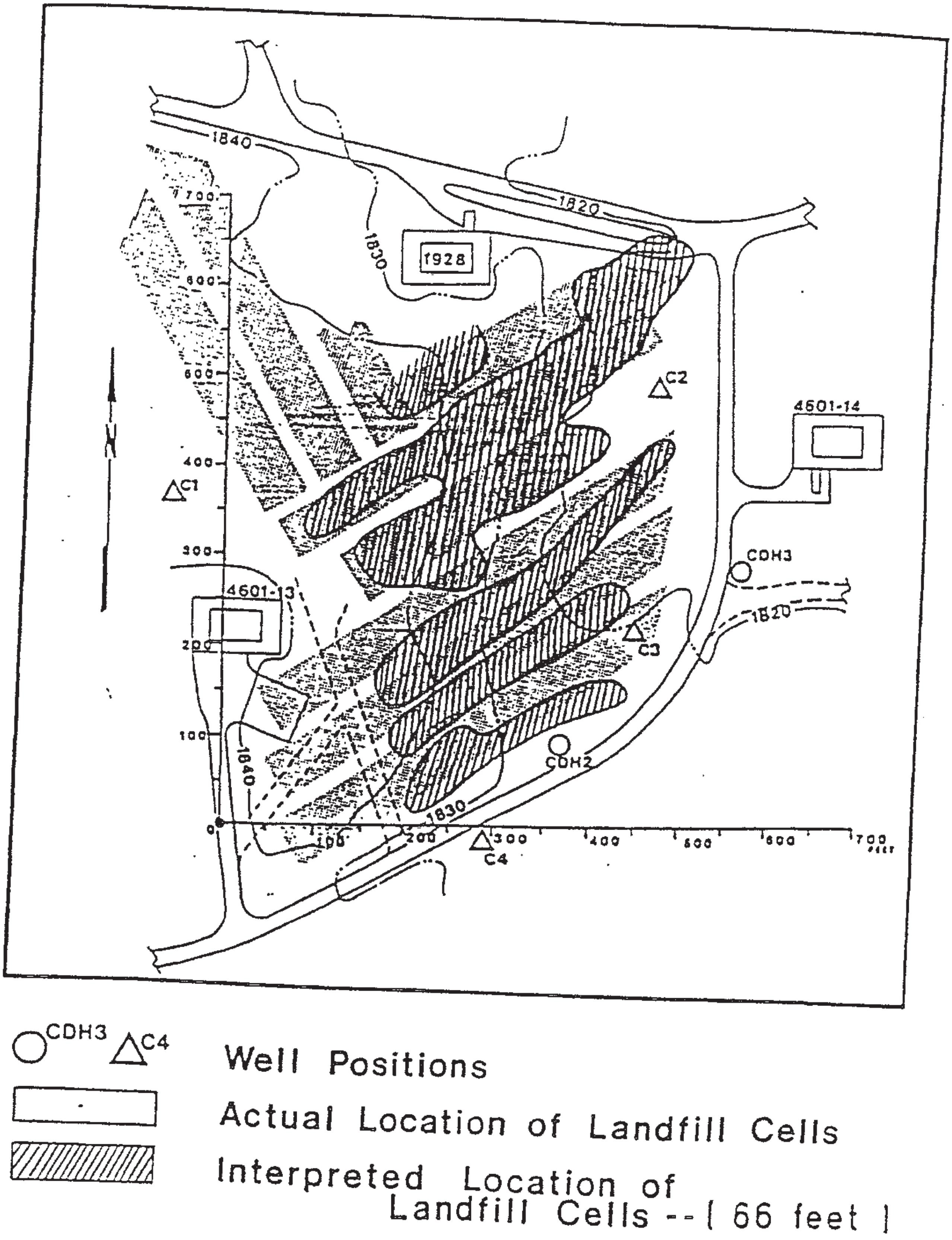


Figure 11. Interpreted location of landfill cells, 66 ft intercoil spacing, perpendicular orientation

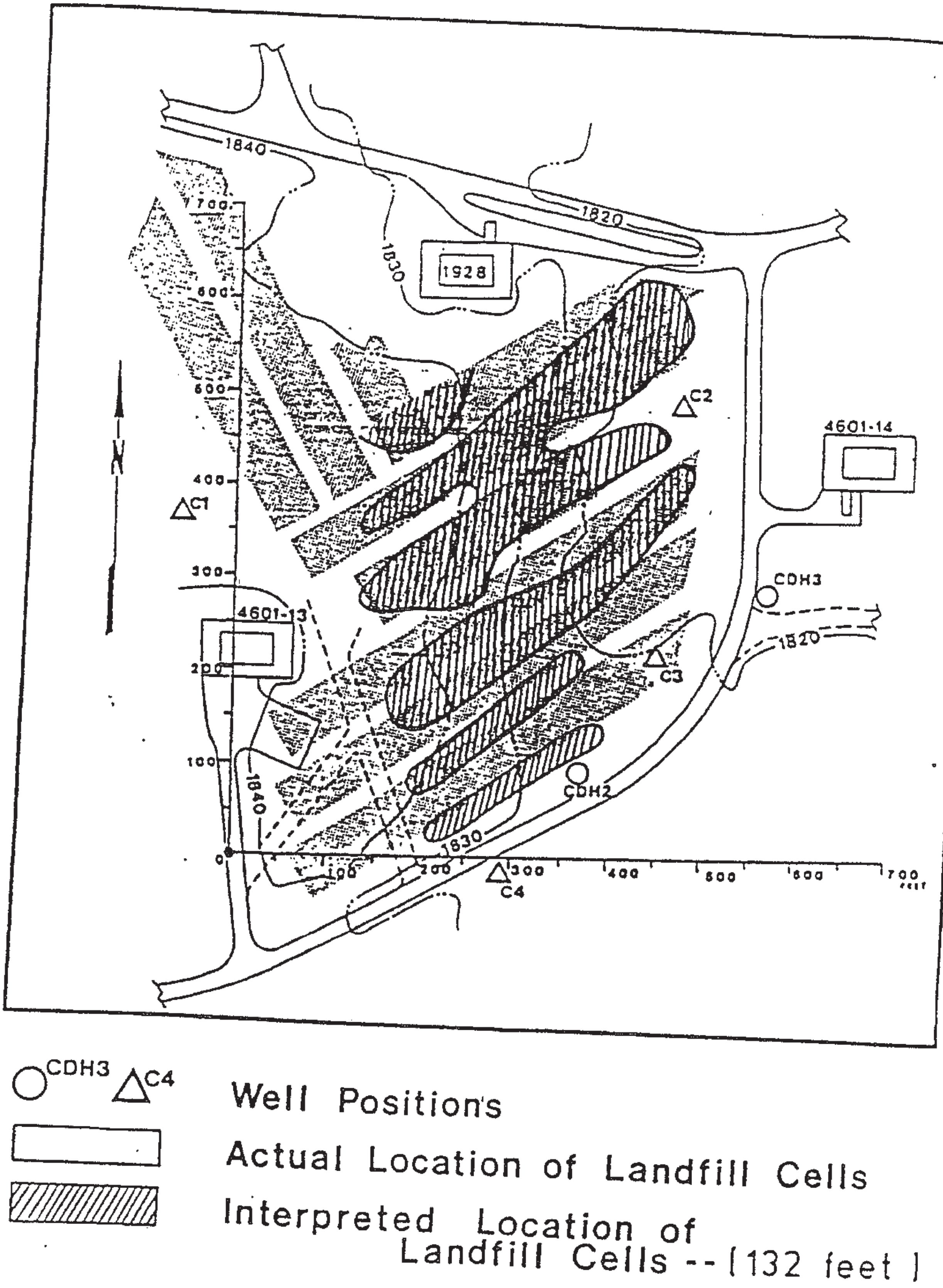


Figure 12. Interpreted location of landfill cells, 132 ft intercoil spacing, perpendicular orientation

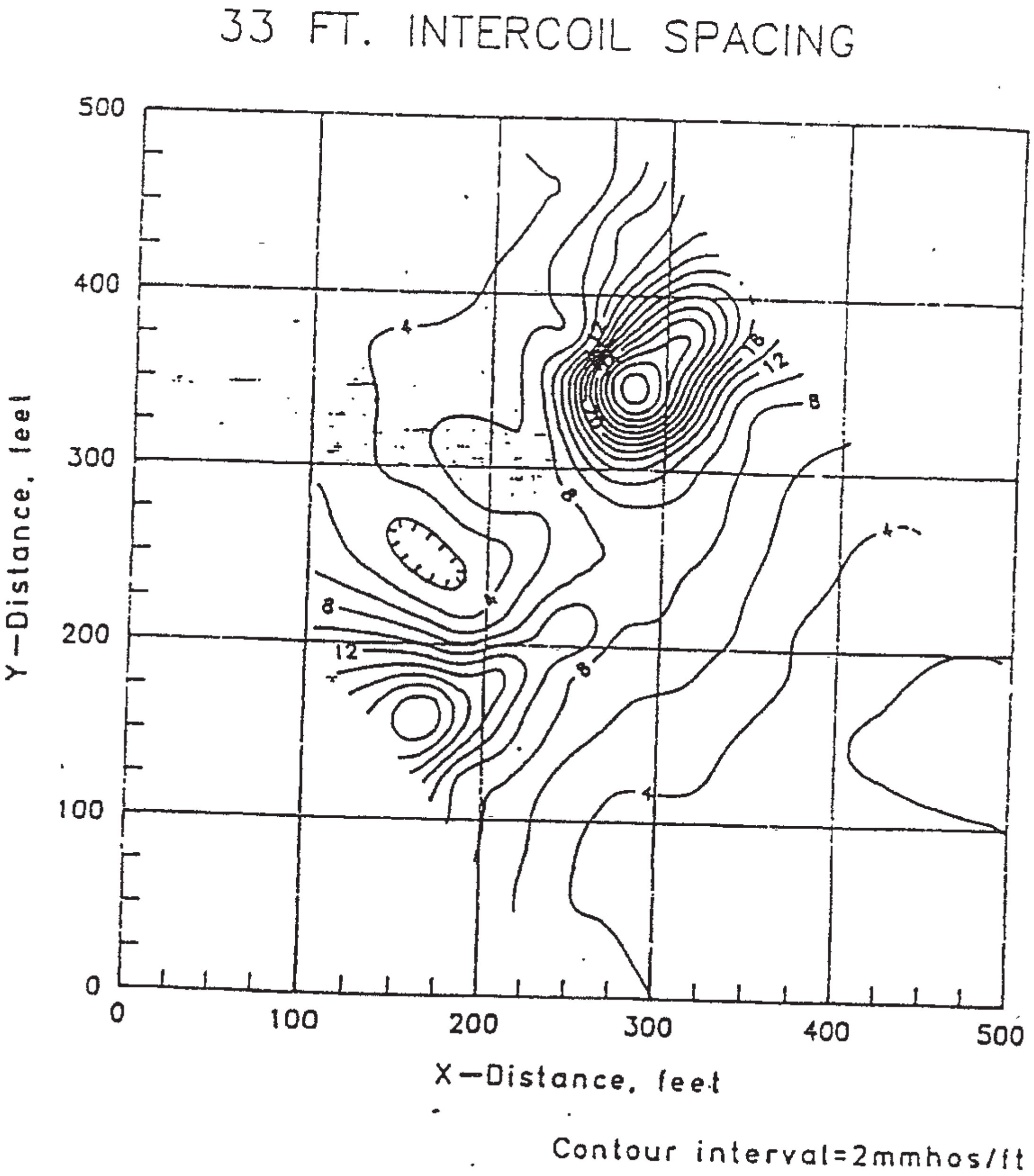
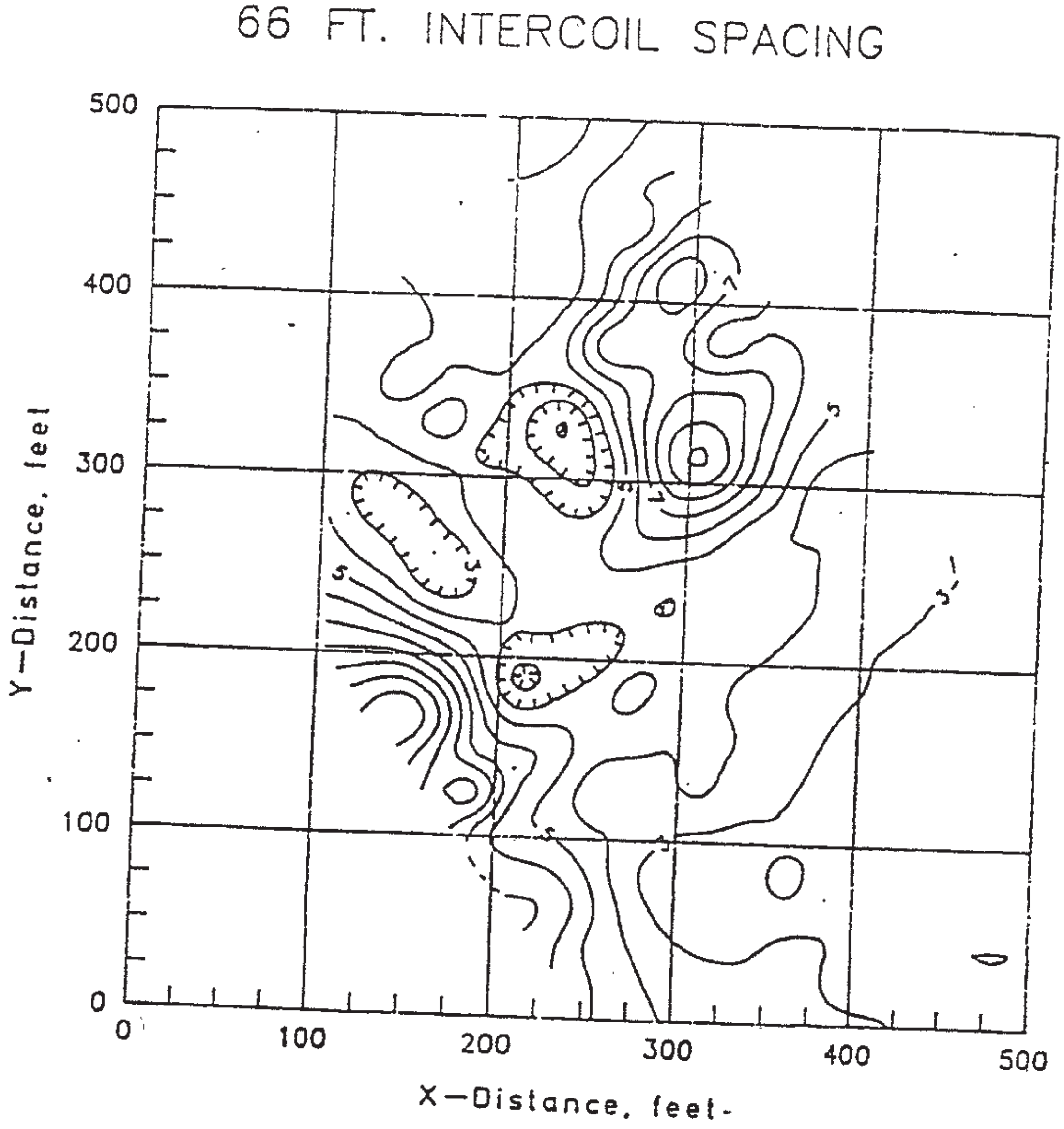


Figure 13. 2-D EM data, 33 ft intercoil spacing, parallel orientation



Contour interval=1mmho/ft

Figure 14. 2-D EM data, 66 ft intercoil spacing, parallel orientation

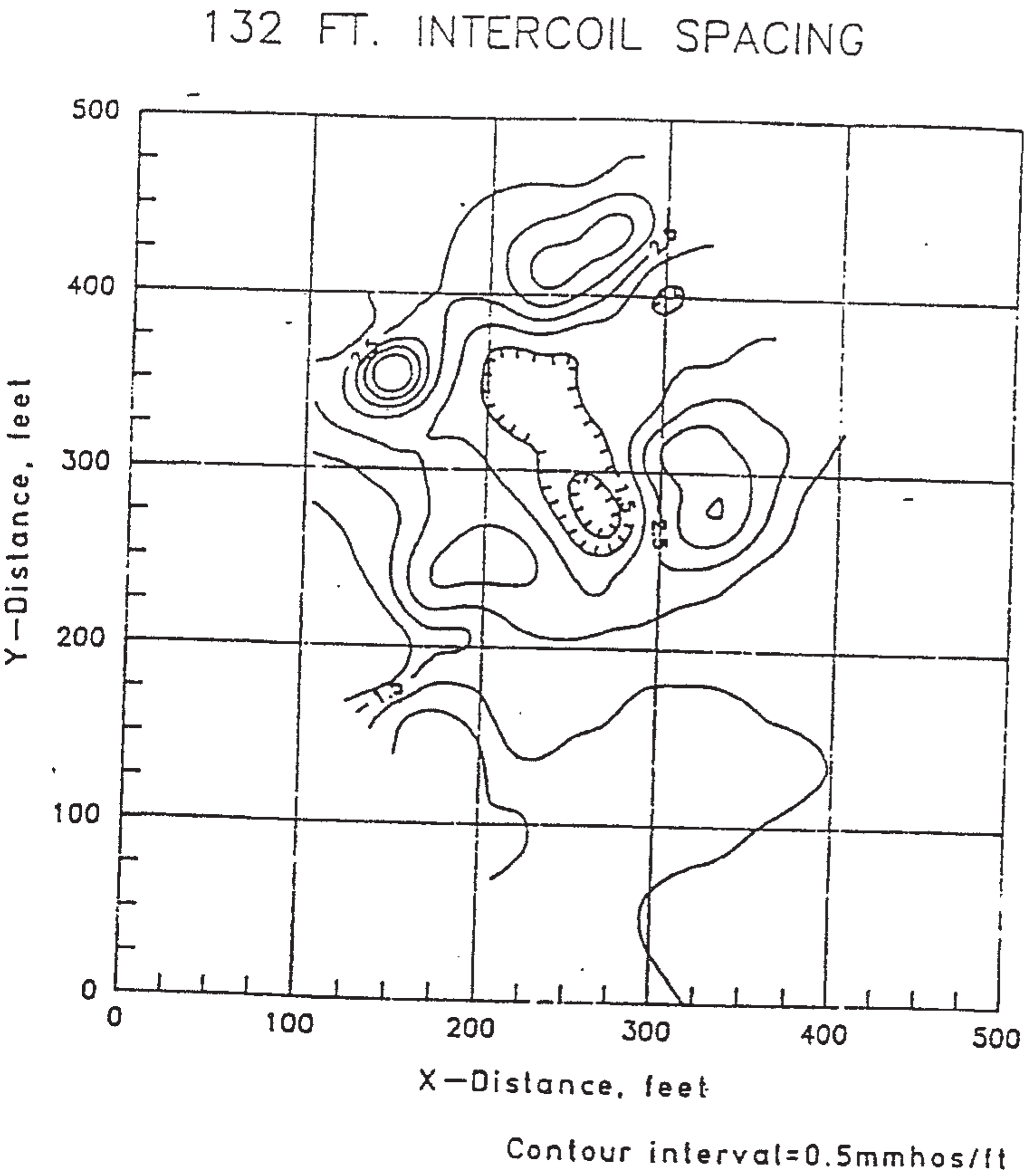


Figure 15. 2-D EM data, 132 ft intercoil spacing, parallel orientation

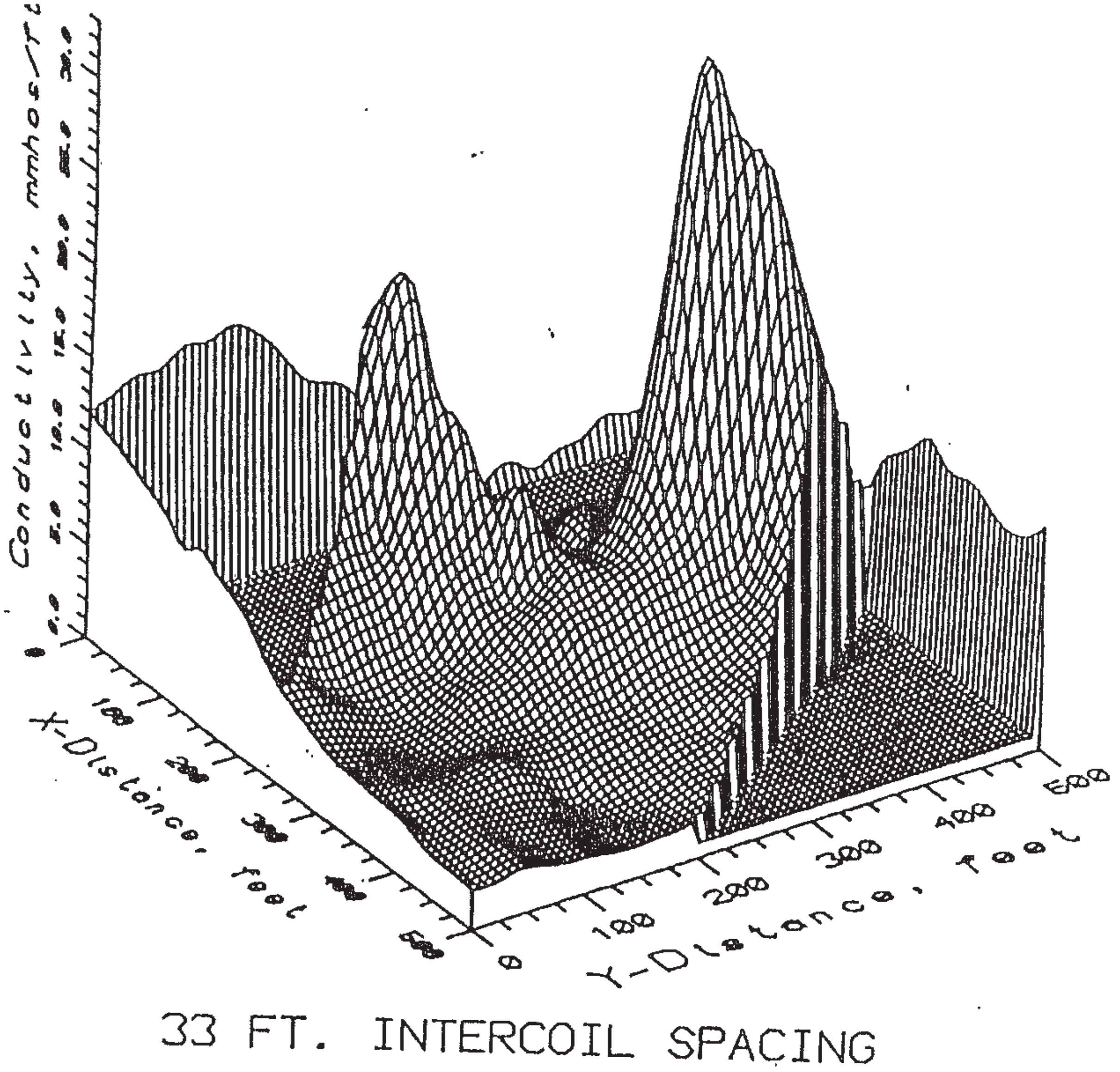


Figure 16. 3-D EM data, 33 ft intercoil spacing, parallel orientation

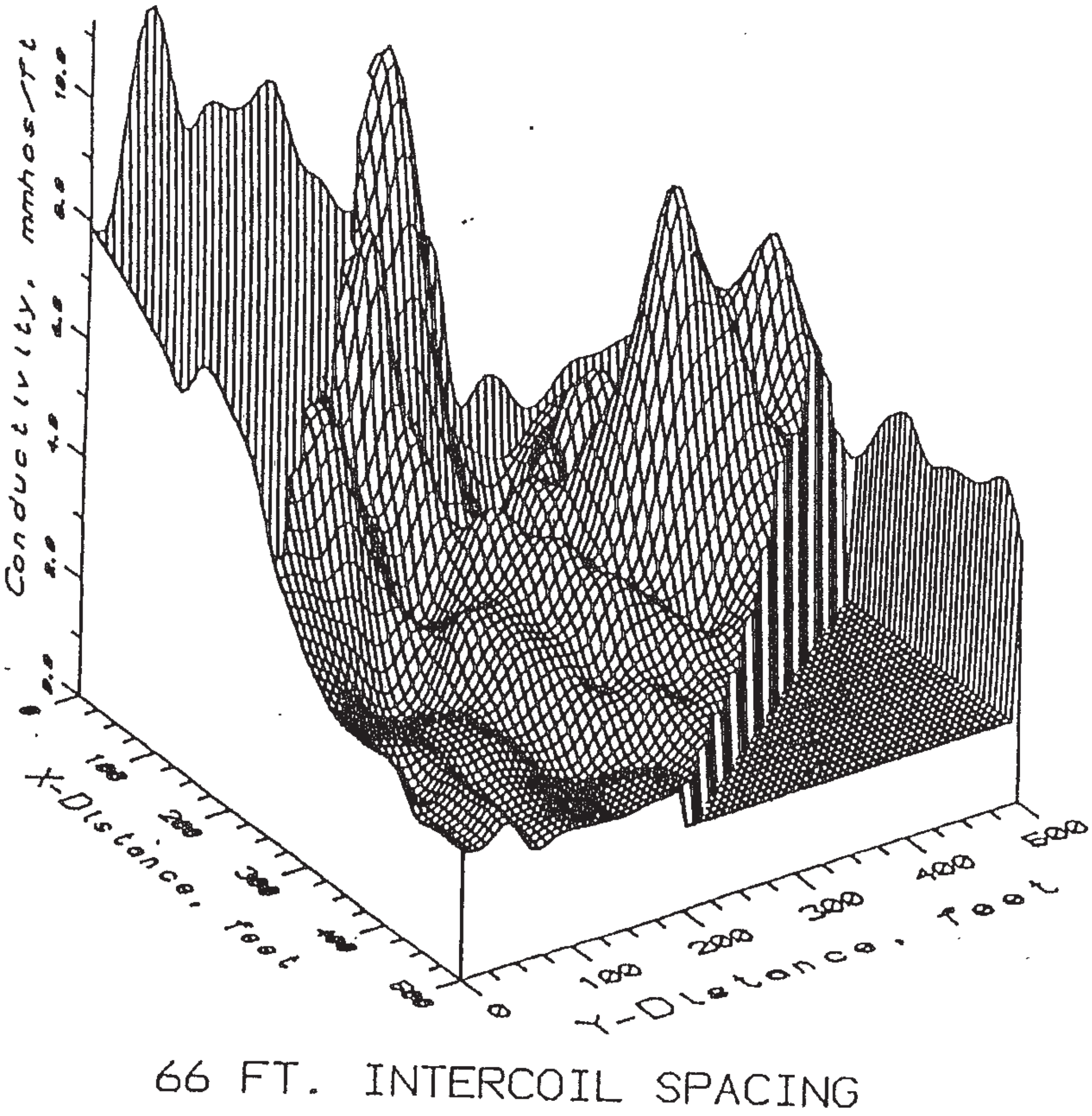
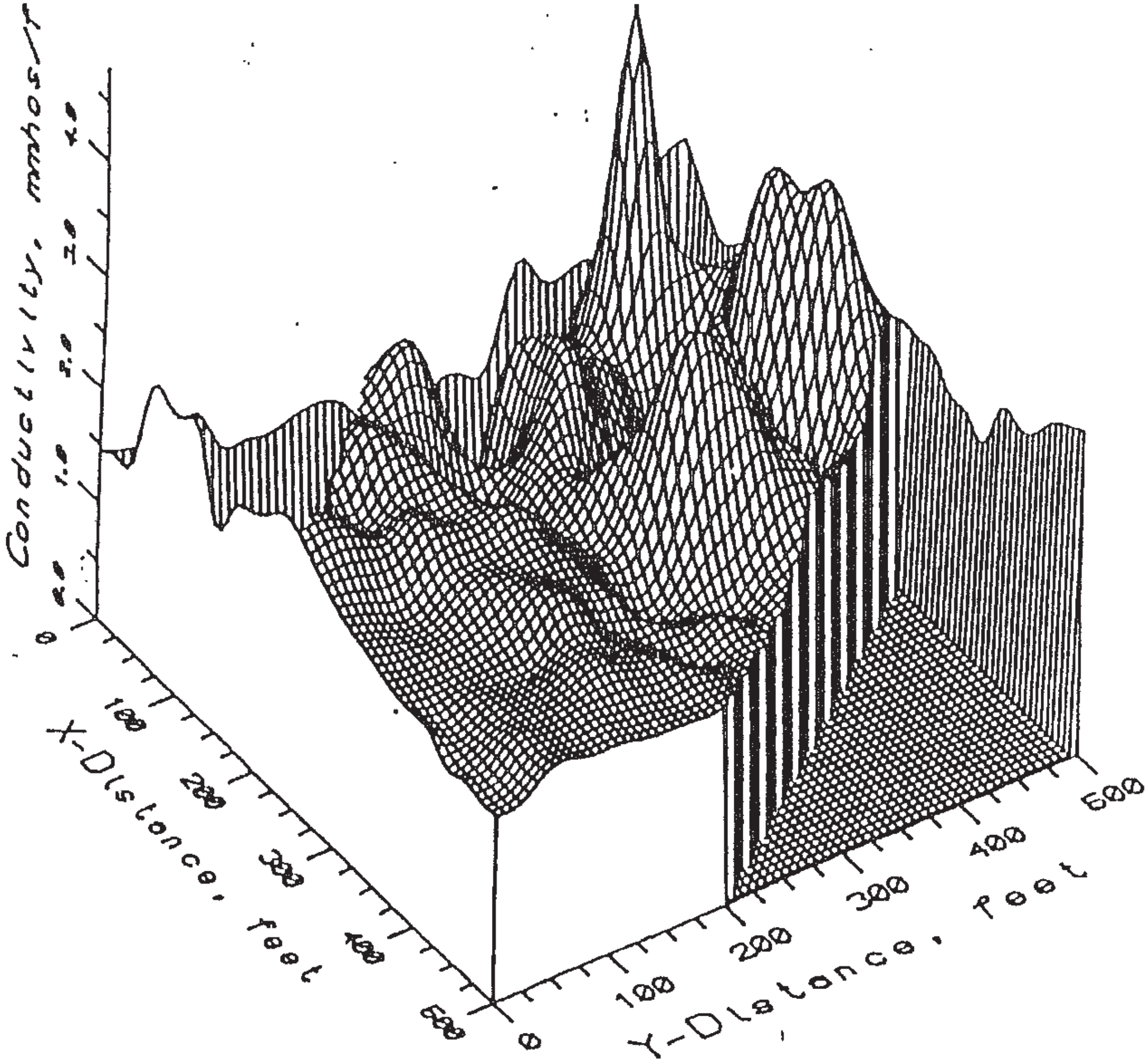


Figure 17. 3-D EM data, 66 ft intercoil spacing, parallel orientation



132 FT. INTERCOIL SPACING

Figure 18. 3-D EM data, 132 ft intercoil spacing, parallel orientation

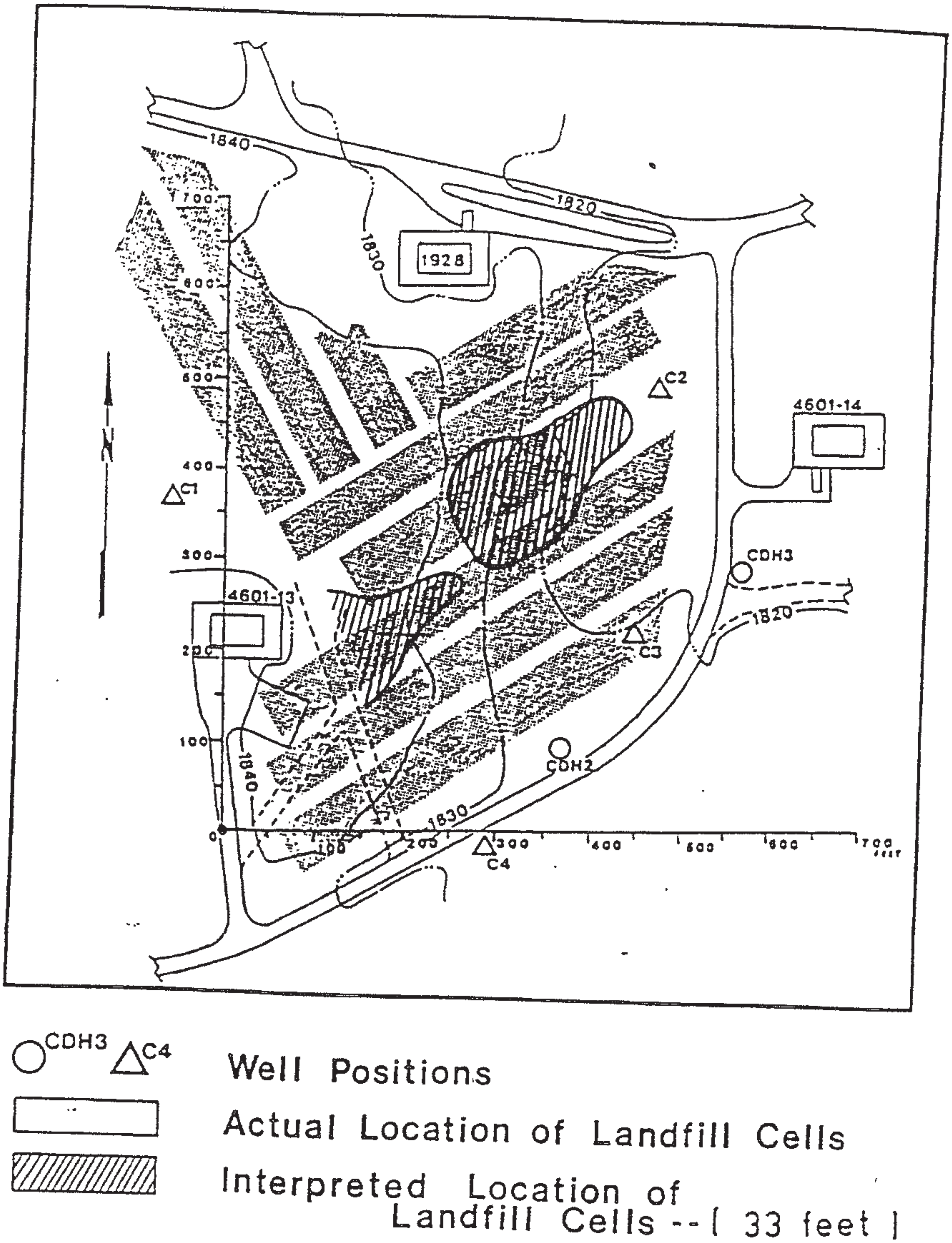


Figure 19. Interpreted location of landfill cells, 33 ft intercoil spacing, parallel orientation

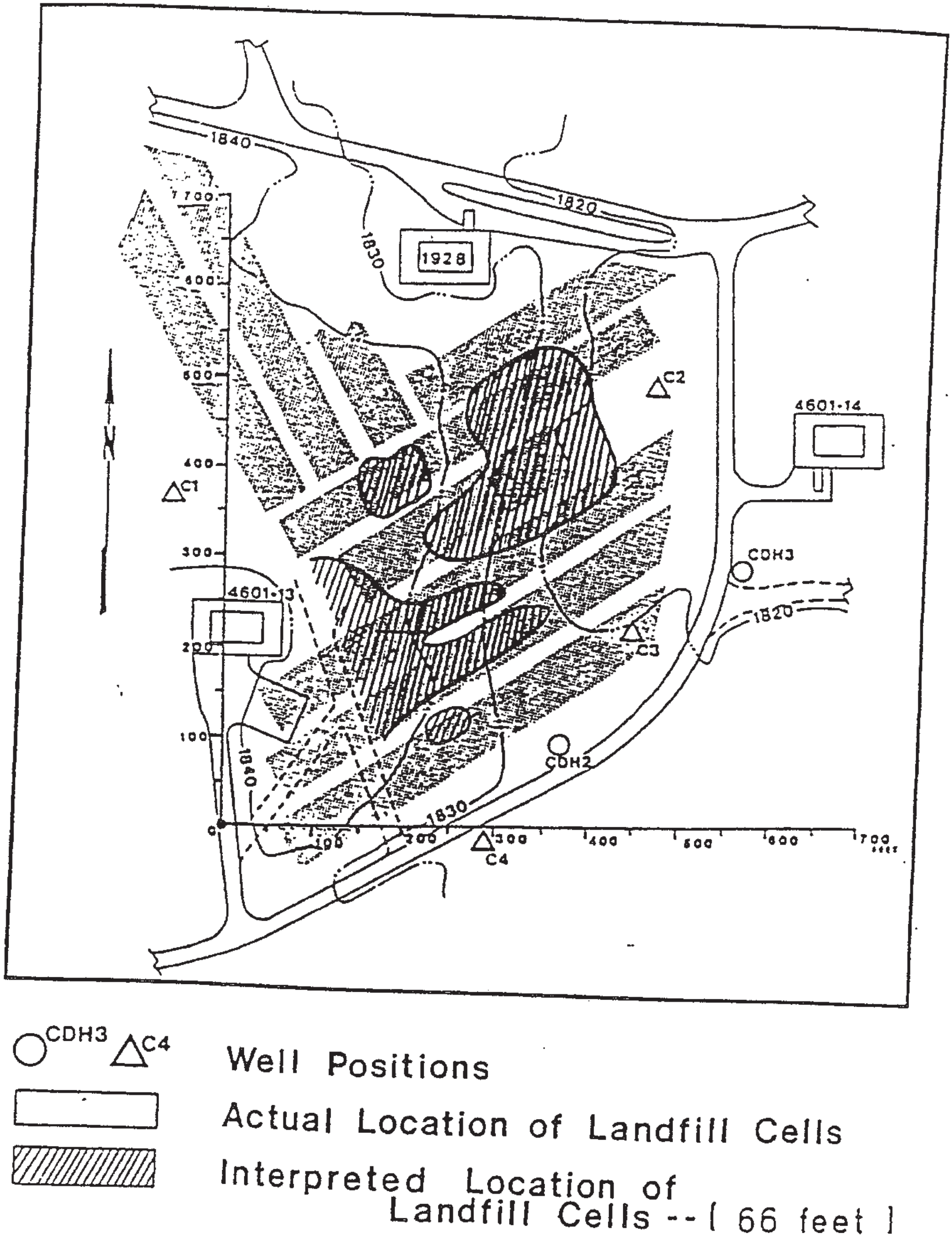


Figure 20. Interpreted location of landfill cells, 66 ft intercoil spacing, parallel orientation

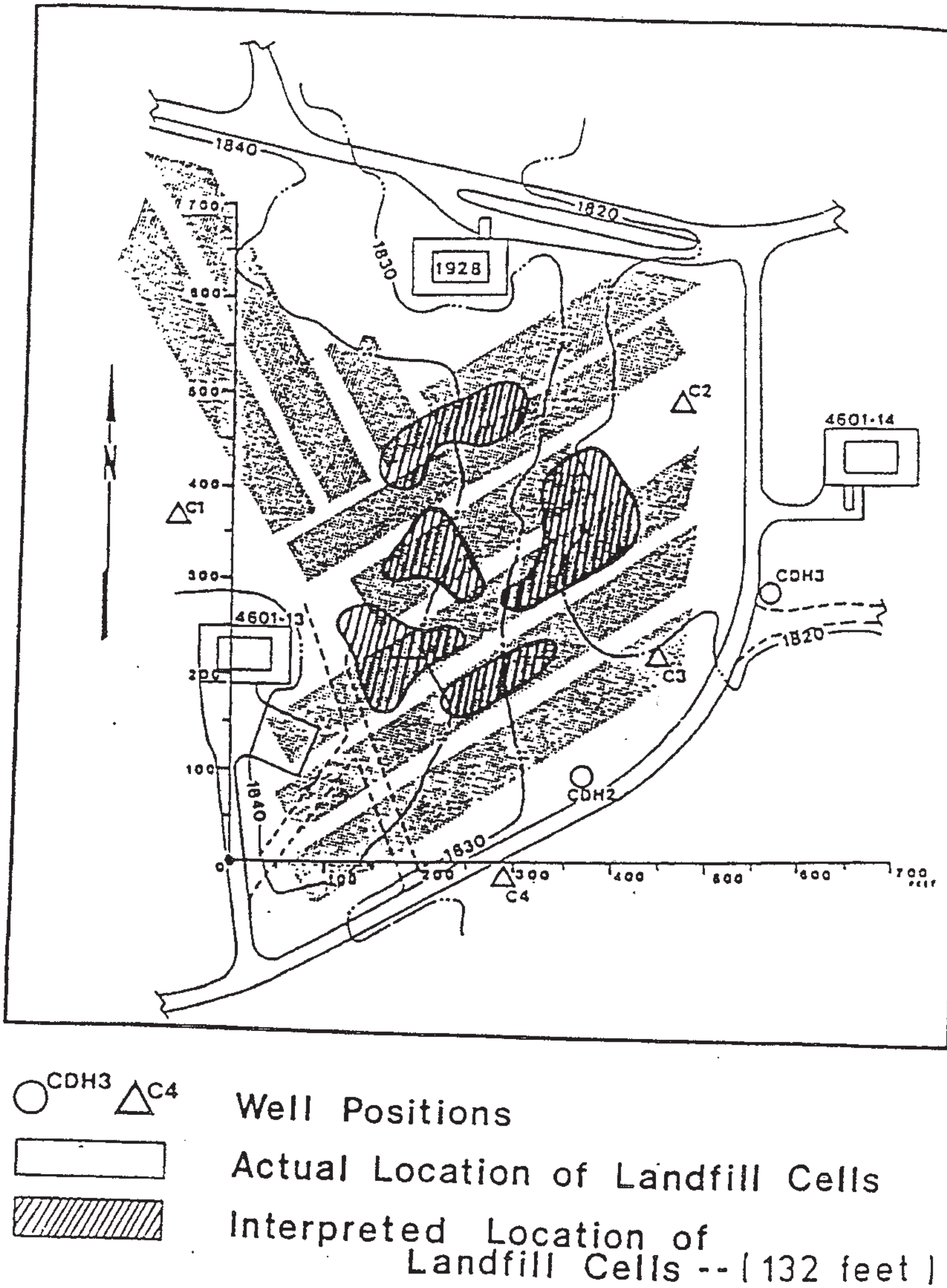


Figure 21. Interpreted location of landfill cells, 132 ft intercoil spacing, parallel orientation

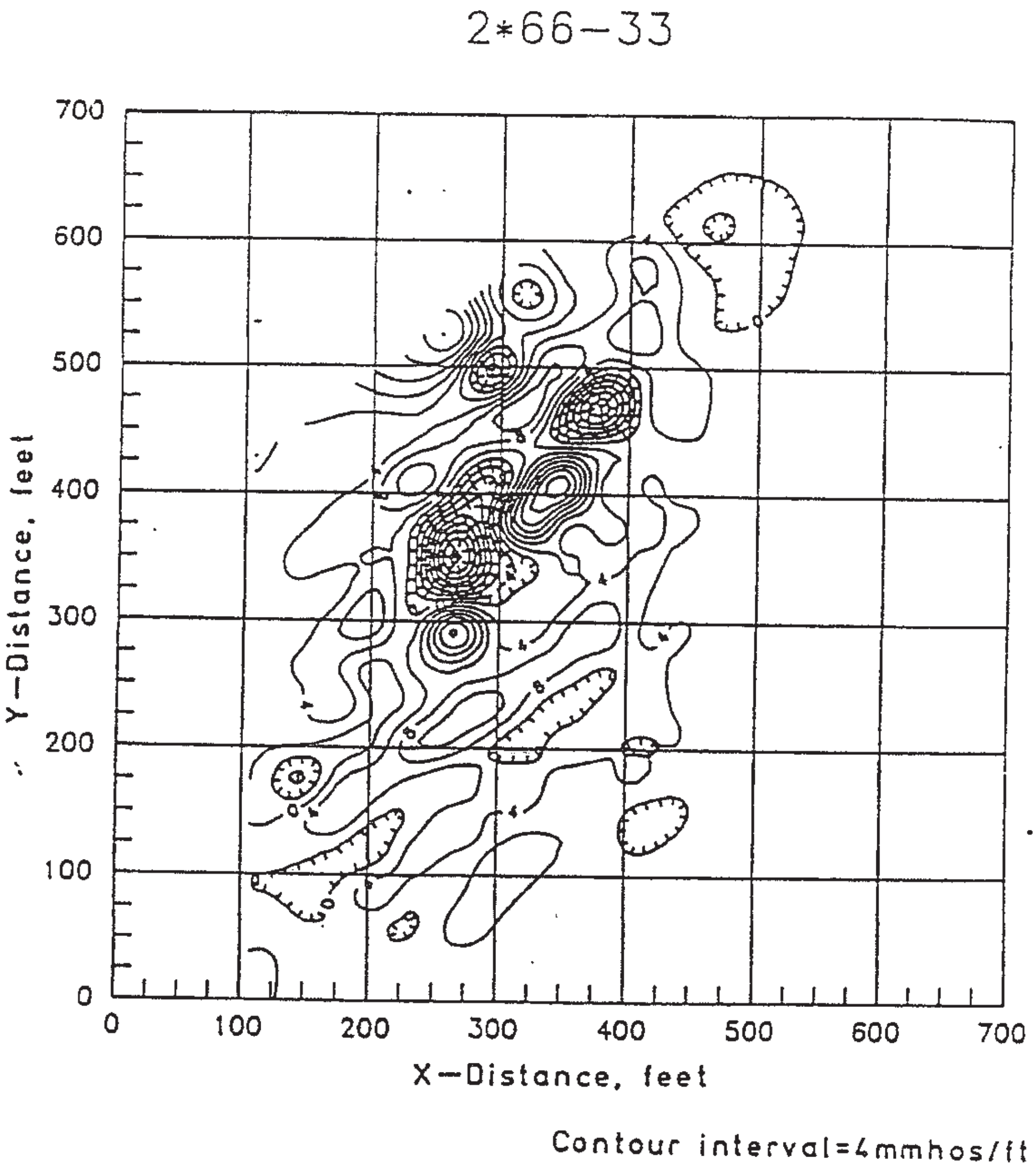


Figure 22. 2-D representation of two spacing method (2*66-33), perpendicular orientation

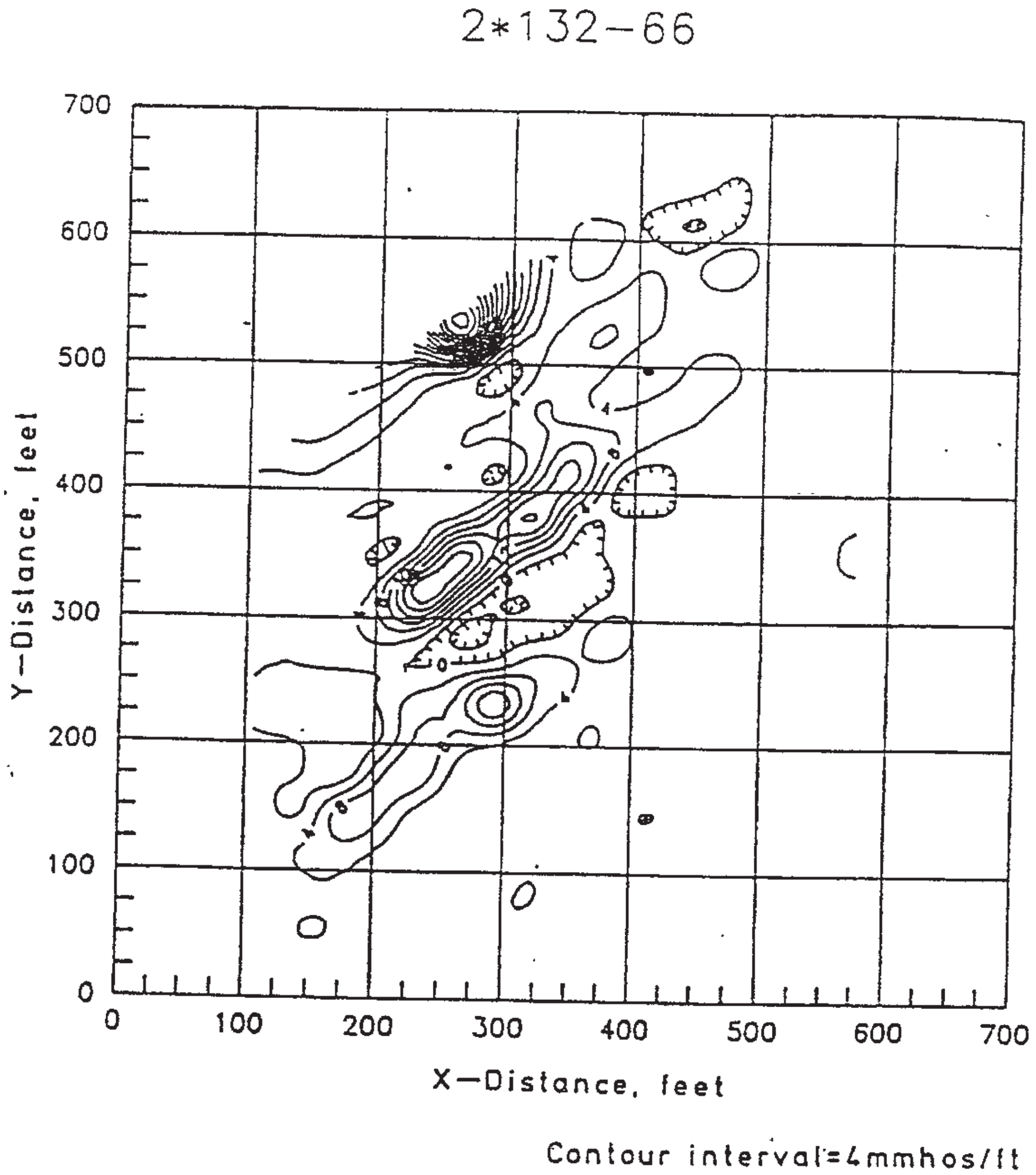


Figure 23. 2-D representation of two spacing method (2*132-66), perpendicular orientation

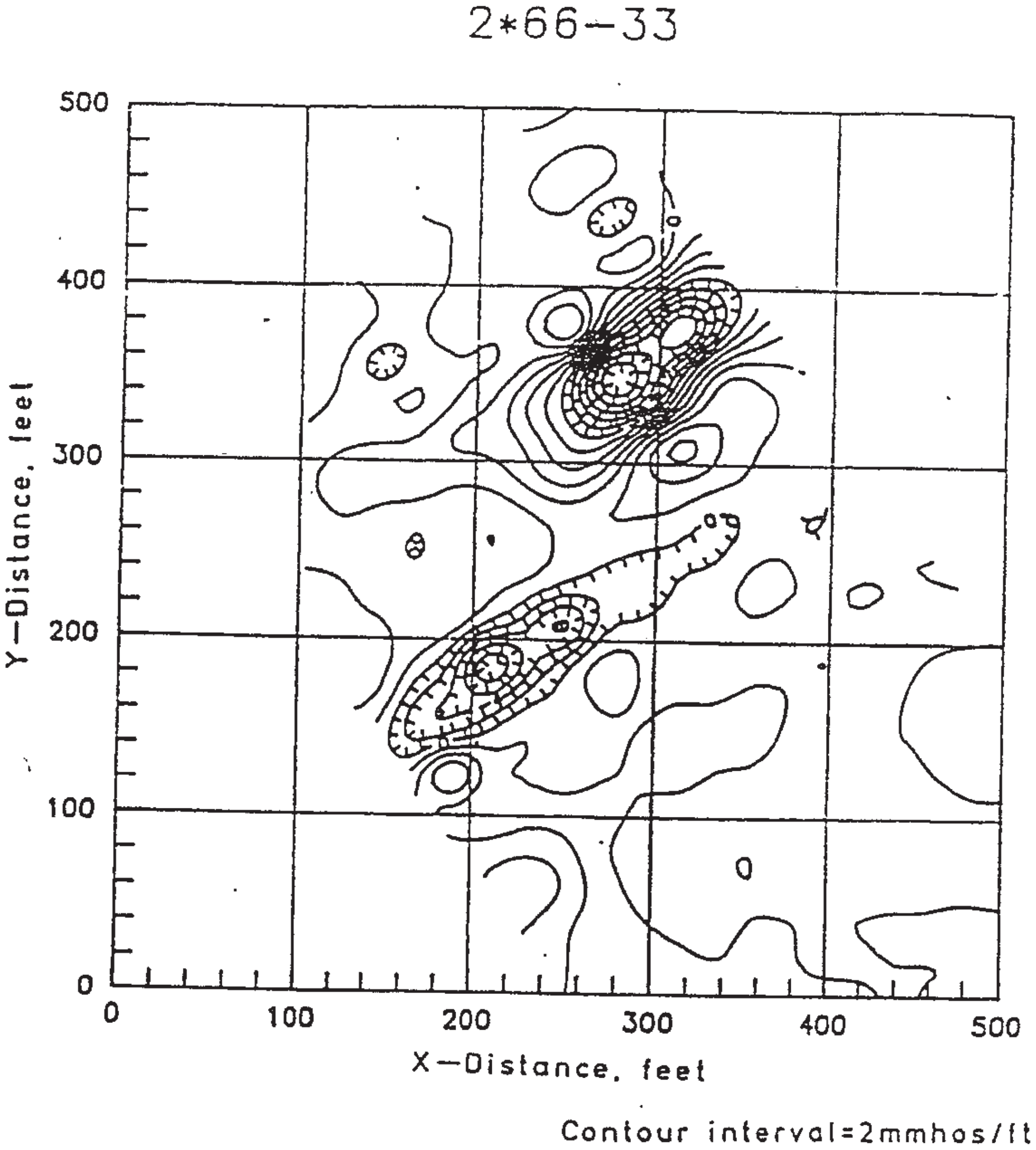


Figure 24. 2-D representation of two spacing method (2*66-33), parallel orientation

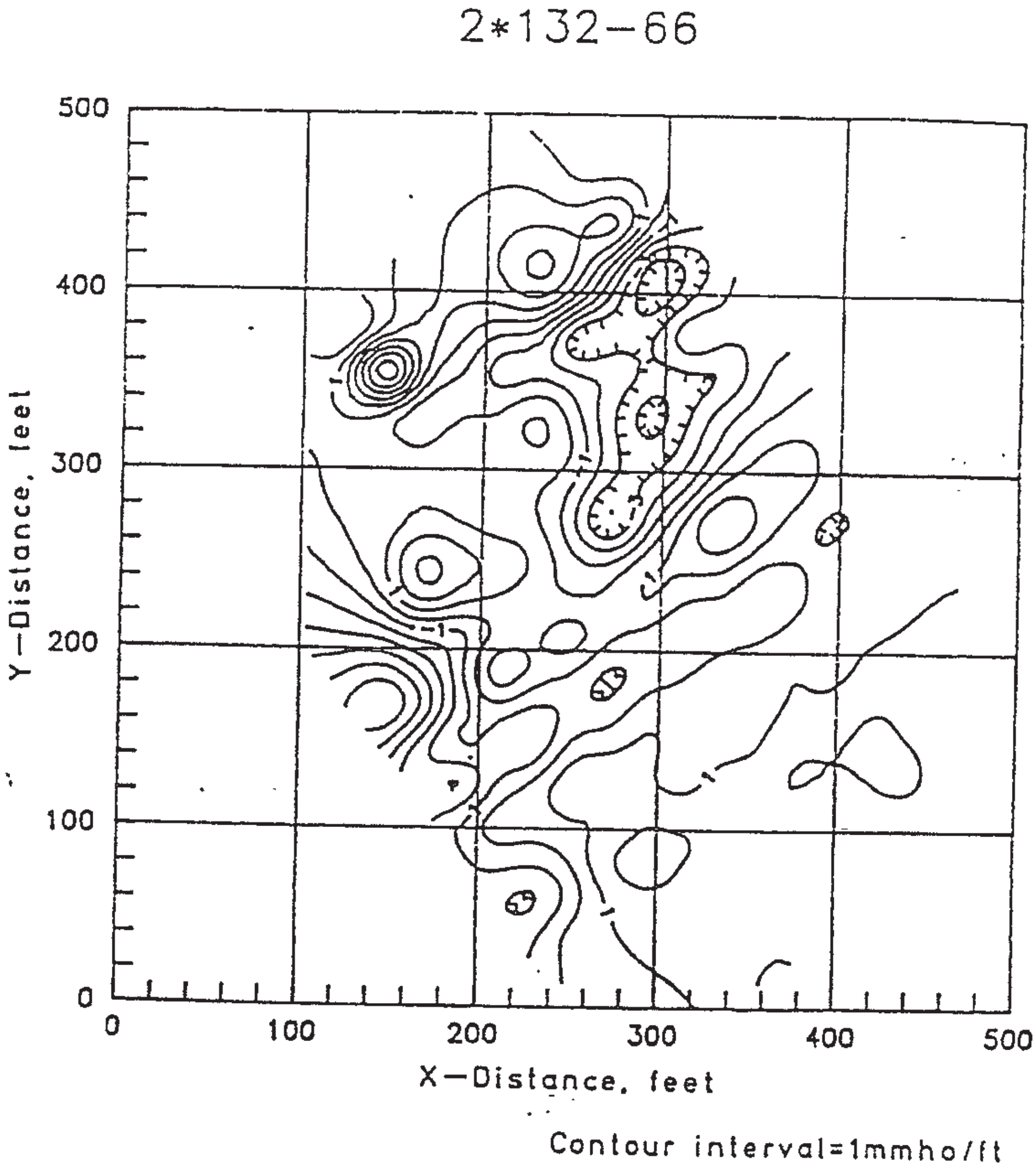


Figure 25. 2-D representation of two spacing method (2*40-66), parallel orientation

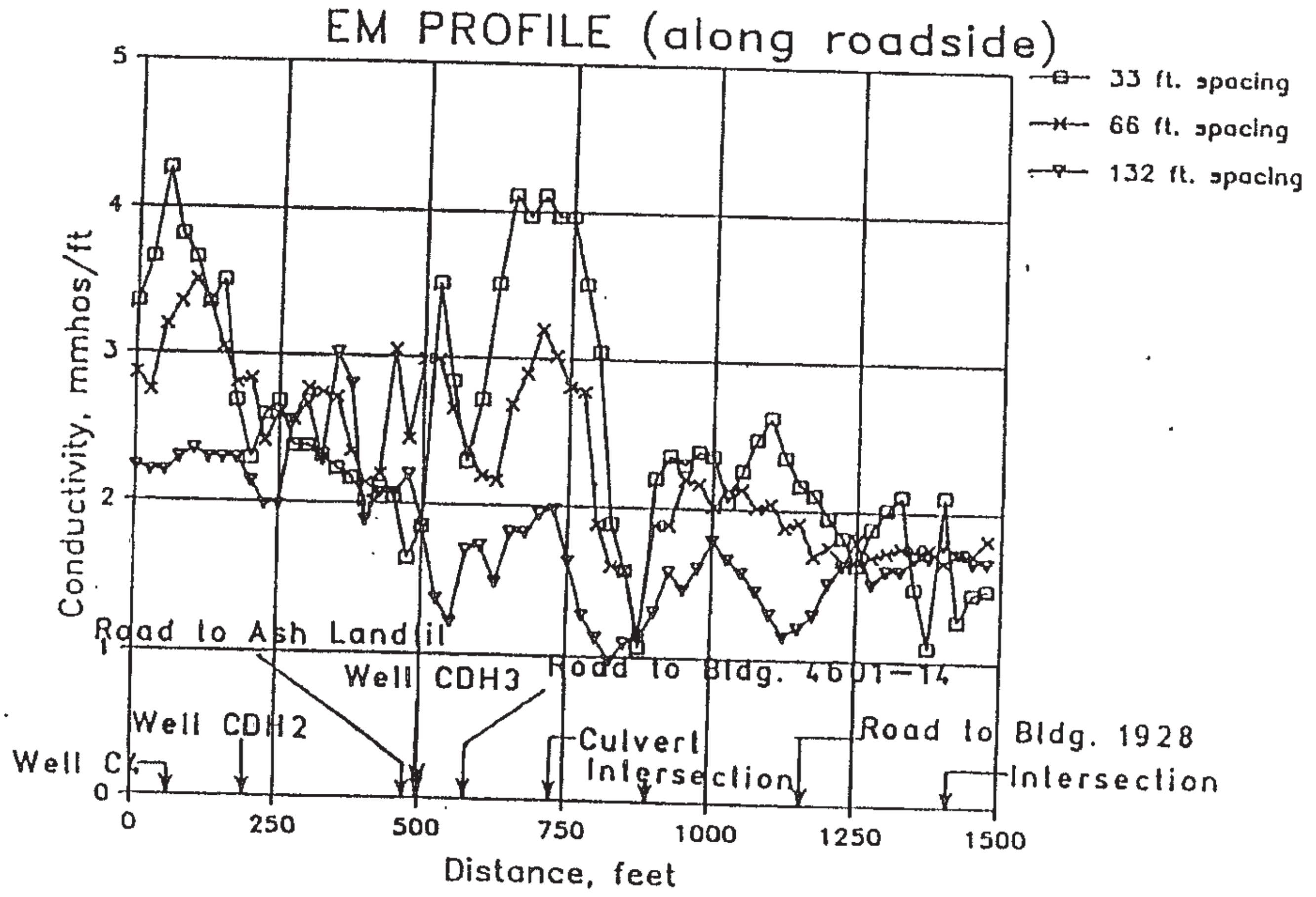
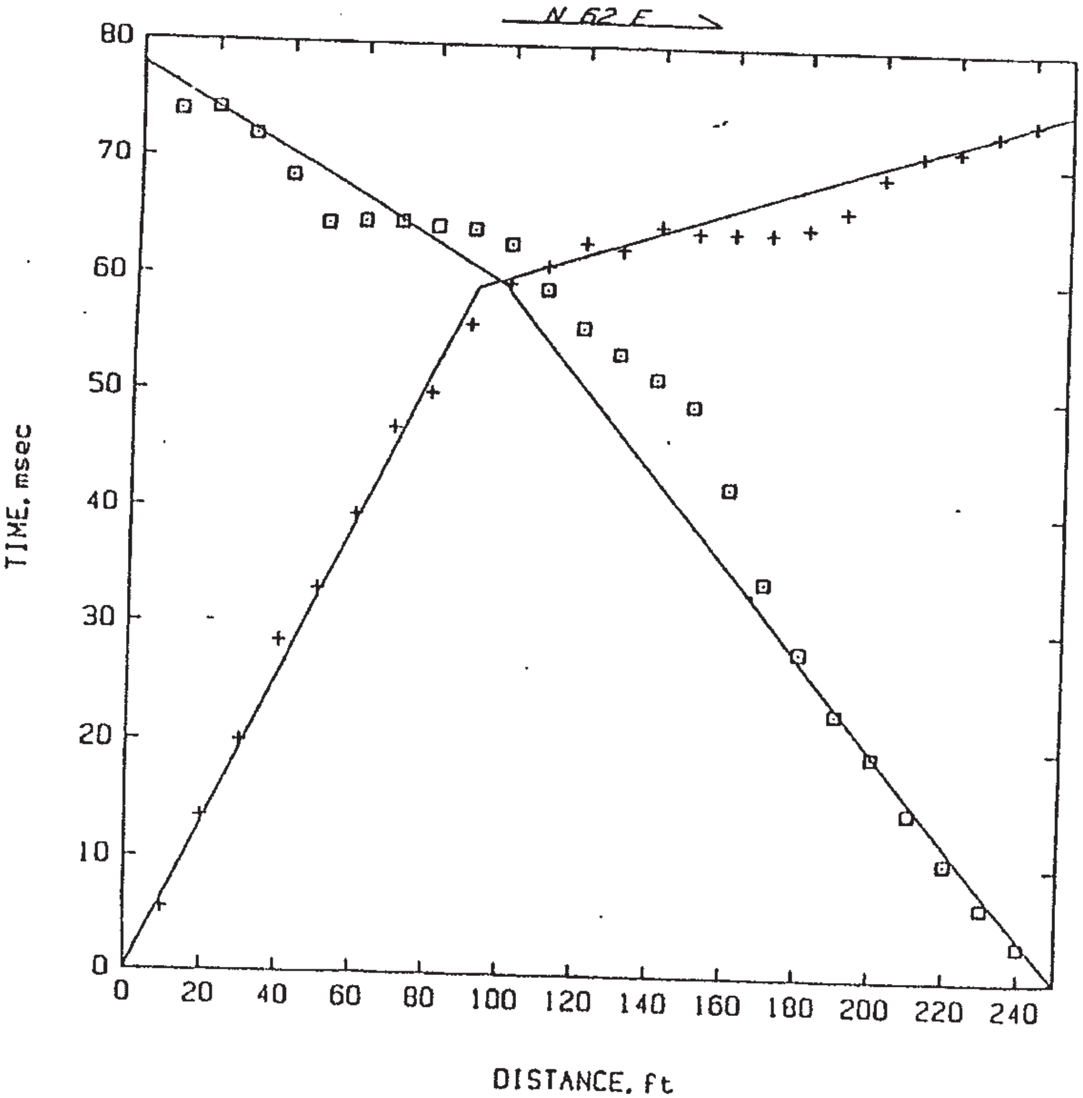


Figure 26. EM profile line along perimeter of HWMS-16



```
                    R-1

          *** INPUT DATA ***

         FORWARD      REVERSE

LAYER   VEL.    TI.    VEL.    TI.
  #     FT/S   MSEC    FT/S   MSEC

  1     1550    0.0    2550    0.0
  2    10000   50.0    5320   31.0


*** COMPUTED.SEISMIC PROFILE ***

 LAYER   TRUE        DEPTH
   #     VEL.     FOR.   REV.
         FT/S     FT.    FT.

   1     2050
   2     6910     54.0   33.5
```

Figure 27. Seismic refraction line R-1

R—2

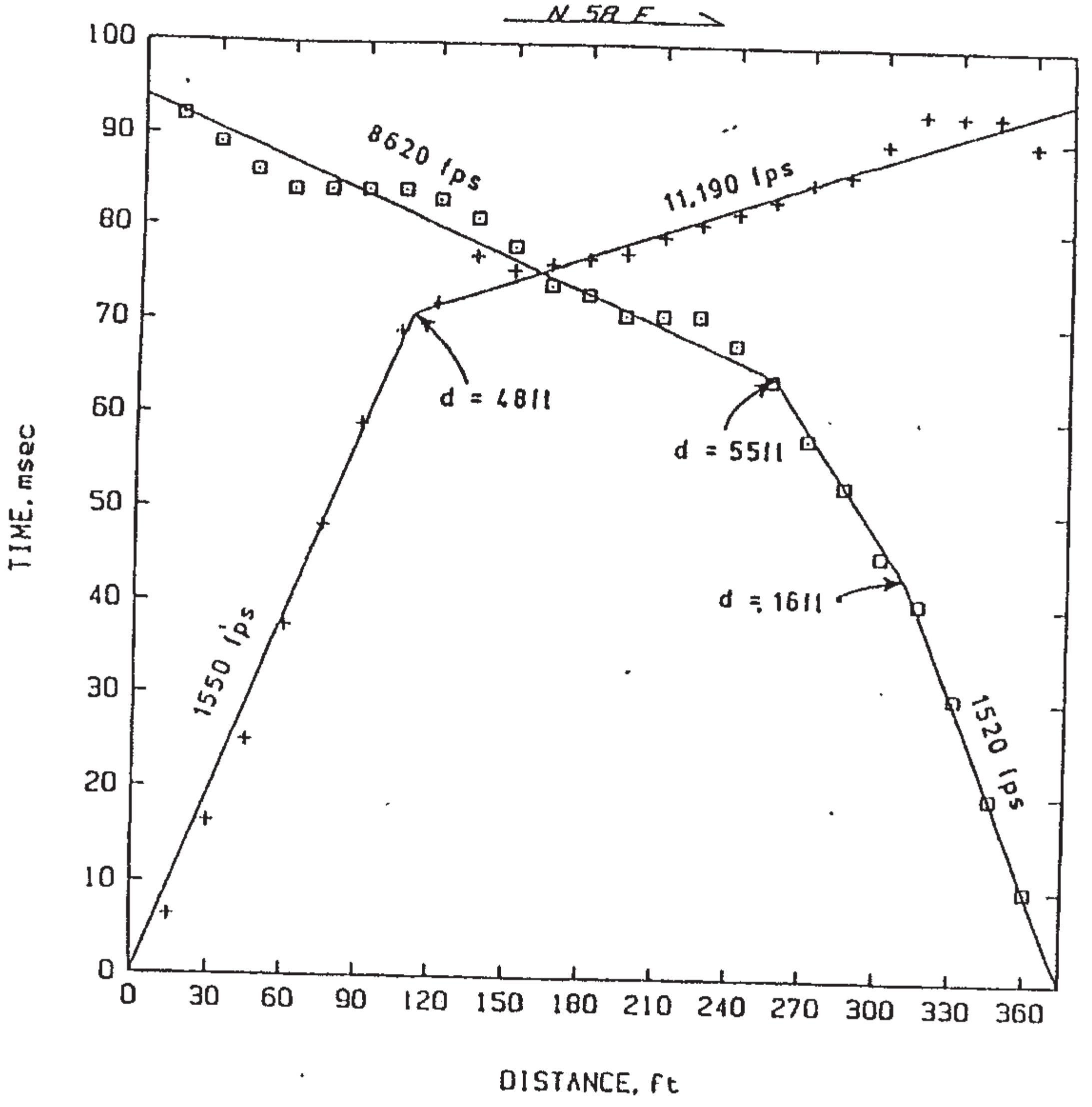


Figure 28. Seismic refraction line R-2

R—3

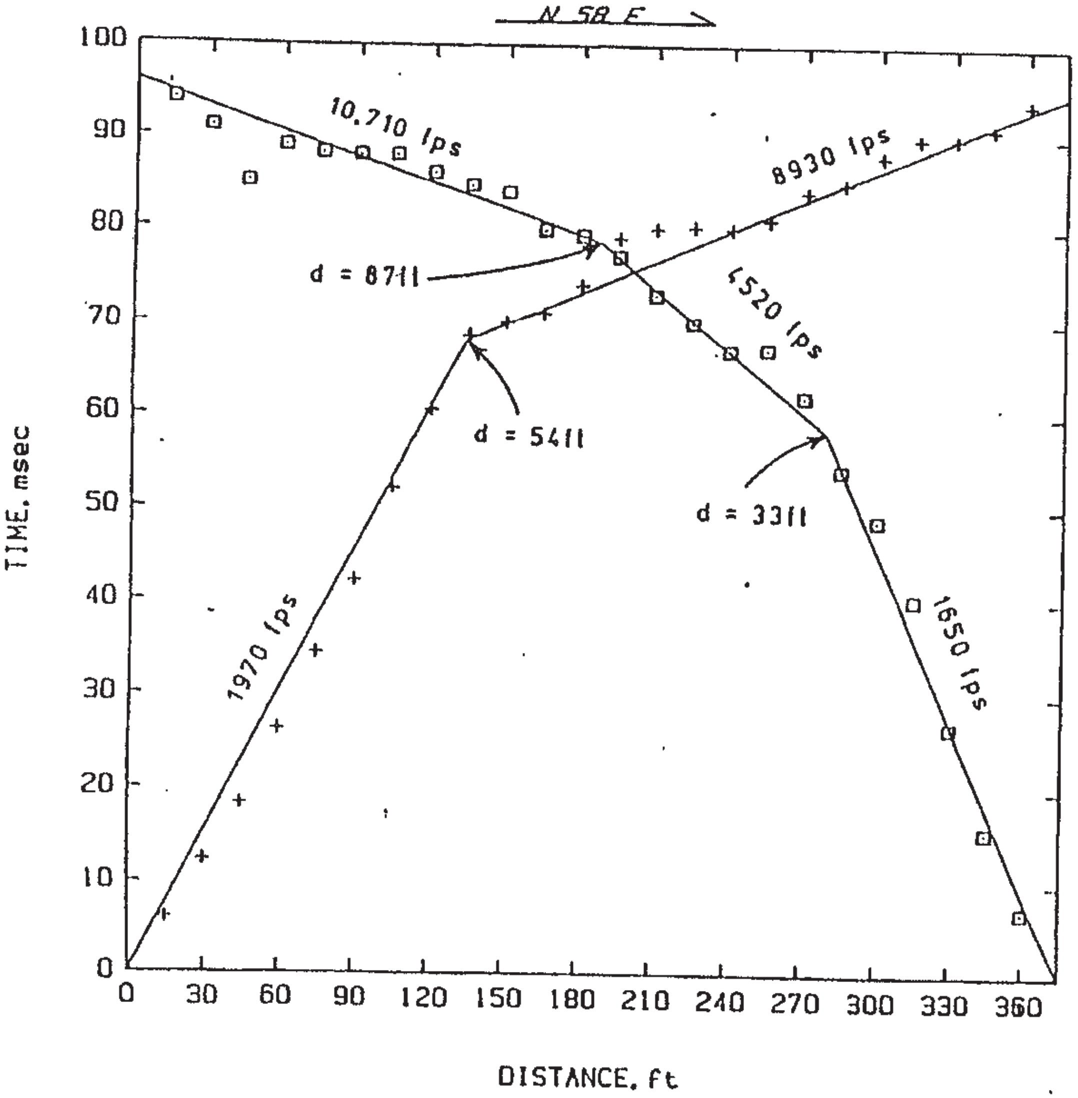


Figure 29. Seismic refraction line R-3

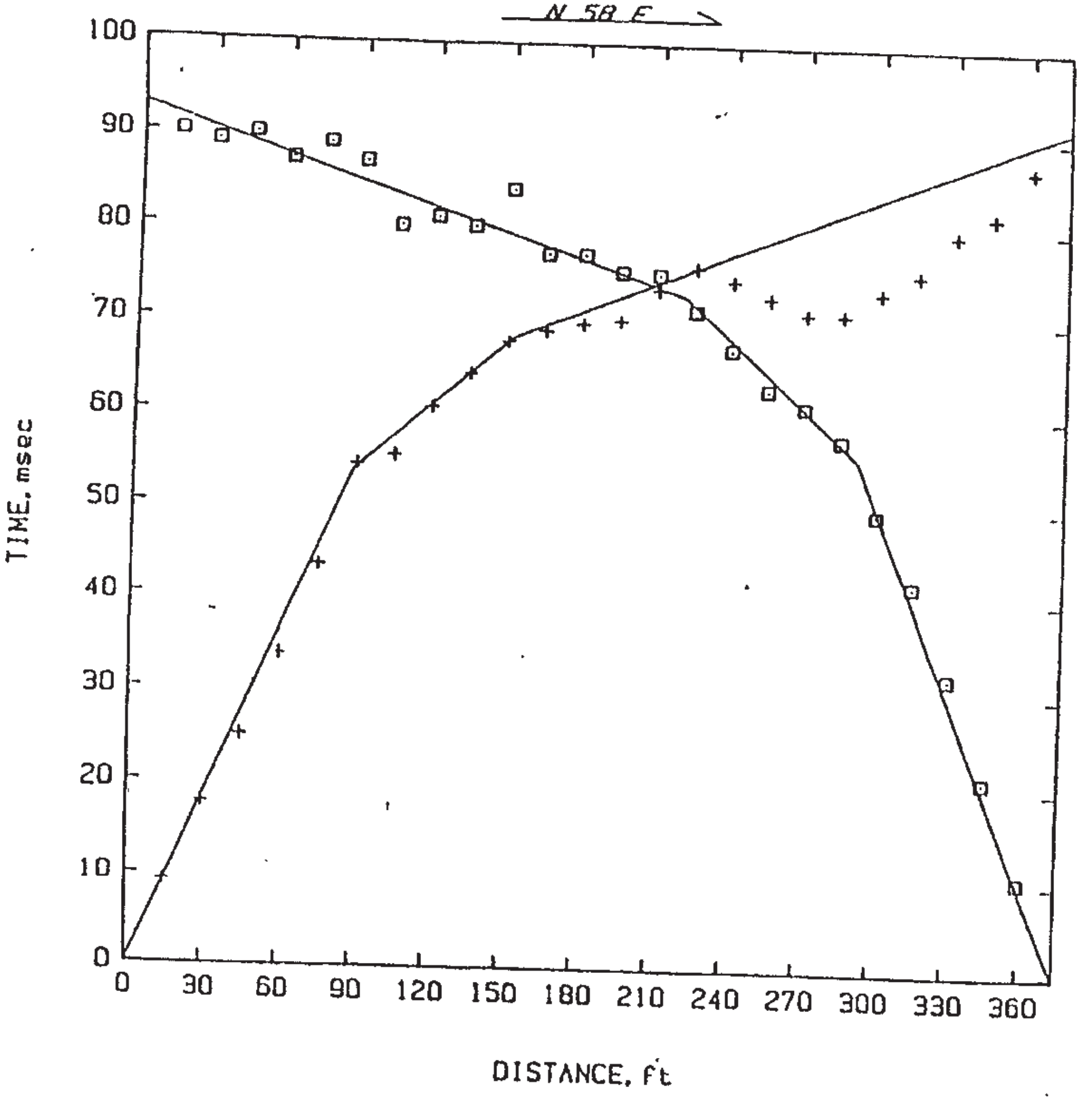


Figure 30. Seismic refraction line R-4

R-4

*** INPUT DATA ***

	FORWARD		REVERSE	
LAYER #	VEL. FT/S	TI. MSEC	VEL. FT/S	TI. MSEC
1	1650	0.0	1500	0.0
2	4470	34.0	4150	35.5
3	9490	52.0	10870	58.5

*** COMPUTED SEISMIC PROFILE ***

LAYER #	TRUE VEL. FT/S	DEPTH FOR. FT.	DEPTH REV. FT.
1	1580		
2	4300	29.0	30.0
3	10100	66.5	79.5

R—5

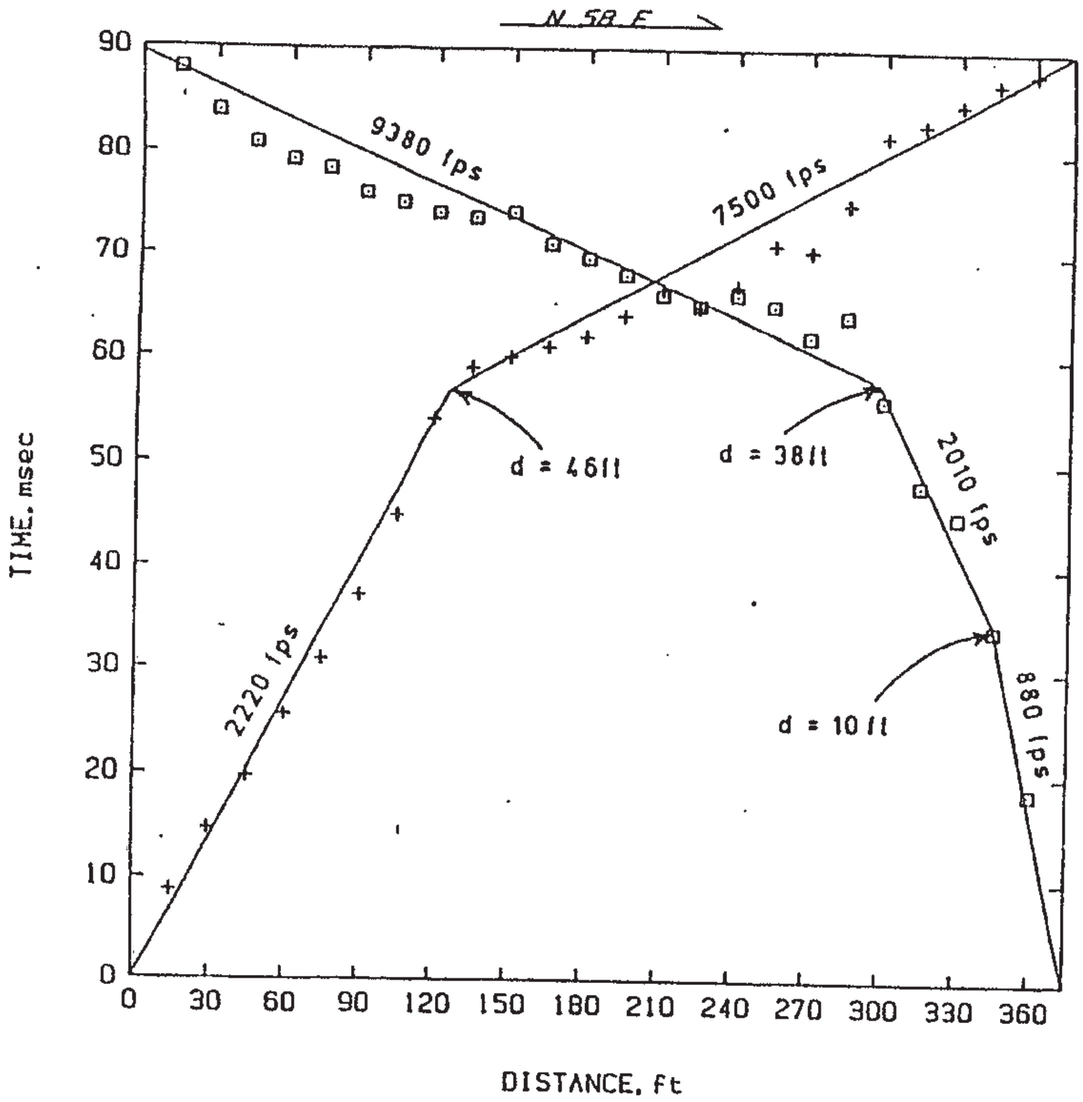
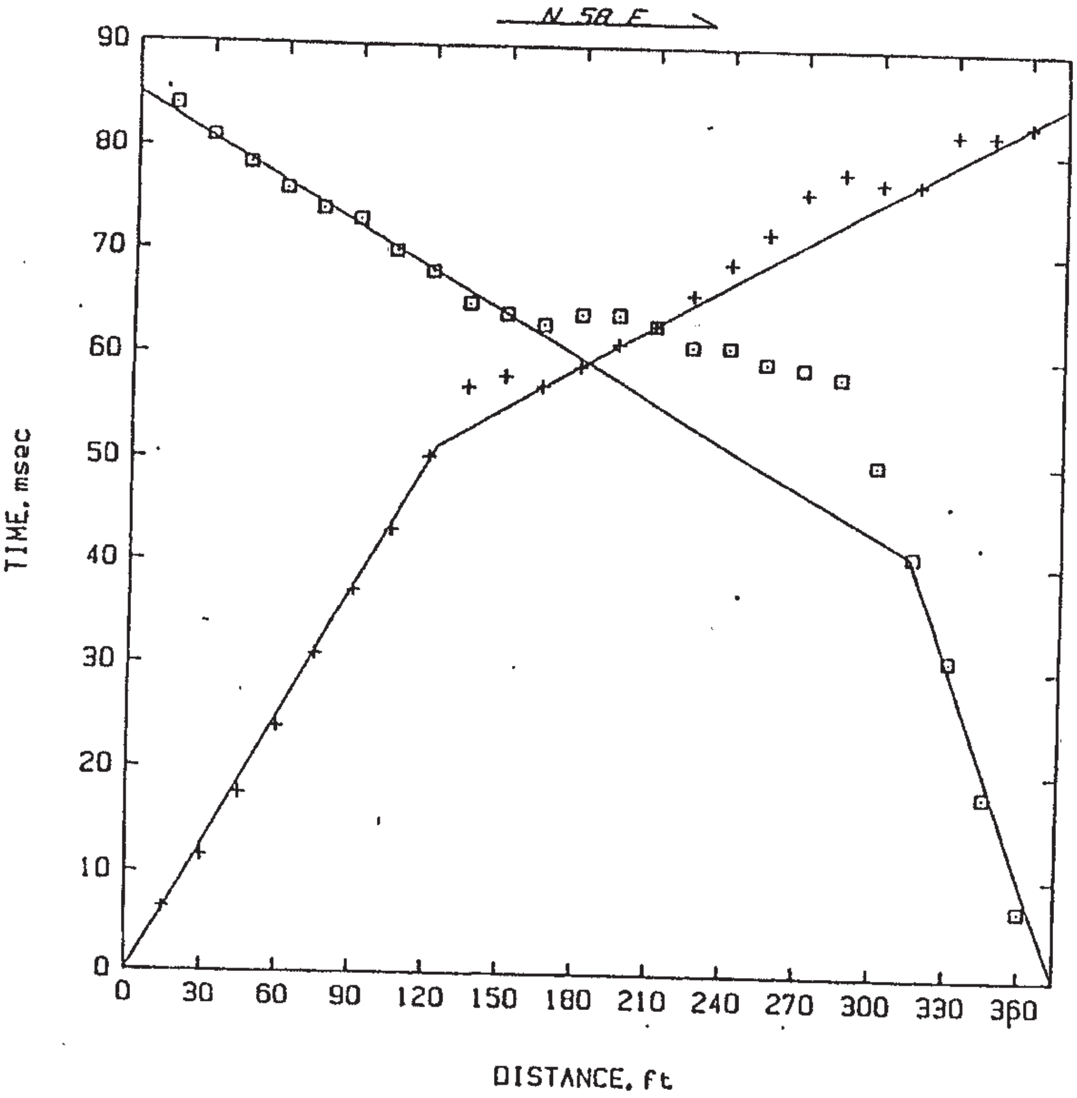


Figure 31. Seismic refraction line R-5



```
                  R-6

        *** INPUT DATA ***

          FORWARD    REVERSE

LAYER   VEL.   TI.   VEL.   TI.
  #     FT/S  MSEC   FT/S  MSEC

  1     2400   0.0   1500   0.0
  2     7500  35.0   7140  32.5


  *** COMPUTED SEISMIC PROFILE ***

  LAYER  TRUE       DEPTH
    #    VEL.    FOR.   REV.
         FT/S    FT.    FT.

    1    1950
    2    7310    35.5   33.0
```

Figure 32. Seismic refraction line R-6

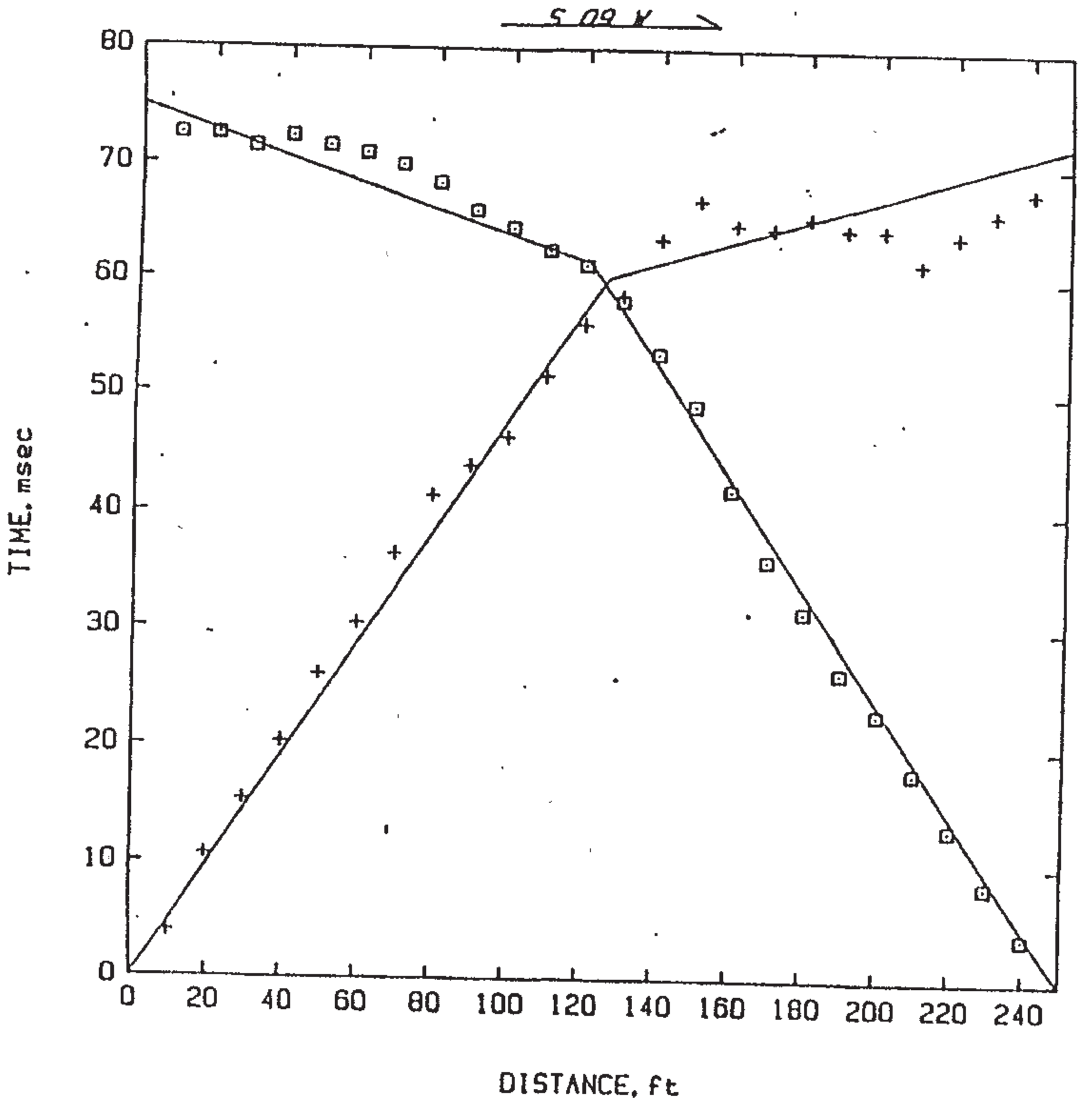


Figure 33. Seismic refraction line R-7

R-7

*** INPUT DATA ***

LAYER #	FORWARD VEL. FT/S	FORWARD TI. MSEC	REVERSE VEL. FT/S	REVERSE TI. MSEC
1	2100	0.0	2100	0.0
2	10420	48.0	8930	47.0

*** COMPUTED SEISMIC PROFILE ***

LAYER #	TRUE VEL. FT/S	DEPTH FOR. FT.	DEPTH REV. FT.
1	2100		
2	9810	51.5	50.5

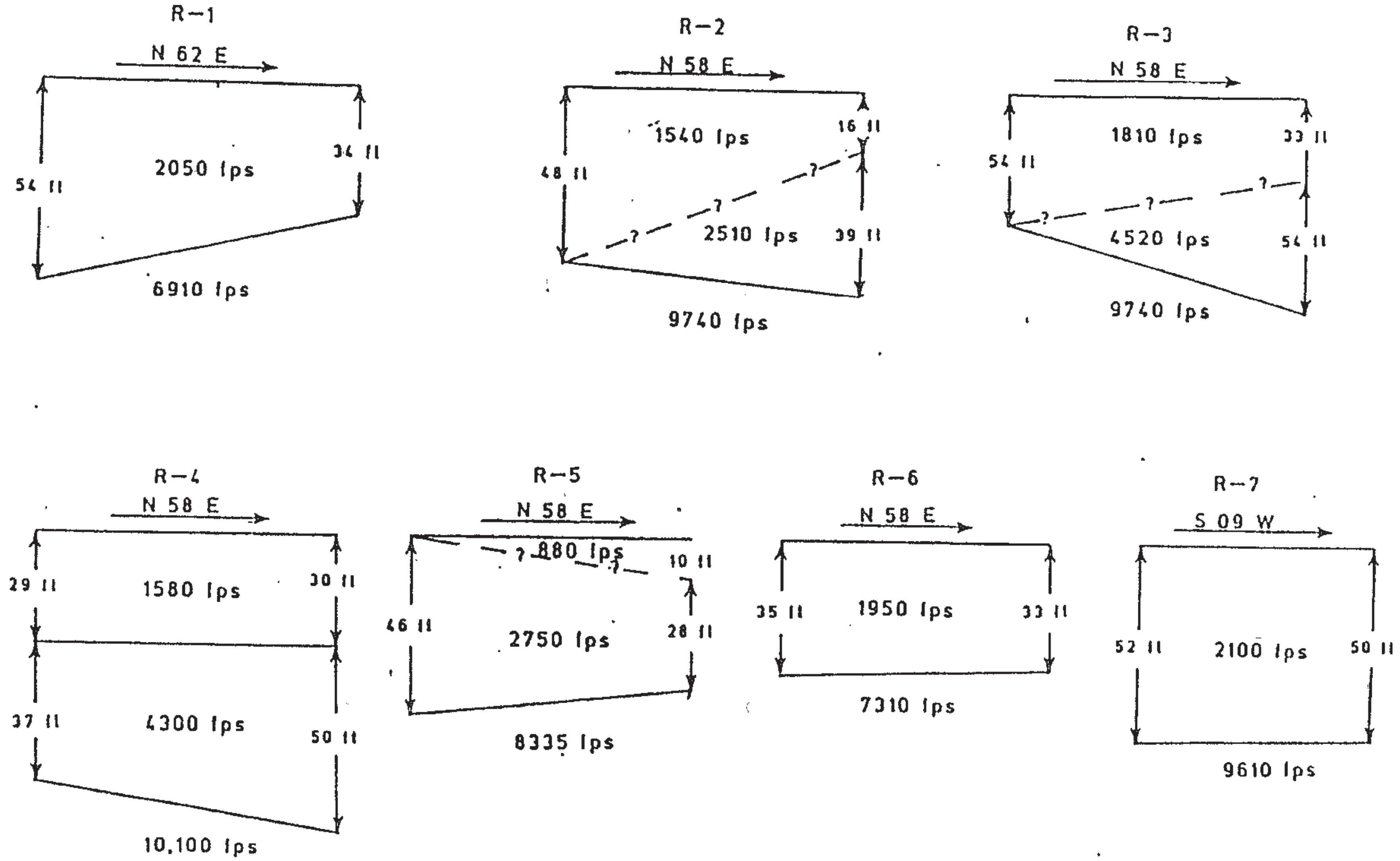


Figure 34. Summary of seismic refraction lines

TOP OF ROCK ELEVATION, FT.

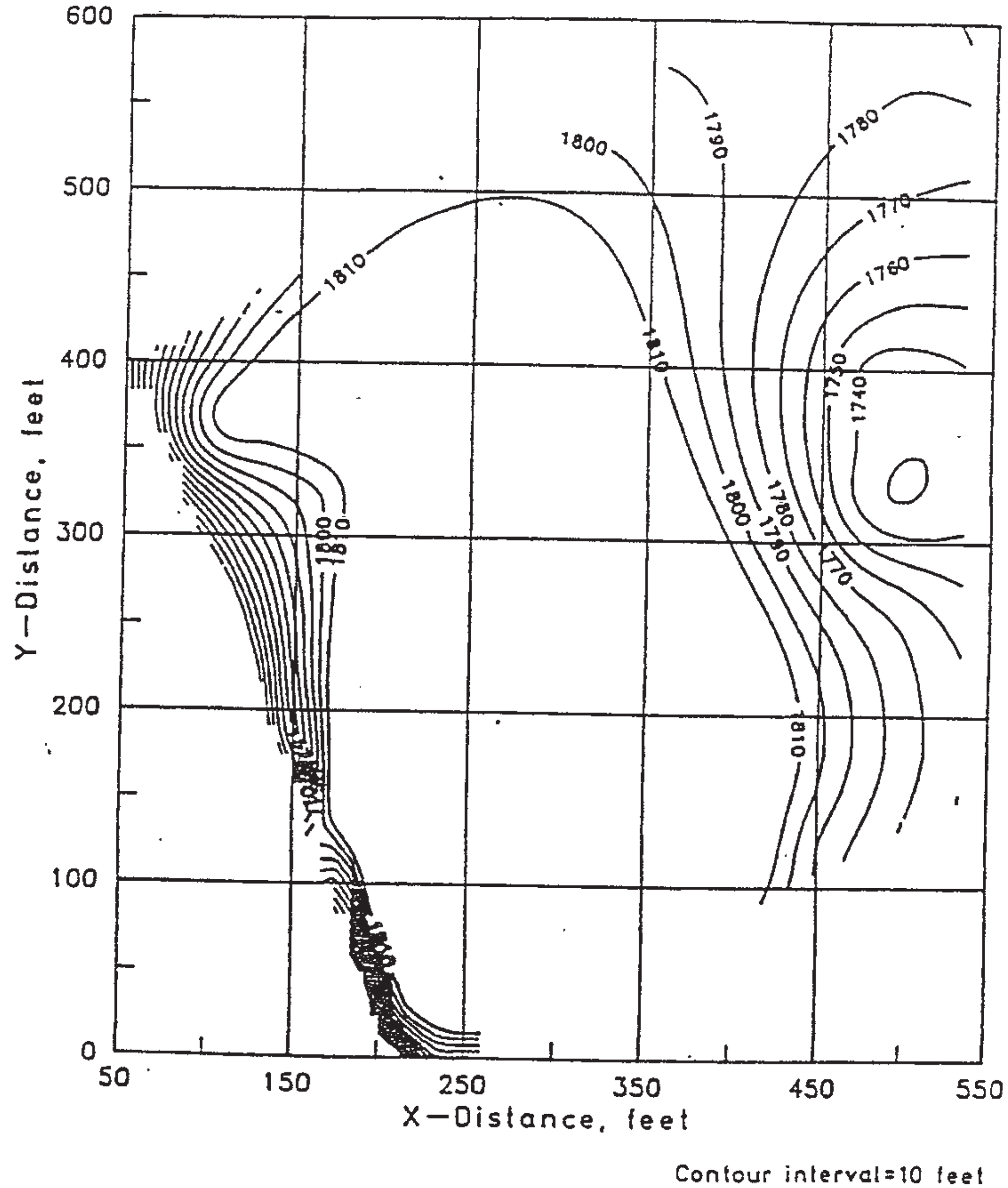


Figure 35. Top of rock elevation based on results of seismic refraction surveys

APPENDIX 1

CORE PHOTOGRAPHS

SITE	WELL NUMBER	PAGE
HWM4	WC1-1	1-1
	WC1-2	1-1
	WC2-2	1-1
	WC2-3	1-1
	WC4-2	1-2
	WC4-3	1-2
HWM5	5WC1-1	1-2
	5WC1-2	1-2
HWM7	7WCA	1-3