FINAL

SAMPLING AND ANALYSIS PLAN ADDENDUM NO. 2

FOR THE

PHASE I REMEDIAL INVESTIGATION OF RAMSDELL QUARRY LANDFILL RAVENNA ARMY AMMUNITION PLANT, RAVENNA, OHIO

PREPARED FOR

US Army Corps of Engineers®

LOUISVILLE DISTRICT
CONTRACT No. F44650-99-D-0007
DELIVERY ORDER CY11

June 2006

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Prepared for

U. S. Army Corps of Engineers
Louisville District
Contract No. F44650-99-0007
Delivery Order No. CY11

Prepared by

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
151 Lafayette Drive
Oak Ridge, Tennessee 37831

06-093(E)/061206

CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

Science Applications International Corporation (SAIC) has completed the Final *Sampling and Analysis Plan Addendum No. 2 for the Phase I Remedial Investigation at Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio*. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumptions; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing Corps policy.

Sally Absher (signature)
Study/Design Team Leader

Date 6/13/06

Kevin Jago (signature)
Independent Technical Review Team Leader

Date 6/13/06

Significant concerns and the explanation of the resolution are as follows:

Internal SAIC Independent Technical Review comments are recorded on a Document Review Record per SAIC quality assurance procedure QAAP 3.1. This Document Review Record is maintained in the project file. Changes to the report addressing the comments have been verified by the Study/Design Team Leader.

As noted above, all concerns resulting from independent technical review of the project have been considered.

(signature)
Principal w/ A-E firm

Date 6/13/06

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FIGURES

TABLE

ACRONYMS

ASTM	American Society for Testing and Materials
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
FSHP	Facility-wide Safety and Health Plan
MEC	munitions and explosives of concern
Ohio EPA	Ohio Environmental Protection Agency
P&A	plugging and abandonment
PVC	polyvinyl chloride
RI	Remedial Investigation
RQL	Ramsdell Quarry Landfill
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SSHP	Site Safety and Health Plan
USACE	U. S. Army Corps of Engineers
UXO	unexploded ordnance

1.0 INTRODUCTION

This Sampling and Analysis Plan (SAP) Addendum No. 2 for the Ramsdell Quarry Landfill (RQL) Phase I Remedial Investigation (RI) at the Ravenna Army Ammunition Plant (RVAAP) has been prepared by Science Applications International Corporation (SAIC) under contract F44650-99-D-0007, Delivery Order CY11, with the U. S. Army Corps of Engineers (USACE), Louisville District. This SAP Addendum No. 2 has been developed to tier under and supplement the *Facility-Wide Sampling and Analysis Plan for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2001), referred to in this report as the Facility-wide SAP. The Facility-wide SAP provides the base documentation, technical procedures, and investigative protocols for conducting RIs under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) at RVAAP. Where appropriate, this SAP Addendum contains references to the Facility-wide SAP for standard procedures and protocols.

Both the Facility-wide SAP and this SAP Addendum have been developed following the USACE guidance document, *Requirements for the Preparation of Sampling and Analysis Plans, EM 200-1-3*, to collectively meet the requirements established by the Ohio Environmental Protection Agency (Ohio EPA), Northeast District, and the U. S. Environmental Protection Agency, Region 5, for conducting CERCLA investigations.

This SAP Addendum describes the rationale for the plugging and abandonment (P&A) of obsolete/substandard monitoring wells at RQL (wells MW-1 through MW-5). These wells have been replaced by newer wells constructed in accordance with Ohio EPA and USACE specifications. This SAP describes the methods to be used to properly decommission monitoring wells at RQL. All other aspects of the work to P&A wells MW-1 through MW-5 (management of investigation-derived wastes, sampling and analysis, ordnance and explosives avoidance, field records, health and safety, etc.) will be performed under the guidance of the previously prepared *Site Safety and Health Plan, Addendum No. 1 for the Phase I Remedial Investigation of Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2003a) and *Sampling and Analysis Plan Addendum No. 1 for Phase I Remedial Investigation of the Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2003b). The P&A methods specified under this SAP Addendum address unique well construction characteristics encountered during 2003 Phase I field activities that are not addressed in these previously prepared SAP addenda.

2.0 RAMSDELL QUARRY LANDFILL HISTORY AND DESCRIPTION

Ramsdell Quarry is located in the northeastern portion of RVAAP and encompasses about 14 acres (Figure 2-1). The quarry was excavated about 9 to 12 m (30 to 40 ft) below existing grade into the Sharon member of the Pottsville Formation. The original unconsolidated glacial material overlying the sandstone was only a few meters thick (< 10 ft) and appears to have been entirely removed. The excavated material, consisting of sandstone and quartzite pebble conglomerate, was used for road and construction ballast. Quarry operations were discontinued about 1941.

The western and southern portion of the abandoned quarry was subsequently used for landfill operations (RQL) between 1941 and 1989 (Figure 2-2). In addition, from 1946 to the 1950s, the bottom of the quarry was used to burn waste explosives from Load Line 1. Approximately 18,000 225-kg (500-lb) incendiary or napalm bombs were reported to have been burned in the abandoned quarry. Liquid residues from annealing operations were also disposed of in the quarry. No information is available regarding landfill disposal activities between 1941 and 1976. From 1976 until the landfill was closed in 1989, only non-hazardous solid waste was disposed in RQL. In 1978, a portion of the abandoned quarry was permitted as a sanitary landfill by the state of Ohio. The permit required a 30-m (100-ft) buffer be maintained between the landfill and the pond; the extent of the pond prior to this time is not known. Closure of the permitted sanitary landfill was completed in May 1990 under state of Ohio solid waste regulations (Ohio Administrative Code 3745-27-10). A requirement of closure was installation and semiannual monitoring of five monitoring wells (MW-1 to MW-5).

Based upon available information and past uses of the abandoned quarry, wastes may include domestic, commercial, and industrial solid and liquid wastes, including explosives (e.g., trinitrotoluene, hexahydro-1,3,5-trinitro-1,3,5-triazine, Composition B), napalm, gasoline, acid dip liquor, annealing residue (e.g., sulfuric acid, shell casings, sodium orthosilicate, chromic acid, and alkali), aluminum chloride, and inert material. Interviews with former RVAAP personnel indicate that much of the landfill wastes and debris at the abandoned quarry were removed in the 1980s.

A much smaller quarry (also abandoned) was located directly southeast of RQL. Although no standing water was observed in the smaller quarry during earlier investigations, it was water-filled in late August as a result of above average rainfall during the summer of 2003. No documentation of waste disposal or treatment exists for this quarry.

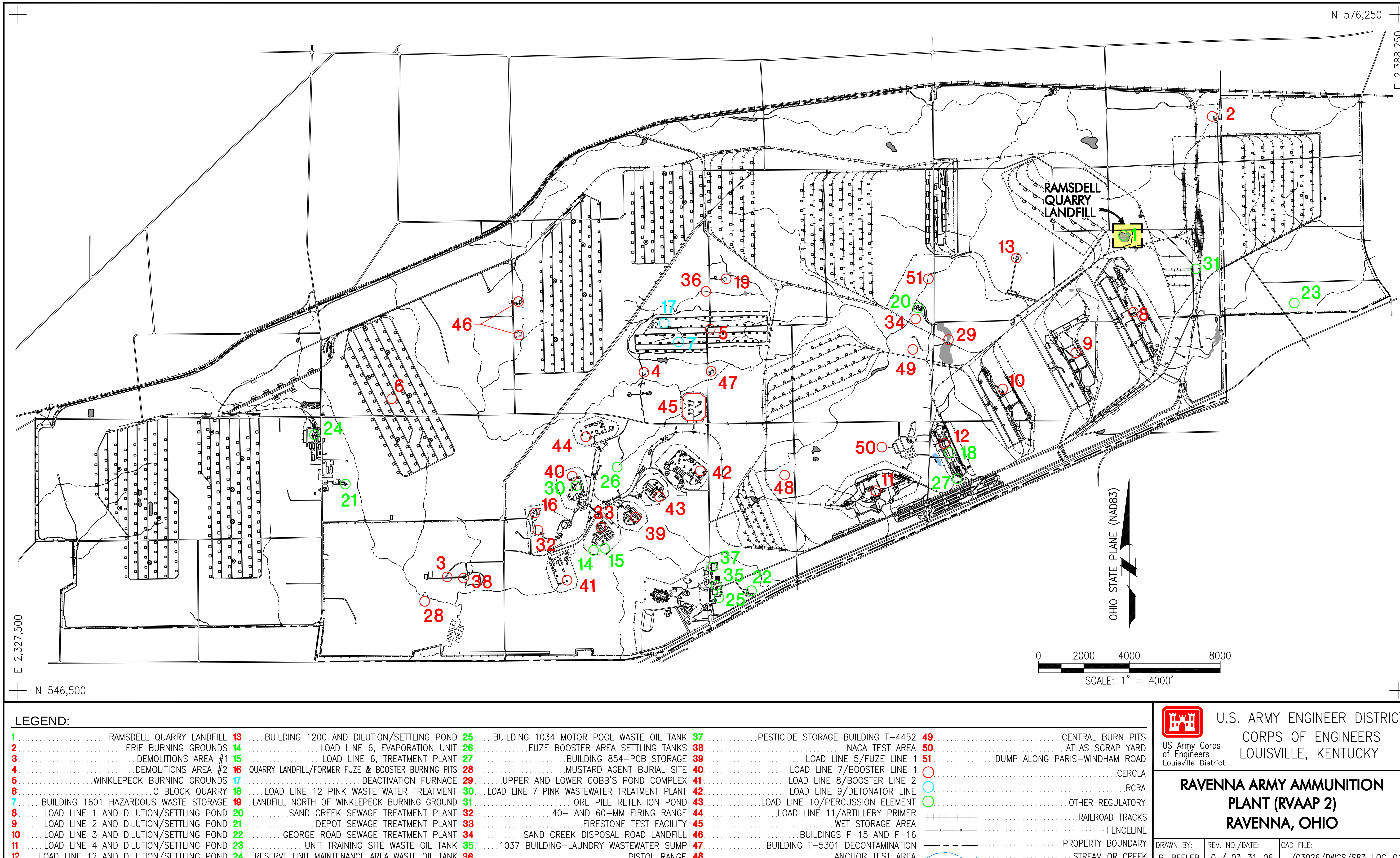


Figure 2-1. Ravenna Army Ammunition Plant Map

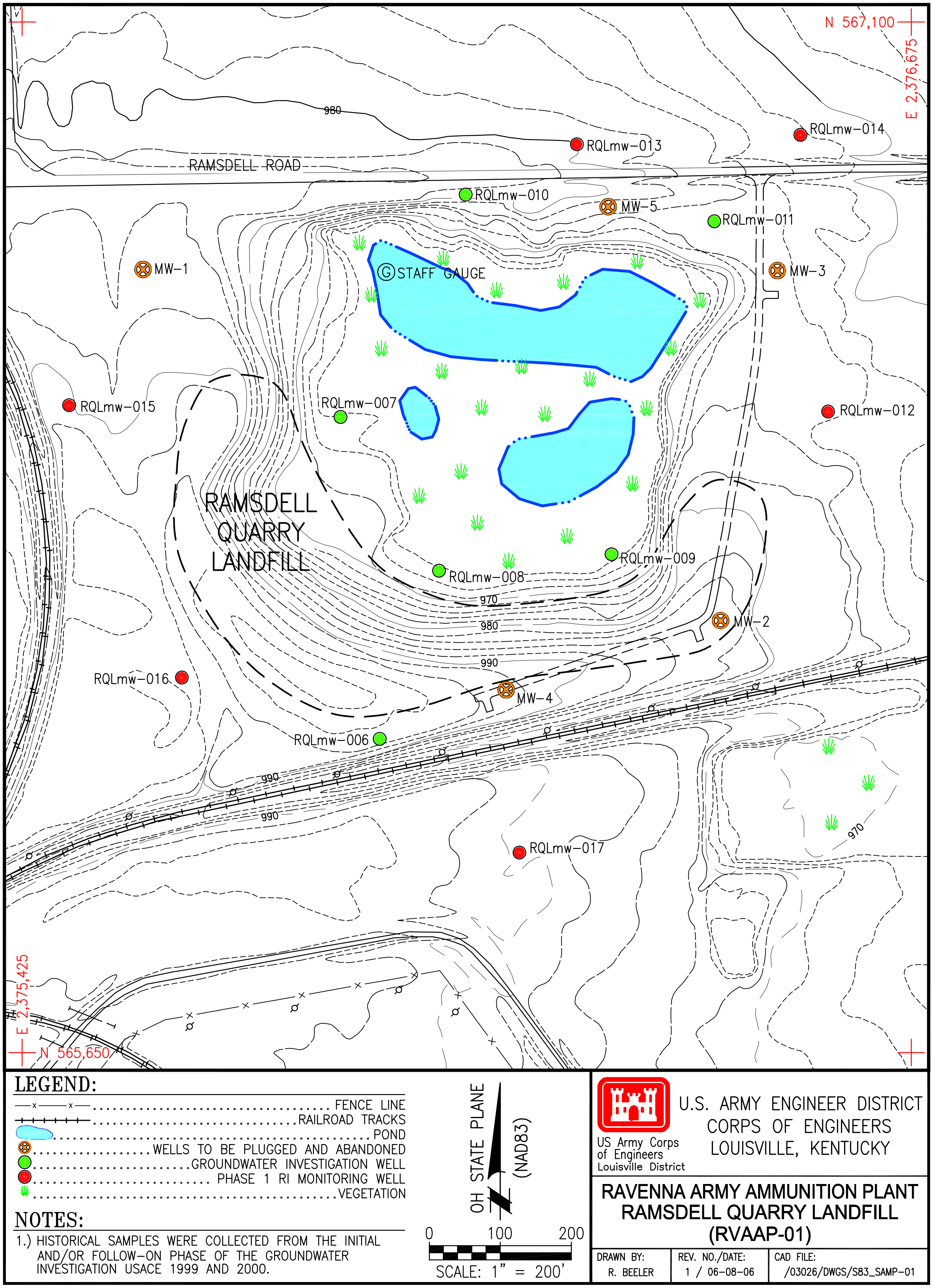


Figure 2-2. Ramsdell Quarry Site Map Showing Wells to be Plugged and Abandoned

3.0 MONITORING WELLS

The monitoring wells scheduled for P&A are: MW-1, MW-2, MW-3, MW-4, and MW-5. The wells are located around the outside of the Quarry excavation (Figure 2-2). Borings for MW-1 through MW-5 were drilled in 1987 and subsequently converted to monitoring wells in 1989. Logs of these borings are provided in Appendix B. The P&A activity on the five wells was originally scoped as part of the Phase I RI for RQL; however, the wells were found to be constructed differently than assumed, and the P&A work was suspended until appropriate P&A methods could be established and additional funding secured to address the new conditions. The surface casings were pulled in 2003 on two of the five wells (MW-2, approximately 10 ft, and MW-3, approximately 20 ft.). The wells have an 8-in.-diameter steel surface/protective casing installed into the bedrock. The steel surface/protective casing on the remaining wells is thought to be 10 to 20 ft in length. Information indicates minor amounts of grout were used to install the steel surface/protective casing in 1987. Upon completion of the surface casing, the borehole was advanced to the top of the Meadville Shale using a 6-in. diameter bit and air rotary drill methods. Well MW-5 was drilled to a depth of 50 ft and did not encounter the Meadville Shale. The boreholes were backfilled with bentonite to the approximate planned depth of the bottom of the well screen, and shallow wells were installed with monitoring intervals set at depths of about 40 to 50 ft below ground surface in 1989. The wells are constructed of 2-in.-diameter polyvinyl chloride (PVC), and the steel surface casing serves as a protective casing. The wells have 10-ft screens with filter sand and bentonite seals. The remainder of the annular space was filled with bentonite grout. Table 3-1 presents construction information and anticipated reaming depths for the monitoring wells. Figure 3-1 depicts the general method of well construction.

Table 3-1. Construction Information for Selected Monitoring Wells at the RQL Landfill, RVAAP

Well Number	8-in. diameter Steel Casing	Total Drilled Depth (6-in. bit)[a]	Total 2-in. diameter Well Depth[a]	Depth to be Reamed with 9-in. Bit[a]
MW-1	10 ft	175	55	60
MW-2	10 ft[b]	165	40	45
MW-3	20 ft[b]	165	44	49
MW-4	10 ft	165	55	60
MW-5	10 ft	50	38	50

[a] Feet below ground surface.
[b] The 8 in. steel casing was removed from MWs -2 and -3 in 2003.
RQL = Ramsdell Quarry Landfill.
RVAAP = Ravenna Army Ammunition Plant.

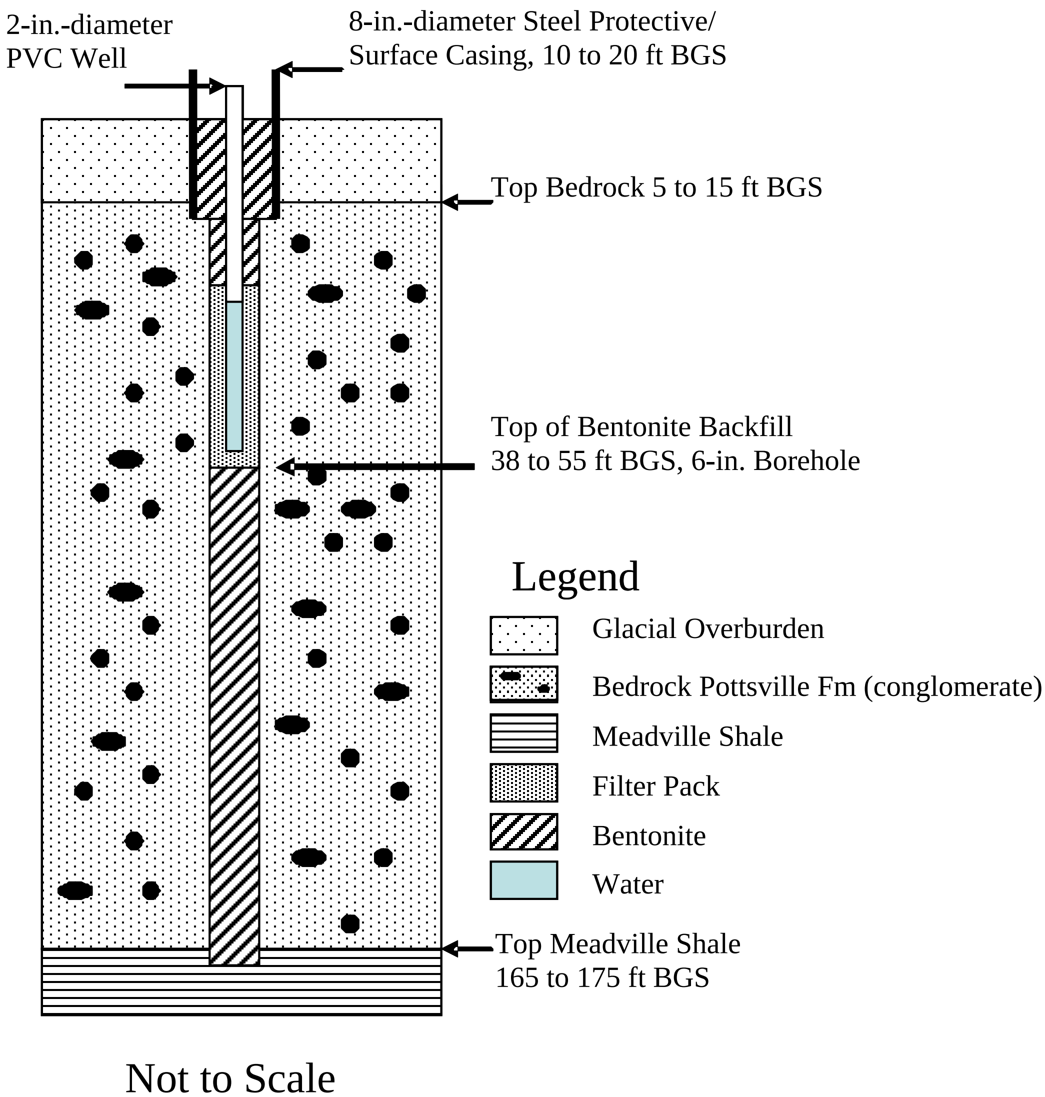


Figure 3-1. General As-Built for Wells MW-1 to MW-5

4.0 WELL ABANDONMENT

P&A of the monitoring wells at RQL will be conducted in a manner precluding any current or subsequent fluid media from entering or migrating within the subsurface environment along the axis or from the endpoint of the well/borehole. This is necessary to: (1) prevent poor quality water from one saturated zone from entering another, (2) prevent contamination of groundwater by surface contaminants, (3) restore the local aquifer to as close to its original condition as possible, (4) eliminate physical hazards, and (5) reduce potential for future liability.

The drill rig and all downhole equipment will be decontaminated prior to the start of work, between each well, and at the completion of the job. A detailed description of the decontamination procedure is provided in the Facility-wide SAP and reiterated below:

Decontamination of equipment used for the drilling of boreholes and collection of subsurface soil samples during the area of concern-specific investigations will be conducted within a temporary decontamination pad to be constructed at a designated location on the facility. The decontamination pad will be designed so that all decontamination liquids are contained from the surrounding environment and can be recovered for disposal as IDW. Drilling equipment will be decontaminated after completion of each borehole. The procedure for decontamination of drilling equipment will be as follows:

1. Remove caked soil material from the exterior of augers and cutting heads using a rod and/or brush.

2. Steam clean interior and exterior of equipment using approved water, using a brush where steam cleaning is not sufficient to remove all soil material.

3. Rinse thoroughly with approved potable water.

4. Allow equipment to air dry as long as possible.

5. Place equipment on clean plastic if immediate use is anticipated, or wrap in plastic to prevent contamination if longer-term storage is required.

Nondedicated sampling equipment will be decontaminated after each use during borehole interval sampling. The procedure for decontamination of sampling equipment will be as follows:

1. Steam clean (hollow-stem auger equipment only) and wash with approved water and phosphate-free detergent using various types of brushes required to remove particulate matter and surface films.

2. Rinse thoroughly with approved potable water.

3. Rinse thoroughly with American Society for Testing and Materials (ASTM) Type I or equivalent water.

4. Rinse thoroughly with methanol.

5. Rinse thoroughly with ASTM Type I or equivalent water.

6. Rinse thoroughly with hydrochloric acid (2% solution).

7. Rinse thoroughly with ASTM Type I or equivalent water.

8. Allow equipment to air dry as long as possible.

9. Place equipment on clean plastic if immediate use is anticipated, or wrap in aluminum foil to prevent contamination if longer-term storage is required.

In addition to the drilling and sampling equipment, field measurement instruments will also be decontaminated between monitoring well locations. Only those portions of each instrument that come into contact with potentially contaminated environmental media will be decontaminated. Due to the delicate nature of these instruments, the decontamination procedure will involve only initial rinsing of the instruments with approved water, followed by a final rinse using ASTM Type I or equivalent water. Decontamination of non-dedicated bladder pumps and other equipment with stainless steel components will be accomplished using only steps 1 through 4 above.

The abandonment of each well/borehole will follow field procedures outlined in Chapter 9 of Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Groundwater Monitoring* (Ohio EPA 1995) and the *Technical Guidance for Sealing Unused Wells* (Ohio's State Coordinating Committee on Groundwater 1996). P&A of the RQL wells will be accomplished using the following general procedure:

- Measure static water level in well. Remove all obstacles (pumps, cables, string-lines, measurement tapes, etc.) from the well, and remove all surface components (i.e., protective casing, concrete pad, traffic posts, etc.).

- Pull 8-in. steel surface/protective casing. In the event the casing cannot be pulled, overdrilling using washover pipe or similar device will be employed to remove the casing.

- Pull the 2-in.-diameter PVC inner casing. The oversight and drill crew will use caution and diligence to remove the PVC casing. If the casing cannot be pulled, the casing will be milled out with a 9-in.-diameter tricone roller bit during reaming. The project geologist will verify the casing destruction by detailed observation of the drill cuttings.

- The borehole will be reamed to 5 ft below the installed well depth using an air rotary rig and 9-in.-diameter tricone roller bit. The entire borehole will be reamed for MW-5 (50 ft). After reaching the desired depth, the hole will be cleared of all cuttings.

- The reamed borehole will be grouted from the bottom up with a high-yield bentonite (e.g., Aquagel or equivalent) in one continuous placement. Bentonite grouting will be emplaced using a tremie pipe. The bottom of the tremie pipe will be within 5 ft of the reamed depth. The bentonite grout will be filled to within 5 ft of ground surface.

- A 3-ft concrete plug will be placed on top of the bentonite grout; and the remaining 2-ft of borehole will be filled with native soil. The site will be restored to original condition by removing tire ruts and other irregular surfaces; and the area will be seeded with an RVAAP-approved grass seed mixture and straw.

For each abandoned monitoring well, a P&A record will be prepared and submitted to the Army, USACE, and Ohio EPA via a letter report. P&A records will also be provided to the Ohio Department of Natural Resources in accordance with Ohio Revised Code 1521.05. An example of an Ohio EPA-approved well P&A report is included in Appendix A. All depths reported in the P&A records will be designated in feet from ground surface. The letter report will include the following information:

- project and well/borehole designation;
- location with respect to the replacement well or borehole (if any);
- open depth of well/borehole before grouting;
- upon notification and approval by Ohio EPA, any casing or items left in borehole by depth, description, composition, and size (if applicable);
- copy of the borehole log;
- copy of construction diagram for abandoned well (if applicable);
- reason for abandonment;
- description and total quantity of grout used initially;
- description and daily quantities of grout used to compensate for settlement;
- dates of grouting; and
- water or mud level prior to grouting and date measured.

5.0 UNEXPLODED ORDNANCE AVOIDANCE

A qualified unexploded ordnance (UXO) subcontractor, approved by the USACE, Louisville District, will be present at RQL during P&A activities. The UXO subcontractor will employ a Schonstedt Model GA-52 and GA-72 (or equivalent) magnetic locator for surface anomaly surveys, and a Schonstedt Model MG-220 (or equivalent) magnetic gradiometer for any downhole surveys. UXO technician support will be present during all field operations. The UXO Team Leader will train all field personnel to recognize and stay away from propellants and munitions and explosives of concern (MEC). Safety briefings for MEC avoidance will also be provided to all site personnel and site visitors. All well locations and access routes to the well locations will be cleared for potential MEC and clearly defined prior to entry using visual and magnetometer surveys. Access routes will be at least twice as wide as the widest vehicle that will use the route. The UXO technician will clearly mark the boundaries of the cleared well locations and access routes. If surface ordnance and explosives are encountered, the approach path will be diverted away from the MEC, the area clearly marked, and the area will be avoided. Any identified magnetic anomaly will also be clearly marked and the anomaly will be avoided. The cleared approach paths will be the only ingress/egress routes to a particular sampling location.

P&A personnel must be escorted by UXO personnel at all times in areas potentially contaminated with MEC until the UXO team has completed the access surveys and the cleared areas are marked. Escorted P&A personnel will follow behind the UXO technician escort. If anomalies or MEC are detected, the UXO technician will halt escorted personnel in place, select a course around the item, and instruct escorted personnel to follow. Downhole magnetometer surveys will be performed at the discretion of the UXO subcontractor after the casing is pulled. Should MEC be discovered, the UXO team will not be tasked with the mission of disposal. In the event of UXO or bulk explosives discovery, the SAIC Field Operations Manager will contact the RVAAP Environmental Coordinator who will initiate the appropriate response actions.

An approved Ordnance and Explosives Avoidance Plan prepared by the UXO support contractor is contained in Appendix B of the *Sampling and Analysis Plan Addendum No. 1 for the Phase I Remedial Investigation of Ramsdell Quarry Landfill, Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 2003b).

6.0 HEALTH AND SAFETY

It is the goal of USACE, Louisville District and RVAAP to conduct monitoring well P&A activities in a manner that ensures maximum safety and health for all RVAAP and subcontractor personnel. All P&A activities will adhere to the Facility-wide Safety and Health Plan (FSHP) and the RQL Phase I RI Site Safety and Health Plan (SSHP) Addendum No. 1. The FSHP presents a list of safety rules applicable to drill rig operations in the section on Standard Operating Safety Procedures (Section 9). A task-specific hazard analysis for soil boring, soil sampling, and monitoring well installation/P&A using drill rig or Geoprobe is provided in the SSHP. It is the responsibility of all site personnel to ensure adherence to these plans. All site personnel are required to (1) have completed the 40-hr Hazardous Waste Site Operations training in accordance with 29 *Code of Federal Regulations* 1910.120 and applicable annual refresher requirements, (2) have had a respirator fit test within the previous year, and (3) be enrolled in a medical monitoring program.

7.0 REFERENCES

Ohio EPA (Ohio Environmental Protection Agency) 1995. *Technical Guidance Manual for Hydrogeologic Investigations and Groundwater Monitoring*, February.

Ohio State Coordination Committee on Groundwater 1996. *Technical Guidance for Sealing Unused Wells*.

USACE (U. S. Army Corps of Engineers). *Requirements for the Preparation of Sampling and Analysis Plans*, EM 200-1-3.

USACE 2001. *Facility-wide Sampling and Analysis Plan for the Ravenna Army Ammunition Plant, Ravenna, Ohio,* DACA62-00-D-0001, D.O. CY02, Final.

USACE 2003a. *Site Safety and Health Plan Addendum No.1 for the Phase I Remedial Investigation of Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio,* F44650-99-D-0007, D.O. CY11, Final.

USACE 2003b. *Sampling and Analysis Plan Addendum No.1 for the Phase I Remedial Investigation of Ramsdell Quarry Landfill at the Ravenna Army Ammunition Plant, Ravenna, Ohio,* F44650-99-D-0007, D.O. CY11, Final.

APPENDIX A
WATER WELL SEALING REPORT FOR ABANDONED OR UNUSED WELLS

WATER WELL SEALING REPORT
(For Abandoned or Unused Wells)
OHIO DEPARTMENT OF NATURAL RESOURCES
Division of Water, Ground Water Resources Section
1939 Fountain Square Drive
Columbus, Ohio 43224-1360

LOCATION

County________ Township________ Section ______
Property Owner________
Address of Property________
Location:______ miles ______ (n, e, s, w) of ________ (nearest intersection)

on the ______ (n, e, s, w) side of ________ (road name)

ORIGINAL WELL

ODNR Well Log Number________ Copy attached? Yes or No (circle one)

MEASURED CONSTRUCTION DETAILS Date of measurements________

Depth of Well________ Static Water Level________
Size of Casing________ Length of casing________
Well Condition________

SEALING PROCEDURE

Method of Placement________

			Sealing Material	Volume
Placement:	From______	To______	______	______
	From______	To______	______	______
	From______	To______	______	______

Was Casing Removed? Yes or No (circle one)

Condition of Casing________
Perforations: From______ To______
From______ To______
Date Sealing Performed________
Reason(s) for Sealing________

CONTRACTOR

Name________ ODH Registration #________
Address________
City/State/Zip________ Signature ________

DNR 7810.93 **SUBMIT COMPLETED FORM TO ODNR-DIVISION OF WATER**

Figure 9.1 ODNR form for reporting well abandonment procedures.

APPENDIX B
FIELD REPORT AND BORING LOGS FOR MONITORING WELLS 1–5

Report on Field Work
at the
Ravenna Army Ammunition Plant
Ravenna, Ohio

by
The Ohio Drilling Company
Massillon, Ohio

August 10, 1987

Scope and Purpose

The contents of this report are intended to summarize all field work accomplished on this site as outlined in the previously submitted report entitled "Geologic/Hydrogeologic Survey Survey and Monitoring Well Placement Proposal", by the Ohio Drilling Company. Rather than reiterate all the research and theory contained in the above-mentioned report, this report should be considered as an implementation and realization of the first report, and should therefore be considered together with it.

There are three subdivisions of the field work; namely, the drilling and emplacement of the monitoring wells, the geohydrologic regime, and the chemical characteristics of each well found in the first round of sampling.

Drilling and Emplacement of Monitoring Wells

A series of four water sample holes was drilled around the perimeter of the Ramsdell Quarry. They are located as originally proposed (see location map next page). Each was drilled using an air rotary drilling rig. The holes are 6" in diameter and were continued until the site geologist was certain that the Meadville Shale was encountered. The driller's logs of the wells are located in the appendix to this report. Each was finished at the top with an 8" diameter x 10 foot long steel locking cap firmly grouted into the bedrock for security. The wells will be converted to permanent monitoring wells as proposed when the appropriate screening interval is determined in consultation with the Northeast District of Ohio EPA. A brief description of each hole follows.

MW #1 - A two-foot thick soil zone overlies the sandstone bedrock. This sandstone is the Sharon Sandstone/Conglomerate, which is the primary aquifer on site. The differences in color reflect changes in mineralization of the rock and other factors such as oxygenation of the groundwater. Two good water bearing zones occur: one at 41 and the other at 60 feet below the surface. The two areas represent well-developed joint and fracture patterns in the sandstone, creating zones of relatively high secondary porosity. In actuality, the sandstone is saturated up to a zone aproximately 15 to 20 feet below the ground surface. These two zones do not represent separate aquifers. Below these fracture zones the Sharon Sandstone continues to a depth of 164 feet, where a thick shale unit interpreted as the Meadville Shale is encountered. The hole was continued downward for a further 11 feet to be sure it was not just a stringer of shale in the sandstone. At this point the hole was stopped and a locking cap fitted.

MW #2 - The ground surface was bare sandstone here; again identified as the Sharon Sandstone/Conglomerate. Alternating zones of mineralization and oxydation were encountered in the sandstone to a depth of 33 feet, where the color remained grey-white to 112 feet. At this depth a 5-foot thick stringer of the Sharon Shale was encountered. Below this the Sharon was again encountered to a depth of 152 feet, where the Meadville was found. The drilling continued for another 13 feet to be sure of the identification, and the hole was completed with a locking cap. The Sharon here contained two well-fractured water-bearing zones: one at 34 feet and the other at 53 feet below the surface.

MW #3 - Here the Sharon Sandstone was overlain by a two-foot thickness of forest soil followed by four-feet of brown-yellow clay. The Sharon continues down to 90 feet, where thin stringers of shale are found. Below these strings the Sharon is again found to 93 feet where a thicker stringer of the Sharon Shale appears. Immediately below this shale unit a 21 foot thickness of the conglomerate unit of the Sharon is encountered. Beneath the conglomerate are 4 feet of shale followed by a final bed of the Sharon to a depth of 151 feet, where the Meadville is encountered. The hole was continued to a depth of 165 feet for identification purposes. Three water-bearing fracture zones occur in the Sharon: namely, at 18 feet, 42 feet and 53 feet below the surface.

MW #4 - Three feet of fill material overly the Sharon Sandstone at this location. The sandstone is continuous to 114 feet where a 3-foot thick string of the Sharon Shale is found. Below this a 38 foot thickness of the Sharon Conglomerate is encountered, followed in turn by a 2-foot thick stringer of Sharon Shale. Underlying the shale a 3-foot thickness of the Sharon Sandstone is found to overly the Meadville Shale which is encountered at 160 feet below the surface. Only one highly-fractured zone of secondary porosity was encountered here, namely, at 55 feet.

The geology revealed in these four holes is fairly uncomplicated and agrees well with that found in previous work on the site and surrounding areas. The linear bed of the conglomerate unit of the Sharon found in monitoring wells 3 and 4 is evidence of the generally held belief that the Sharon represents fresh water riverine channel fill deposits whose beds trends very roughly north to south.

When the appropriate screening interval is determined in consultation with Northeast District Ohio EPA the wells will be completed with 2" diameter flush-joint PVC casing with 5 feet of PVC screen. If backfilling is required, the wells will be backfilled with a non-reactive grout material such as bentonite/sand slurry. After emplacement, the wells will be sampled every six months and then annually after the first year. The contaminant(s) to be analyzed for will be determined in consultation with Ohio EPA.

Water samples will be drawn using a gas-operated (non-water-contact) Geofilter Small Diameter Well Pump designed for monitoring well work. This pump will be dedicated for these monitoring wells. All water-contact areas of the pump will be decontaminated between samplings using distilled water. If the wells are screened near the surface the wells may be sampled using a PVC or Teflon bailer, using similar decontamination procedures.

The tops of the protective steel locking caps (with lids open) were shot in with a transit referenced to an arbitrary datum. The elevations are tabulated in the appendix.

The appendix contains two geologic cross-sections showing the strata encountered in the drilling and their relative water levels on July 21, 1987. The rock units are classified as to lithology and not according to formation names. In all cases, the lowest shale unit is the Meadville Shale, and the remaining consolidated rock units overlying it are the Sharon Sandstone/Comglomerate. The stratigraphic columns are corrected for differences in relative elevation.

Hydrogeology

Previous hydrogeologic site work has determined the groundwater to be moving towards the east-southeast, at least at the time the work was done. The present study, however, has found that the groundwater movement is toward the northeast. Water level measurements were taken on two separate dates (6/26/87 and 7/21/87) to confirm this conclusion. The fact that the groundwater in MW 3 is more highly mineralized than that found in the other three wells corroborates the water level data.

The appendix contains two piezometric surface maps of the Ramsdell Quarry area, reflecting the water levels measured on each date. As can be seen, the gradient fluctuates somewhat but through the year would seem to average 65 feet per mile. On the map dated June 26, 1982 the flow lines would be uniformly distributed and move toward the northeast. On the second map, dated July 26, 1987, the piezometric contour lines are somewhat uniform towards the southwest but become increaingly divergent and non-parallel toward the southeast, especially in the area of MW 3. The water level measurements were taken nearly a month apart, and it might be speculated that the maps describe two different interactive states of the pond with respect to the groundwater. Obviously it is desirable to have several sets of water level data taken during different seasons to assess the relationship between a surface body of water and the groundwater, but the data are at least suggestive of at least intermitted or seasonal interaction. The pond is quite marshy and silted up with wind-blown material. The bottom probably has quite low hydraulic conductivity during most of the year, and is thus minimally involved with the general groundwater flow at these times. However if periods of heavy rainfall (such as occurred in July) raised the water level of the pond, thereby increasing the hydraulic head on the bottom, a piezometric surface map similar to the one dated July 26, 1987 could result if the increased head is sufficient to force the passage of water through the bottom to recharge the aquifer. When the hydraulic head diminishes the bottom returns to a nearly impermeable condition. The chemical analyses of MW 3 suggest that there may be a connection of at least occasional significance.

Although previous studies of the area have been made, it must be pointed out that none have been conducted at this particular site. Therefore inconsistencies in the determination of the direction of groundwater movement may be only apparent in nature. Hydrogeologic subregimes are quite common, and indeed occur in other parts of the Arsenal compound. Another explanation of the apparent differences between present groundwater vectors and those found in the past is that there could have been a change in the regional groundwater dynamics in the proximity of the Ramsdell Quarry acting to add a more northerly component to the gradient.

In summary, the aquifer underlying the Ramsdell Quarry is comprised of a thick unit of sandstone bounded on the top by a discontinuous forest soil and clay, and on the bottom by a thick shale unit which is considered an aquiclude. The aquifer is unconfined in nature with a gradient of approximately 65 feet toward the northeast. Recharge mechanisms for the sandstone must be determined by field measurements taken through several seasons, and so are beyond the scope of this study.

Chemical Analyses of Wells

After the wells were drilled they were allowed to equilibrate for a period of several days, after which the initial sampling was begun. The samples were withdrawn using a point-source teflon bailer to obtain samples from the top, middle and bottom of the aquifer. Deionized water was used to decontaminate the bailer between samplings. The chemical analyses were performed at the Wadsworth/Alert Laboratories in Canton. The samples were chilled between the time of collection and their delivery to the lab. A chain of custody form was filled out.

The parameters tested for were suggested by Northeast District, Ohio EPA. The analytical results are summarized in the appendix. For the sake of comparison, MW 4 would have to be considered the "up-gradient" or "background" well.

Since the parameters sampled are of a regulated nature, they are best discussed in detail with Ohio EPA rather than in this report. Suffice it to say that the great bulk of the parameters are reflective of groundwater generally present in the consolidated rock aquifers of northeast Ohio; for example, high iron, high to medium dissolved solids and specific conductivity, and spotty occurences of moderate to high amounts of sulfate where interbedding with shales or coal seams occurs.

Respectfully submitted,

THE OHIO DRILLING COMPANY

By

Thomas J. Perkins, Geologist

TJP:ee

APPENDIX

THE OHIO DRILLING CO.

INCORPORATED

MASSILLON, OHIO

DRILLED FOR Ravenna Arsenal, Inc. - Ravenna, Ohio HOLE NO. MW 1

DRILLED BY Paul Ortz DRILLER COMPLETED June 18, 19 87

LOCATION Northwest corner of Ramsdell Quarry

THICKNESS OF STRATA	STRATA	TOTAL DEPTH	HEAVED	WATER FROM SURFACE
2 ft.	Soil	2 ft.		
7 ft.	Red Sandstone	9 ft.		
2 ft.	Grey Sandstone	11 ft.		
7 ft.	Red Sandstone	18 ft.		
146 ft.	Grayish-White Sandstone	164 ft.		
11 ft.	Shale	175 ft.		
	First water-bearing zone - 41 ft.			
	Second water-bearing zone - 60 ft.			

THE OHIO DRILLING CO.

INCORPORATED

MASSILLON, OHIO

DRILLED FOR Ravenna Arsenal, Inc. - Ravenna, Ohio HOLE NO. MW 2

DRILLED BY Paul Ortz DRILLER COMPLETED June 17, 19 87

LOCATION Southeast corner of Ramsdell Quarry

THICKNESS OF STRATA	STRATA	TOTAL DEPTH	HEAVED	WATER FROM SURFACE
11 ft.	Reddish Sandstone	11 ft.		
11 ft.	White Sandstone	22 ft.		
11 ft.	Red Sandstone	33 ft.		
74 ft.	White Sandstone	107 ft.		
5 ft.	Shale	112 ft.		
40 ft.	White Sandstone	152 ft.		
13 ft.	Shale	165 ft.		
	First water-bearing zone - 34 ft.			
	Second water-bearing zone - 53 ft.			
	8" casing with locking cap installed to bedrock.			

THE OHIO DRILLING CO.

INCORPORATED

MASSILLON, OHIO

DRILLED FOR Ravenna Arsenal, Inc. - Ravenna, Ohio HOLE NO. MW 3

DRILLED BY Paul Ortz DRILLER COMPLETED June 17, 19 87

LOCATION Northeast corner of Ramsdell Quarry

ICKNESS OF STRATA	STRATA	TOTAL DEPTH	HEAVED	WATER FROM SURFACE
2 ft.	Soil	2 ft.		
2 ft.	Clay	4 ft.		
12 ft.	Sandstone	16 ft.		
2 ft.	Brown Sandstone	18 ft.		
35 ft.	Light Sandstone	53 ft.		
37 ft.	Grayish-White Sandstone	90 ft.		
1½ ft.	Shale Streaks	91½ ft.		
[illegible] ft.	White Sandstone	93 ft.		
5 ft.	Shale	98 ft.		
29 ft.	Sandstone Conglomerate	127 ft.		
4 ft.	Shale	131 ft.		
20 ft.	White Sandstone	151 ft.		
14 ft.	Shale	165 ft.		
	First water-bearing zone - 18 ft.			
	Second water-bearing zone - 42 ft.			
	Third water-bearing zone - 53 ft.			
	8" casing with locking cap installed to bedrock.			

THE OHIO DRILLING CO.

INCORPORATED

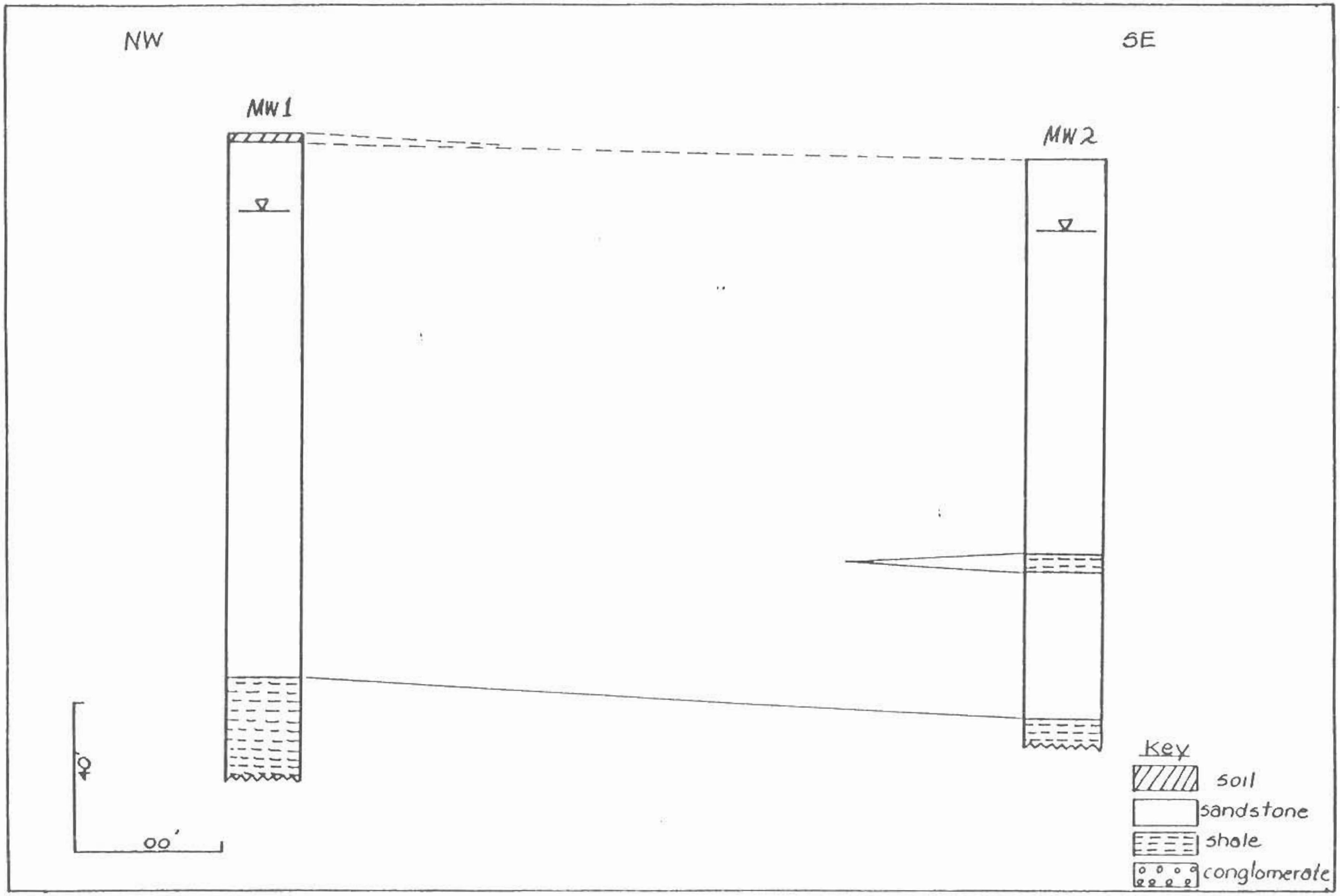
MASSILLON, OHIO

DRILLED FOR Ravenna Arsenal, Inc. - Ravenna, Ohio HOLE NO. MW 4

DRILLED BY Paul Ortz DRILLER COMPLETED June 18, 19 87

LOCATION Southwest section of Ramsdell Quarry

KNESS OF STRATA	STRATA	TOTAL DEPTH	HEAVED	WATER FROM SURFACE
3 ft.	Fill Material	3 ft.		
3 ft.	Brown Sandstone	6 ft.		
6 ft.	Red Sandstone	12 ft.		
5 ft.	Gray Sandstone (damp)	17 ft.		
12 ft.	Brown Sandstone	29 ft.		
85 ft.	White Sandstone	114 ft.		
3 ft.	Shale	117 ft.		
[illegible] ft.	Sandstone Conglomerate	155 ft.		
2 ft.	Shale	157 ft.		
3 ft.	Sandstone	160 ft.		
5 ft.	Shale	165 ft.		
	Water-bearing zone - 55 ft.			
	8" casing with locking cap installed to bedrock.			



Stratigraphic Cross-section Northwest - Southeast

THE OHIO DRILLING CO.

INCORPORATED

MASSILLON, OHIO

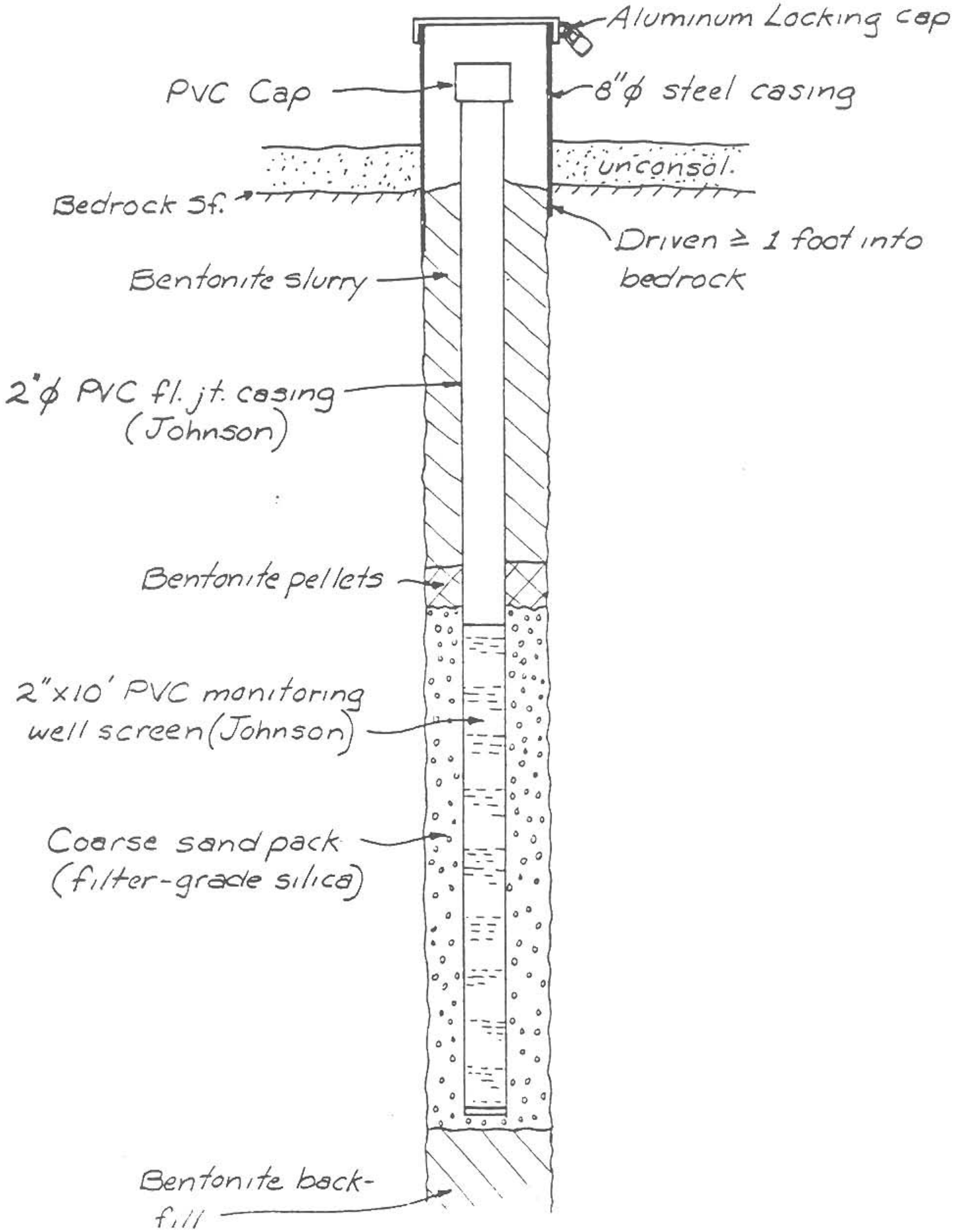
DRILLED FOR Ravenna Arsenal, Inc. - Ravenna, Ohio HOLE NO. MW-5
6" Well

DRILLED BY Randy McKay DRILLER COMPLETED January 12, 19 88

LOCATION 50 ft. south of Ramsdell Rd., 231 ft. west of MW-3

THICKNESS OF STRATA	STRATA	TOTAL DEPTH	HEAVED	WATER FROM SURFACE
11 ft.	Brown Sandstone	11 ft.		
1 ft.	Gray Sandstone	12 ft.		
2 ft.	Brown Sandstone	14 ft.		
2 ft.	Gray Sandstone	16 ft.		
3 ft.	Brown Sandstone	19 ft.		
3 ft.	Gray Sandstone	22 ft.		22 ft.
ft. 11	Brown Sandstone (water-bearing)	33 ft.		
ft. 5	Gray Sandstone	38 ft.		
12 ft.	Brown Sandstone	50 ft.		
	Converted to 2" diameter monitoring well, screened			
	33 to 43 ft. below grade.			

Typical Monitoring Well Installation



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