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ARCADIS G&M, Inc.
441 New Karner Road
Suite 4
Albany
New York
Tel 518 452 7826
Fax 518 452 4398

Transmittal Letter

ENVIRONMENTAL

To:
Mr. Martin Doster, P.E.
Mr. David Locey ✓

Copies:
Mr. David Sordi
Ingersoll-Rand Company

From:
Marc Sanford

Date:
17 June 2004

Subject:
Pneumatic Fracturing Work Plan
ARO Corporation Site – Cheektowaga, NY

ARCADIS Project No.:
AY000220.0008

We are sending you:
☒ Attached ☐ Under Separate Cover Via _____ the Following Items:

☐ Shop Drawings ☐ Plans ☐ Specifications ☐ Change Order
☐ Prints ☐ Samples ☐ Copy of Letter ☐ Reports
☐ Other:

Copies	Date	Drawing No.	Rev.	Description	Action*
2				Pneumatic Fracturing Work Plan	

Action*
☐ A Approved ☐ CR Correct and Resubmit ☐ Resubmit ____ Copies
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Comments:

Work Plan
Remedial Enhancement via Pneumatic Fracturing Technology

ARO Corporation Site
Cheektowaga, New York

ARCADIS

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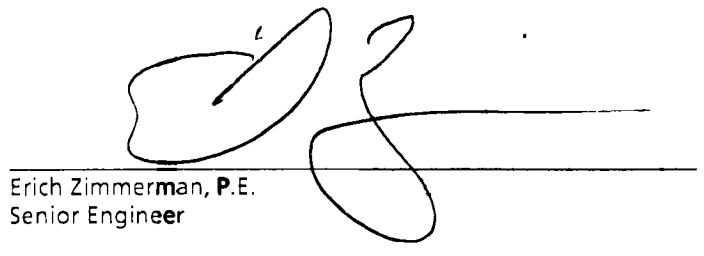
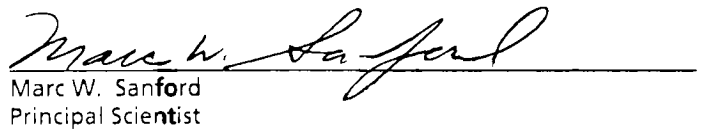
PREPARED FOR

Ingersoll-Rand Corporation

ARCADIS



Erich Zimmerman, P.E.
Senior Engineer



Marc W. Sanford
Principal Scientist

Work Plan
Remedial Enhancement via Pneumatic Fracturing Technology

ARO Corporation Site,
Cheektowaga, New York

Prepared for:
Ingersoll-Rand Corporation

Prepared by:
ARCADIS G&M, Inc.
441 New Karner Road
Suite 4
Albany
New York 12205
Tel 518 452 7826
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Our Ref.:
AY000220.0007

Date:
June 17, 2004

ARCADIS

Work Plan
Remedial Enhancement
via Pneumatic Fracturing

ARO Corporation Site
Cheektowaga, NY

Figures

1. Introduction

ARCADIS G&M, Inc. (ARCADIS) was retained by Ingersoll-Rand Corporation (IR) to prepare this Work Plan for evaluating pneumatic fracturing (PF) technology as a means to enhance the existing Vacuum-Enhanced Recovery (VER) system at the former ARO Corporation (ARO) Site. The goal of the PF program is to pneumatically enhance the intrinsic permeability of the geologic formation, thereby increasing the radial influence (RI) of the existing VER recovery wells. This will increase the rate of induced airflow through the vadose zone, thereby increasing the mass removal rate for volatile organic compounds (VOCs) present within the overburden, while greatly reducing the flow rate of co-produced groundwater. Pneumatic fracturing is proposed at two locations on site.

2. Background

The ARO Corporation site is an inactive hazardous waste site in Cheektowaga, New York. The site is currently in the remedial action (RA) phase of the remedial program under a Consent Order with the NYSDEC. ARCADIS designed and installed a VER system in 1998 to remediate chlorinated hydrocarbons (CAHs) in groundwater at the site. A total of ten recovery wells are operated under the current VER system configuration. Performance monitoring activities are currently completed in accordance with the approved New York Department of Environmental Conservation monitoring schedule and include the following:

- Monthly analysis of groundwater and vapor samples from the VER system; and
- Semi-Annual groundwater monitoring of monitoring wells; and submission of an annual report.

3. Pneumatic Fracturing Process

Pneumatic fracturing is a patented technology, which enhances the in situ removal and treatment of VOCs in low permeable formations. The process may be generally described as injecting a gas into a contaminated geologic formation at a pressure, which exceeds the natural in situ stresses, and at a flow rate, which exceeds the permeability of the formation. This causes failure of the geologic unit and creates a fracture network radiating from the injection point (e.g., radially or directionally).

Once established, the fractures increase the rate at which vapors or liquids can travel through the formation (i.e., increases advective flow and shortens diffusive flow paths) thereby making the VOCs more acceptable to remediation. For example, at the ARO Site, the process is expected to create new convective pathways in the formation (extend the ROI of existing VER recovery wells) resulting in increase permeability and shorten diffusive distances in the target treatment zone.

4. Pilot Study Objective

The objective of the pilot study is to evaluate the use of PF technology to enhance the performance of the existing VER system. This includes the creation of a network of radial fractures in the target treatment zone (e.g., 5 feet to 19 feet below grade surface (bgs) in two test areas.

The effectiveness of the PF enhancement program will be based upon the following criteria:

- Increased ROI of the existing recovery wells (e.g., ≈ 5 feet to >15 feet),
- Improved intrinsic permeability of dense till soils within the pilot study area (e.g., increased air flow rates),
- Increased VOCs mass removal rates (e.g., 2 to 3 times), and
- Increase the distribution of VOCs in the vapor phase (i.e., percentage of individual compounds compared with baseline conditions).

5. Scope of Work

The scope of work for the PF pilot study consists of three major tasks, including baseline monitoring, the performance of the pneumatic fracturing pilot study and reporting of results. A more complete description of these tasks is provided within the following sections.

Prior to the performance of any field activities, ARCADIS will revise the site-specific Health & Safety Plan (HASP) in compliance with 29 CFR 1910.20 to reflect modifications to the project scope of work, and outline any additional hazards anticipated.

5.1 Baseline Monitoring

ARCADIS will perform baseline monitoring prior to implementing this pilot study to confirm existing site conditions and system performance characteristics. Parameters to be evaluated will include groundwater elevation measurements and vacuum gauge readings in monitoring wells, measurement of airflow rates, groundwater flow rates, and collection of influent vapor and water samples to determine VOC mass removal rates and distribution of VOCs in the selected VER recovery wells RW-1 and RW-10.

Subsequent to the completion of baseline monitoring, ARCADIS will shut down the VER system to avoid upsets during the installation and development of the pneumatic fracturing well network.

5.2 Pneumatic Fracturing Pilot Study

Based upon a desktop evaluation of the Site data and use of the pneumatic fracturing model, ARCADIS proposes to install two fracture wells (FWs) in each of the two test plots. Fracture wells will be installed at a radial distance of approximately 12 feet and 18 feet from RW-1, and approximately 15 feet and 21 feet from RW-10, respectively.

RW-1 is located downgradient from the former loading dock source area, and was the site of the first VER pilot study. This area was selected because the VER pilot study results, although favorable, could not be duplicated in other areas of the site during full-scale system operation. Implementing PF in this area should also greatly increase the VOC mass removal rate, and provide a means to cost-effectively shorten the O&M period at this site.

The second pilot study area will be located near the former metals preparation source area (i.e., surrounding RW-10). This area was selected because the effectiveness of the VER system is currently limited (i.e., VER pilot study results were not duplicated) by the low permeability of soils in this area, and high VOC concentrations are currently measured in the groundwater. Performance of the pilot study in this area will also provide a clear point of comparison between locations with distinctly different subsurface characteristics.

Wells will be pneumatically fractured using a proprietary radial nozzle in two-foot lifts for a total of seven fracture zones per well, twenty-eight for all four PF wells. All PF

wells will subsequently be developed to assure steady-state conditions within the subsurface.

Subsequent to the completion of pneumatic fracturing and well development activities, ARCADIS will restart the VER system and perform a subsequent round of monitoring to assess variations in system performance, mass removal rate and groundwater recovery. The following data will be recorded daily for a period of one week to assess changes as the system approaches steady-state operation:

- Groundwater elevations in system monitoring wells
- Induced vacuum at the liquid ring pump, existing VER extraction wells, fracture wells and fracture monitoring wells;
- Groundwater recovery rate
- Induced air flow rate
- VOC concentrations at the system exhaust (measured at the discharge from the vapor/liquid separator)

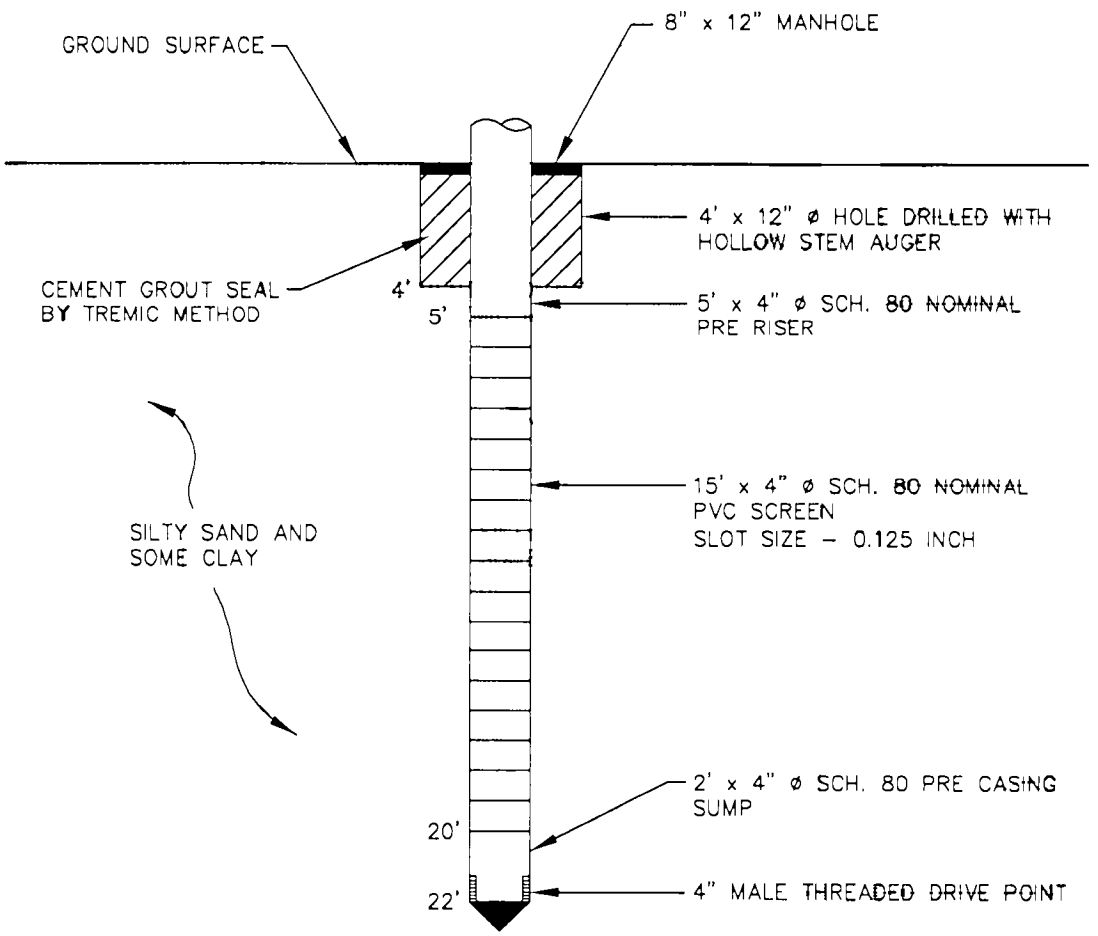
Figure 1 shows a schematic of a typical FW in each of the two pilot study areas. Figure 2 identifies the location of existing and proposed wells to be instrumented during the PF program.

5.3 Reporting

Upon completion of these tasks, ARCADIS will prepare a findings report summarizing the work performed and evaluating pre- and post-fracturing parameters. The report will include the system performance data sheets, summary data tables and figures depicting well installation logs, anticipated fracture cross sections and the anticipated extent of fracture zones based on vacuum influence readings detected during the pilot study.

6. Schedule

The proposed project schedule is shown on Figure 3. The task estimates assume that the fieldwork is not delayed due to weather, access, regulatory review or other unforeseen delays.



NOTES:

1) PRE-DRILL A 3.5"-3.75" ø PILOT HOLE WITH SOLID STEM AUGER
2) PRESS OR PUSH ON DRIVE POINT TO SET WELL DEPTH SHOWN ON DRAWING OR AS DIRECTED BY ARCADIS REPRESENTATIVE.
3) FINAL DEPTH OF WELLS WILL BE DETERMINED AT TIME OF INSTALLATION
4) 2' x 4" ø SUMP TO BE PRESSED 1'-2' BEYOND DEPTH OF AUGERED BOREHOLE

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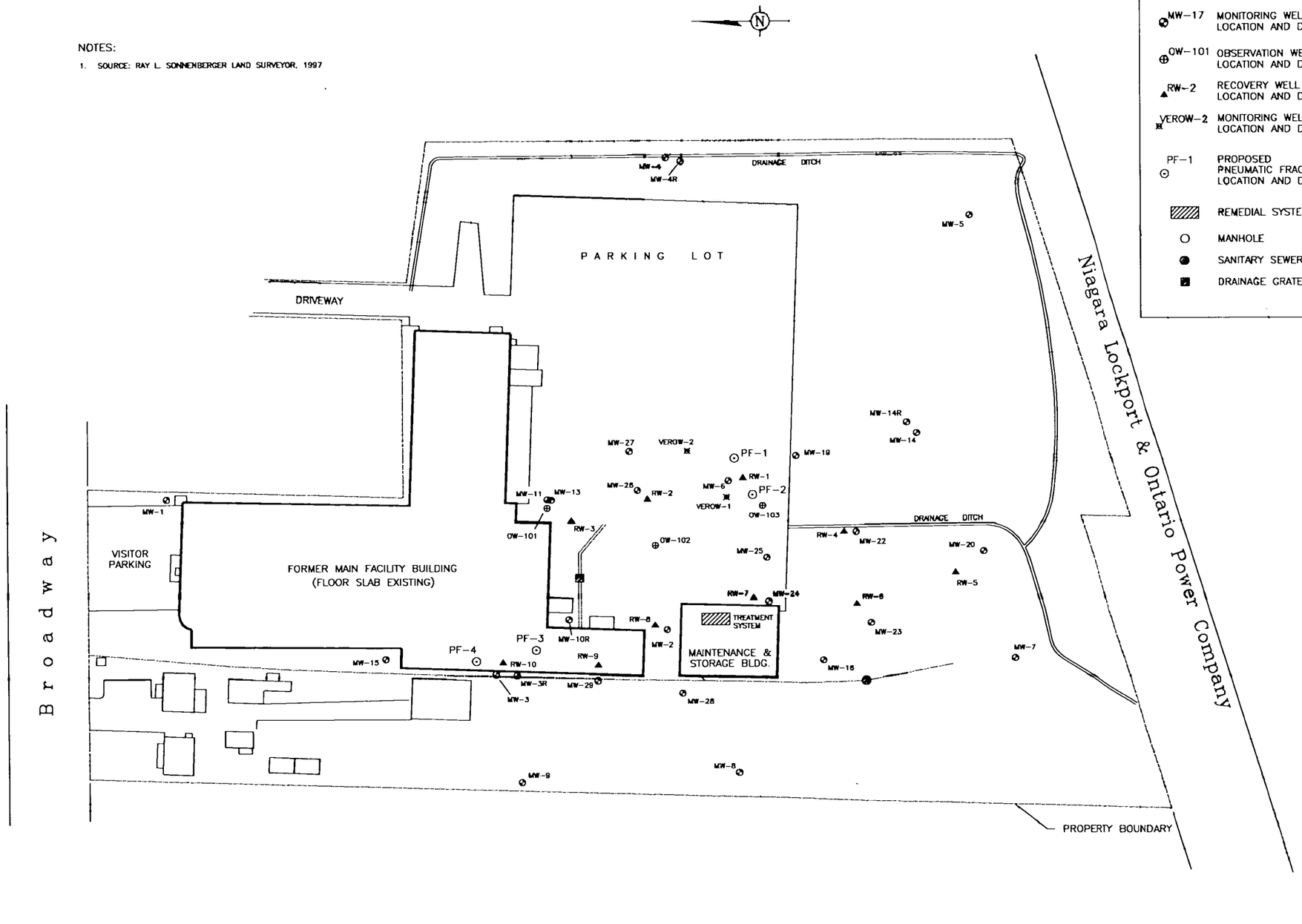
TYPICAL PNEUMATIC FRACTURING WELL DETAIL

ARO CORPORATION SITE
CHEEKTOWAGA, NEW YORK

PROJECT MANAGER T. CARIGNAN	DRAWING NUMBER G265N
CHECKED BY M. SANFORD	PROJECT NUMBER AY000220G005
DRAWN BY CSW/FJF	FIGURE NUMBER 1
DATE DRAWN 09-09-03	

NOTES:

1. SOURCE: RAY L. SONNENBERGER LAND SURVEYOR, 1997



EXPLANATION

- MW-17 — MONITORING WELL LOCATION AND DESIGNATION
- OW-101 — OBSERVATION WELL LOCATION AND DESIGNATION
- RW-2 — RECOVERY WELL LOCATION AND DESIGNATION
- VEROW-2 — MONITORING WELL LOCATION AND DESIGNATION
- PF-1 — PROPOSED PNEUMATIC FRACTURING WELL LOCATION AND DESIGNATION
- REMEDIAL SYSTEM LOCATION
- MANHOLE
- SANITARY SEWER MANHOLE
- DRAINAGE GRATE

NO.	DATE	REVISION DESCRIPTION	BY / CKD

ARCADIS
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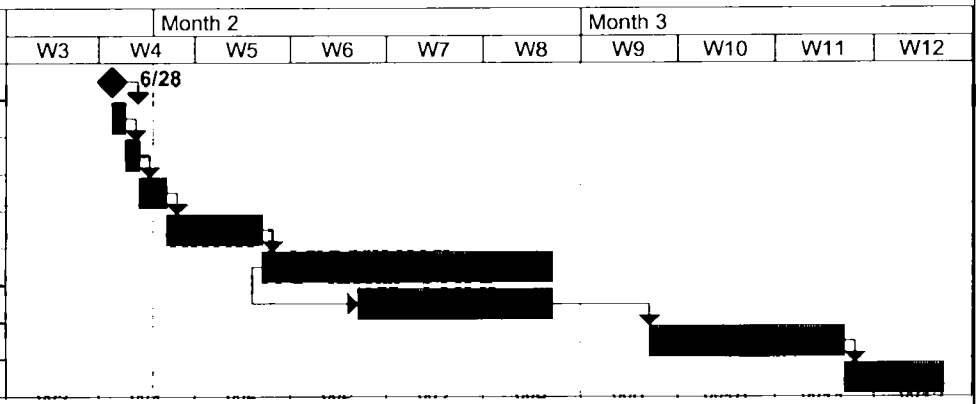
SITE PLAN SHOWING LOCATIONS OF PILOT TEST AND LAYOUT OF PNEUMATIC FRACTURING WELLS

ARO CORPORATION SITE
CHEEKTOWAGA, NEW YORK

PROJECT MANAGER M. SANFORD	DRAWING NUMBER G266M
CHECKED BY T. CARIGNAN	PROJECT NUMBER AY000220006
DRAWN BY TAD/TJF	FIGURE NUMBER 2
DATE DRAWN 9-02-03	

Remedial Enhancements via Pneumatic Fracturing
Former ARO Corporation Site - Cheektowaga, New York
Project Schedule

ID	Task Name	Duration	Start	Finish
1	Authorization to Proceed	0 days	Mon 6/28/04	Mon 6/28/04
2	Revise Health & Safety Plan	1 day	Mon 6/28/04	Mon 6/28/04
3	Baseline Monitoring	1 day	Tue 6/29/04	Tue 6/29/04
4	Install Fracture Wells	2 days	Wed 6/30/04	Thu 7/1/04
5	Perform Pilot Study	5 days	Fri 7/2/04	Thu 7/8/04
6	Data Analysis	15 days	Fri 7/9/04	Thu 7/29/04
7	Prepare Draft Report	10 days	Fri 7/16/04	Thu 7/29/04
8	Receive Comments re Draft Report	10 days	Fri 8/6/04	Thu 8/19/04
9	Prepare Final Report	5 days	Fri 8/20/04	Thu 8/26/04



Project: PF Project Schedule
Date: Thu 6/17/04

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

Figure 3