

COST AND PERFORMANCE REPORT

Electrical Resistive Heating and Biosparging
at the ICN Pharmaceutical Site
Portland, OR

November 2007

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: ICN Pharmaceuticals Incorporated

Location: 6060 NE 112th Ave., Portland, Oregon

Regulatory Context: Oregon Department of Environmental Quality (DEQ) oversight

Technology: Electrical resistive heating (ERH) and Biosparging

Scale: Full-scale

TECHNOLOGY APPLICATION

Period of Operation: May 2000 to December 2001 for ERH and December 2002 to October 2003 for biosparging

Type/Quantity of Material Treated during Application [4]: Source zone - Estimated 48,000 to 65,000 cubic yards based on a treatment area of three-quarters to one acre in size and a depth of 40 ft.
Groundwater - Plume size estimated to be 120 ft by 80 ft

BACKGROUND [1,2]

The ICN Pharmaceuticals site, located in Portland, Oregon, was used as a clinical laboratory from 1961 to 1980. The laboratory used a variety of organic and inorganic compounds with wastes from laboratory operations disposed in a dry well, which was about 20 ft deep. In 1980, the laboratory was shut down and materials and machinery were removed. In 1993 and 1994, the laboratory building and associated structures were removed from the site. Results of groundwater investigations at the site identified the former dry well as the source of groundwater contamination. The groundwater in the vicinity of the former dry well was determined to be contaminated with volatile organic compounds (VOCs) including trichloroethene (TCE); cis-1,2-dichloroethene (DCE); vinyl chloride (VC); benzene; and toluene. TCE, DCE, and VC were detected in the groundwater at concentrations greater than 1% of their solubility, suggesting the presence of dense non-aqueous phase liquid (DNAPL). On August 23, 1999, a record of decision (ROD) was signed for the site to address the groundwater contamination in the area of the dry well. ERH, in conjunction with soil vapor extraction (SVE), was implemented at the site to treat the DNAPL source and dissolved phase VOCs in groundwater.

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MATRIX DESCRIPTION

MATRIX AND CONTAMINANT IDENTIFICATION [1,2]

Type of Media Treated: Source zone (saturated and unsaturated)

Primary Contaminant Groups: Chlorinated solvents - TCE; cis-1,2-DCE; VC

SITE HYDROGEOLOGY AND EXTENT OF CONTAMINATION [2,4]

The site geology consists of fluvial and lacustrine depositional sequences (Overbank) to a depth of approximately 60 feet bgs. Silts and sands are discontinuously interlayered throughout the Overbank deposits. The water table is encountered in the Overbank at approximately 8 ft bgs. Troutdale Gravel Aquifer (TGA) underlies the Overbank formation and consists of unconsolidated and cemented gravels of the Troutdale Formation. The TGA is approximately 175 feet thick in the site area (60 to 235 feet bgs). A confining layer encountered at a depth of 235 ft bgs at the base of the TGA consists of sand, silt, and clay of lacustrine origin and is approximately 100 feet thick at the site.

DNAPLs were present in the Overbank, with dissolved phase VOCs present in both the Overbank and TGA layers. The areal extent of the DNAPL source in the Overbank was estimated to be three-quarters to one acre in size, extending about 120 ft to the south of the dry well with a width of about 80 ft.

Table 1 lists the matrix characteristics affecting technology cost and performance for this application.

Table 1. Matrix Characteristics Affecting Technology Cost or Performance [1,2,4]

Parameter	Value
Soil Classification	Silts and sands
Clay Content and/or Particle Size Distribution	Upper 15 feet of the Overbank consists predominantly of silts. Silts and sands are discontinuously interlayered throughout the Overbank Deposits.
Depth to Groundwater	The water table was encountered in the silts at approximately 8 ft bgs
Hydraulic conductivity	The transmissivity of the Overbank ranges from 5 to 11 gpd/foot. The conductivity ranges from 2.6×10^{-5} to 5.2×10^{-5} cm/sec.

Table 1. Matrix Characteristics Affecting Technology Cost or Performance [1,2,4] (continued)

Parameter	Value
Air permeability	Not available
Porosity	Not available
Presence of NAPLs	Suggested presence of DNAPL
Total organic carbon	Not available
Electrical resistivity of soil	Not available

TECHNOLOGY SYSTEM DESCRIPTION

TREATMENT TECHNOLOGY

Electrical Resistive Heating (Six-Phase Heating™) and Biosparging

TREATMENT SYSTEM DESCRIPTION AND OPERATION [1,4,5,6]

The ERH system at the site was operated from May 2000 to December 2001. The initial ERH system consisted of 60 electrodes installed to a depth of 58 feet. The electrodes were placed in hexagonal arrays of 6 electrodes each, with a seventh neutral electrode in the middle of each array. The annular spaces in the boreholes into which the electrodes were installed were packed with steel shot to improve conductivity and increase the effective diameter of the electrodes. In addition, impermeable seals were placed in the annular spaces to prevent hot vapors and liquids from escaping through the boreholes. Each electrode was capable of directing power to three zones in the Overbank: 20-30 ft bgs, 34-44 ft bgs, and 48-58 ft bgs. A 95 kW transformer was used to convert standard three-phase electrical power to six separate phases. The system was monitored using 13 subsurface pressure monitoring points and 8 subsurface thermocouples. The treatment system began operating in May 2000. The initial heating was limited to the bottom interval (45 to 58 ft bgs) to establish a “hot floor” and prevent downward migration of contamination. No information was provided about how long this initial heating was conducted or when heating in other zones began.

During the operation, steam and hot water were observed outside the treatment area. In addition, steam and hot water at the surface of the site were identified as a health and safety hazard. In December 2000, 50 “electrode vents” screened from 25-35 feet bgs were placed along the perimeter of and throughout the treatment area to control the migration of steam and hot water. In addition, because the steam and hot water were contaminated, the treatment area was expanded in May 2001.

The additional treatment areas were located along the eastern, southern, and northern portions of the initial treatment area where contaminated steam and hot water had been observed. Nine electrodes, four “electrode vents”, two groundwater monitoring wells, and one thermocouple were installed in the eastern portion of these expanded treatment areas. In the southern portion, 4 electrodes, 11 “electrode vents” screened from 25-35 ft bgs, two groundwater monitoring wells, and two thermocouples were installed. In the northern portion, two “electrode vents” were installed.

In August 2001, a blower failed, and steam and vapors could not be removed from an unspecified portion of the treatment area. The system was turned off in this area. A new blower was installed in September 2001 and the treatment was restarted. In December 2001, the entire heating system was shut down when

data indicated that all DNAPL appeared to have been removed and the expected benefits from continued operation were not warranted when compared to the cost.

When the ERH remediation area was expanded in December 2000 and May 2001, electrodes were placed within close proximity to the security fence that surrounded the perimeter of the ERH remediation area. As a result, an induced voltage was detected during a routine step-and-touch voltage survey on the security fence gate. The voltage on the fence was an induced voltage caused by the fence crossing through the electro magnetic field (EMF) generated by the power transfer between the different phased electrodes. This condition was further enhanced by the concurrent operation of two separate treatment zones at least 100 yards apart, where the same perimeter fence encircled both zones. This configuration caused an increased difference in voltage potential at any point where the fence was broken (e.g., at a gate). This problem was remedied by making sure that the fence line remained unbroken, so that it formed one continuous loop. This corrective action was accomplished by grounding the gates to a wire mesh screen that was buried beneath shallow soils, and attached to both adjacent fence sections. The fence was also grounded on both sides of the site (i.e., separate treatment zones) to help decrease the voltage potential at the fence. Before these two corrective actions were implemented voltage at the fence was as high as 40 V at any point where the fence line was broken, after the fixes the voltages were below 12 V for the remainder of the project.

A SVE system was used to recover the steam and contaminant vapors from the unsaturated region immediately above the heated region. The initial 53 vapor extraction wells were screened from 5-10 feet bgs. The SVE system was designed to separate the vapor and liquid phases and separately treat the two effluent streams. The vapor treatment system consisted of a heat exchanger/condenser, followed by granular activated carbon and potassium permanganate treatment. Recovered water was discharged to a municipal sewer.

In addition, biosparging was conducted at the site following ERH treatment to further reduce contaminant concentrations. Biosparging was able to utilize the existing treatment system infrastructure and was conducted intermittently from December 2002 through October 2003. Groundwater monitoring is continuing, with data available through April 2005.

TIMELINE

August 1999	ROD signed for the site
May 2000	Full-scale operation began
December 2000	50 "electrode vents" added
May 2001	Treatment expanded with the addition of 13 electrodes and 19 "electrode vents"
December 2001	Remediation completed; ERH system was shut off. Groundwater monitoring started and continues
December 2002 - October 2003	Biosparging conducted intermittently
October 2005	No further action determination made by Oregon DEQ

TECHNOLOGY SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES [2]

The Remedial Action Objectives for this site, specified in the ROD, were to:

- Prevent and contain migration of separate-phase DNAPL during treatment
- Reduce contaminant groundwater concentrations to levels that indicate DNAPL has been removed or treated

The ROD specified that the primary goal of the action was to remediate DNAPL and that the residual risk to human health and the environment and the need for further remediation would be assessed following remediation of the DNAPL. No numeric clean-up levels for contaminants were identified in the ROD, therefore the cleanup goals were based on Oregon maximum contaminant levels (MCLs).

TREATMENT PERFORMANCE [1,4,6]

Figure 1 shows the location of the shallow, intermediate, and deep monitoring wells at the site, relative to the area that was treated. TCE, DCE, and VC concentrations were monitored in the Overbank area and DCE, VC, and benzene concentrations were monitored in the TGA layer. Table 2 shows the maximum groundwater contaminant concentrations before treatment, when the ERH system was shut down (December 2001), and six months later (June 2002). As of December 2001, maximum groundwater contaminant concentrations in the Overbank area had been reduced from 150,000 µg/L to 100 µg/L for TCE; from 370,000 µg/L to 1,300 µg/L for DCE; and from 24,000 µg/L to 50 µg/L for VC. Through June 2002, TCE concentrations decreased to 8.11 µg/L while DCE and VC concentrations were unchanged. The concentrations of all three contaminants were above Oregon MCLs.

Initial contaminant concentrations in the TGA layer were at or below the Oregon MCLs. As of December 2001, the concentrations of DCE and benzene had increased to 49.5 µg/L and 200 µg/L, respectively. VC concentrations decreased from 2.11 µg/L to not detected. According to the vendor, the increase in benzene concentrations indicated a possible compromise in three well casings, which provided a conduit for contamination migration from the Overbank layer. These wells were abandoned in April 2002. As of June 2002, benzene was detected at levels above the preliminary remediation goal (PRG) of 0.35 µg/L.

Because dissolved phase VOCs remained above DEQ generic risk-based screening levels at various locations at the site, biosparging was conducted from December 2002 through October 2003.

Figures 2 through 5 show the concentrations of DCE over time in the source zone (intermediate well MW-28 and deep well MW-31), the treated area outside the source zone (MW-25), and downgradient from the treated area (MW-53). As shown in these figures, DCE concentrations in the source zone treatment area wells decreased following ERH treatment of the source, with the concentrations in the downgradient wells remaining relatively level.

Figure 1. Application and Monitoring of ERH at the ICN Pharmaceuticals Site in Portland, Oregon [1]

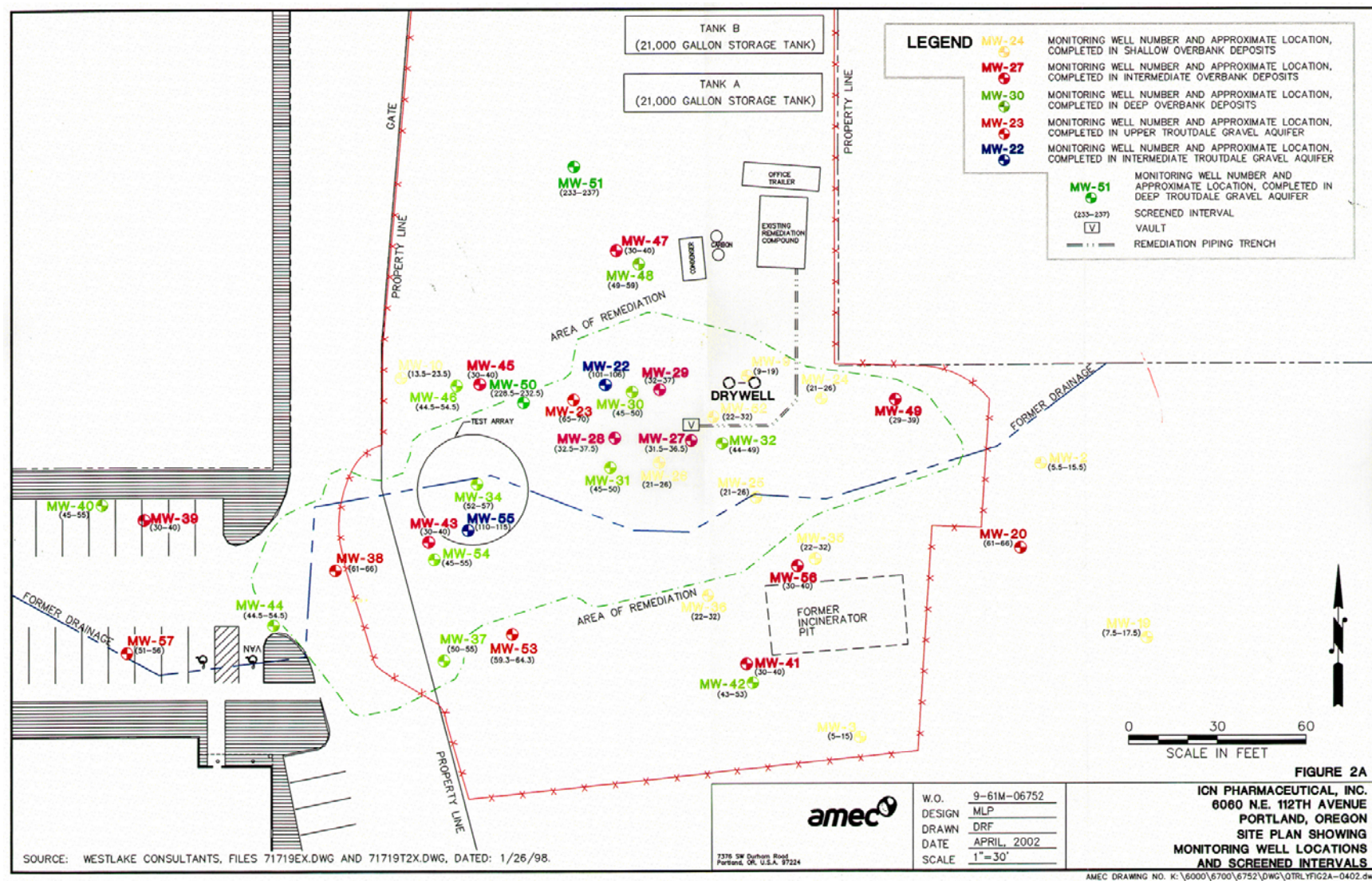


Table 2. ERH Groundwater Monitoring Results, Maximum Concentrations Measured [1, 4]

Contaminant	Oregon MCLs (µg/L)	Concentrations in Overbank (µg/L)			Concentrations in TGA (µg/L)		
		Initial Concentrations Before ERH Treatment	December 2001 (when system was shut down)	June 2002 (6 months after system shut down)	Initial Concentrations Before ERH Treatment	December 2001 (when system was shut down)	June 2002 (6 months after system shut down)
TCE	5	150,000	100	8.11	Not detected	Not available	Not available
DCE	70	370,000	1,300	1,300	1.71	49.5	Not detected
VC	2	24,000	50	50.5	2.11	Not detected	Not detected
Benzene	Not available	51	Not available	Not available	5.98	200	>0.35
Toluene	5,600	Not available	Not available	Not available	16.4	Not available	Not available

When ERH was completed in December 2001, VOC concentrations in groundwater had been reduced by more than 99 percent. The data strongly suggested that the remaining groundwater contamination would likely be addressed by an active microbial population and biosparging was implemented. Monitoring results from April 2005 indicated that VOC concentrations were slightly above MCLs in a few wells in the Overbank layer and in one well in the TGA layer and that in general, concentrations appeared to be declining. Based on these results and the determination that remaining groundwater contamination does not pose a significant risk (by either human ingestion or to ecological receptors), DEQ determined no further action is warranted for this site. However, long-term groundwater monitoring at the site continues in accordance with the DEQ-approved Long-Term Monitoring Plan.

COST OF THE TECHNOLOGY SYSTEM

COST DATA

No cost data were provided for this application.

Figure 2. ICN Site: cis-1,2-DCE Concentrations in Source Zone (MW-28)
May 1996 - June 2002 (log scale) [1]

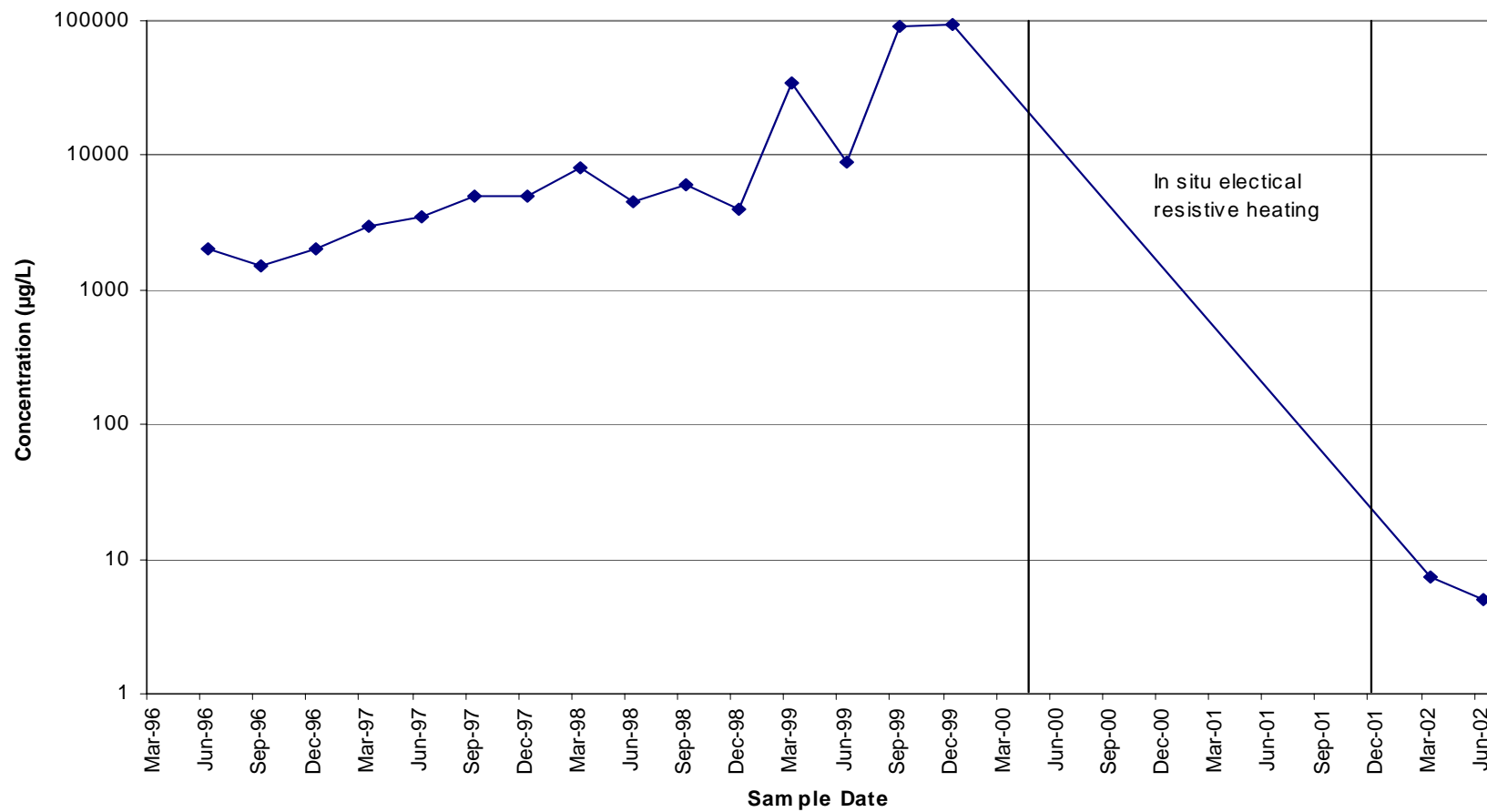


Figure 3. ICN Site: cis-1,2 DCE Concentrations in Source Zone (MW-31)
May 1996 - June 2002 (log scale) [1]

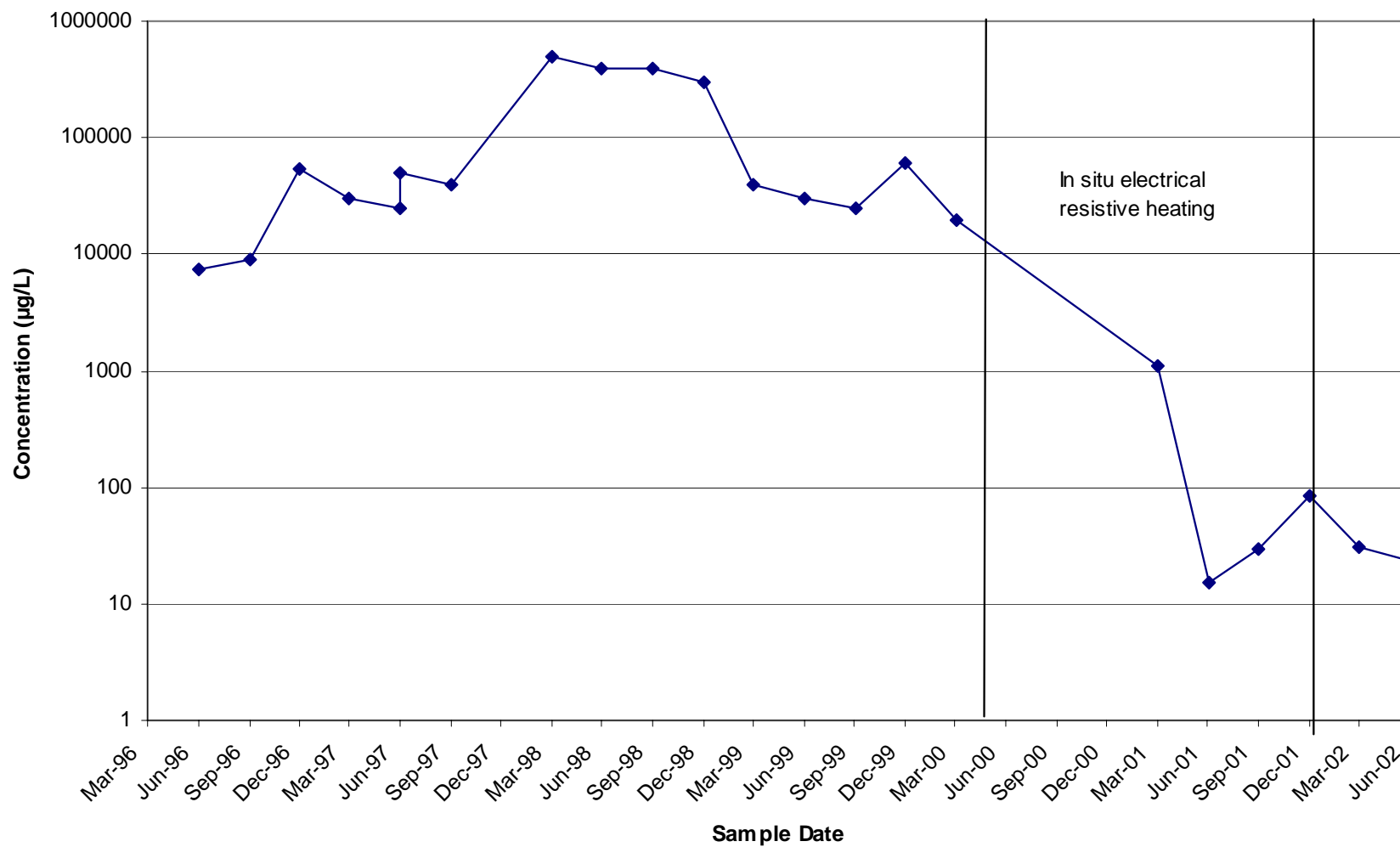


Figure 4. ICN Site: cis-1,2-DCE Concentrations in Treatment Area (MW-25)
May 1996 - June 2002 (log scale) [1]

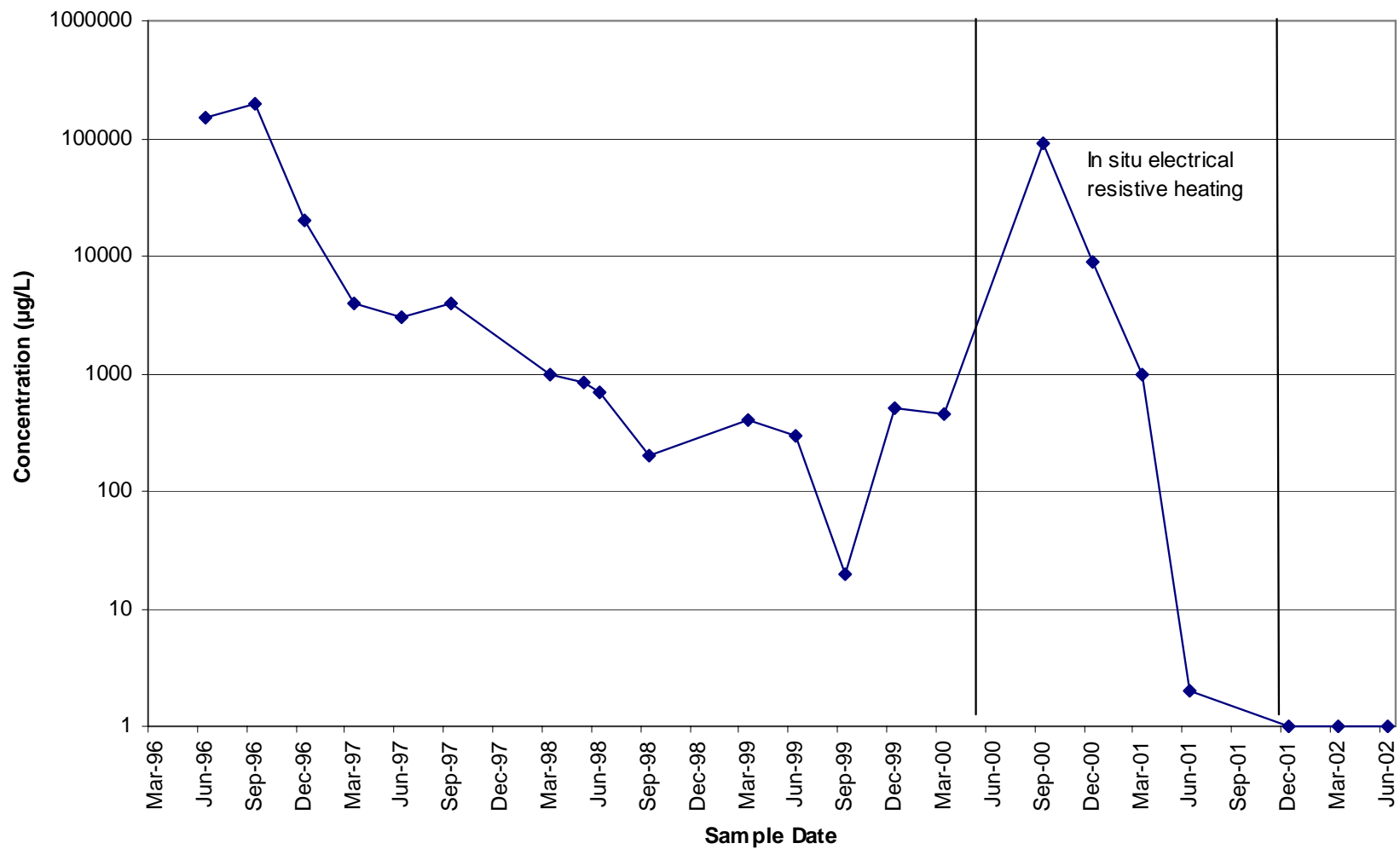
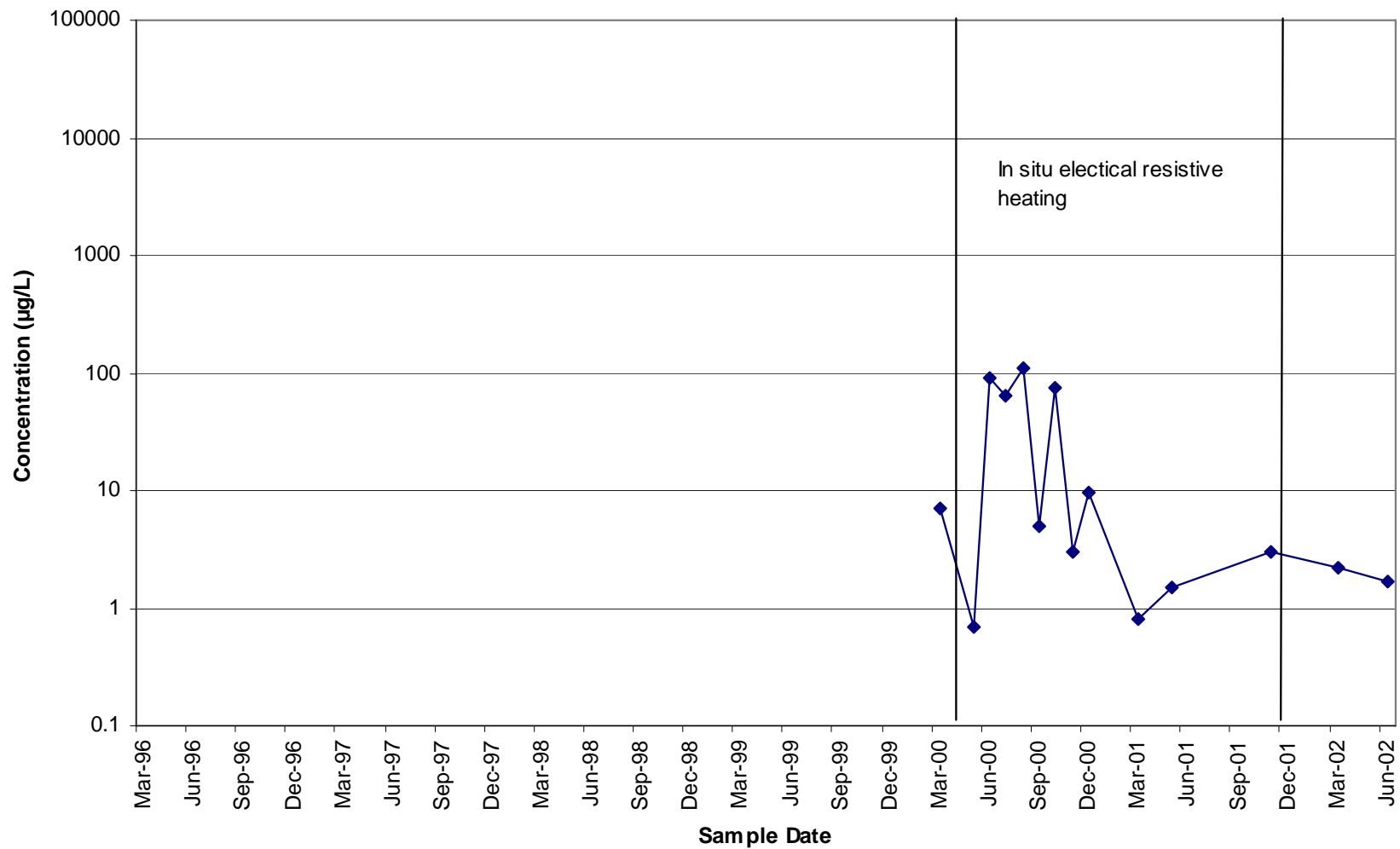


Figure 5. ICN Site: cis-1,2-DCE Concentrations in Downgradient Area (MW-53)
May 1996 - June 2002 ((log scale) [1])



OBSERVATIONS AND LESSONS LEARNED

OBSERVATIONS AND LESSONS LEARNED

ERH reduced concentrations of TCE, DCE, and VC in the source zone by more than 99 percent. However, after 18 months of treatment, contaminant concentrations remained above the state MCLs. Further treatment using biosparging was conducted to address these elevated concentrations. Monitoring results from April 2005 indicated that in general, contaminant concentrations appeared to be declining. Based on these results and a determination that remaining groundwater contamination does not pose a significant risk, the site was designated as requiring no further action. However, long-term groundwater monitoring continues in accordance with the DEQ-approved Long-Term Monitoring Plan.

The vendor provided the following observations regarding ERH:

- At some locations, steam pressures built up inside monitoring wells to the extent that some wells vented steam for several hours. The steam moved out laterally along more permeable pathways. Vertical movement upward was inhibited by cooler temperatures within 20 feet of the surface and by less permeable soils, creating a high pressure zone. Removal of a well cap could release the pressure and cause steam and hot water to flash up the well casing. As a solution, existing 3/8-inch diameter vent lines from the electrodes were replaced with larger (1-inch diameter) tubing. These electrode vents were also connected to the vapor extraction system.
- Several modifications to the system were required as a result of the high temperatures achieved during the remediation and modifications needed to handle boiling water. These included replacing polyvinyl chloride (PVC) in wells with chlorinated PVC (CPVC) to minimize heat damage, replacing bentonite with concrete as a seal, and modifications to groundwater sampling using bailers.
- Biological growth increased significantly during heating. The condenser/heat exchanger required frequent cleaning. As a solution, a knockout tank was added to the system to remove some of this material before entering the heat exchanger. The heat exchanger still required frequent cleaning, but the problem was reduced.

REFERENCES

1. AMEC Earth & Environmental, September 2002. "Quarterly Monitoring and Project Status Report, ICN Pharmaceuticals, Inc. Site, June 2002".
2. Record of Decision, Selected Remedial Action for ICN Pharmaceuticals, Inc. DNAPL Contamination, Multnomah County, Oregon, August 23, 1999.
3. Notice of Selected Environmental Cleanup Method, ICN Pharmaceuticals DNAPL Contamination, September 1, 1999.
4. ITRC Team Case Study Report, ICN Pharmaceuticals Site, Portland, Oregon, Undated.
5. Jennifer Sutter, Oregon DEQ. E-mail comments to James Cummings, EPA. ICN Stray Voltage Discussion. January 5, 2004.

6. Dick Pederson, Oregon DEQ. Letter to Ted Timmons, Valeant Pharmaceuticals, Inc. No Further Action Determination and Certification and Completion for ICN Pharmaceuticals site. October 19, 2005.