Management Summary

UCRL-AR-122292

Environmental Restoration
at

Lawrence Livermore National Laboratory
Site 300
Livermore, California

U.S. Department of Energy

MARCH 1996

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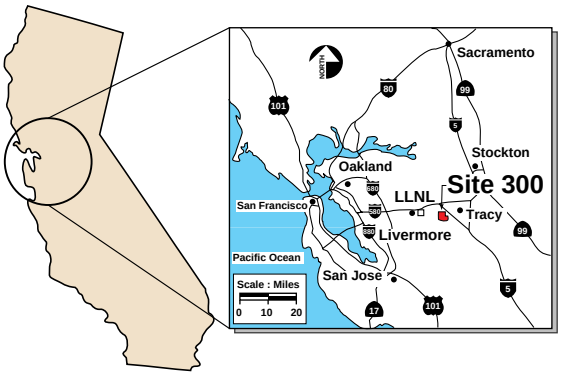
Management Summary

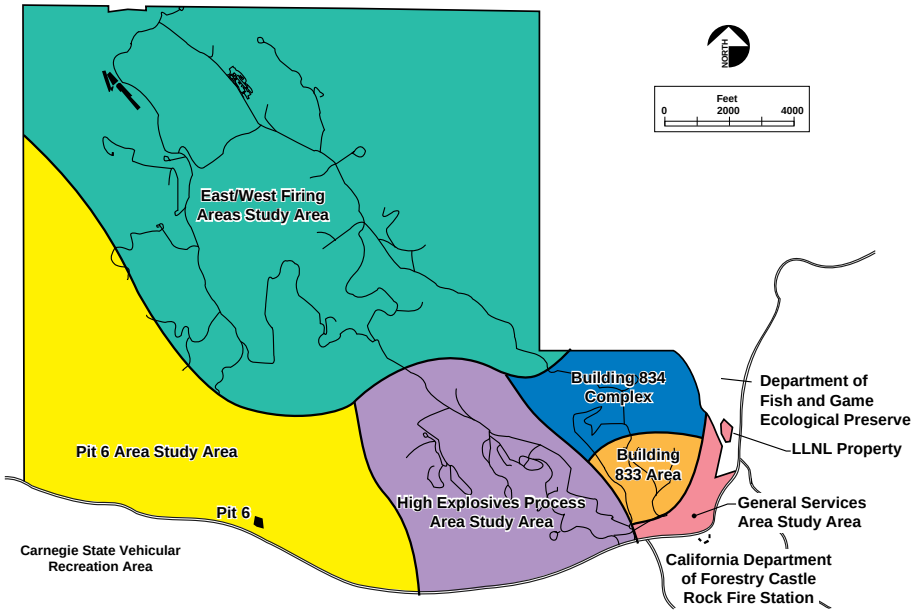
SITE

This report summarizes the status of environmental assessment and cleanup at Lawrence Livermore National Laboratory (LLNL) Site 300, located 8.5 miles southwest of Tracy, California. As a result of past releases, soil, rock and ground water have become contaminated with volatile organic compounds (VOCs), high explosives (HE), tritium, uranium, metals (such as lead and barium), and fuel hydrocarbons. LLNL uses source removal and isolation; ground water extraction and treatment; optimized hydraulic control; and applicable advanced technologies to clean up this contamination. Treatment facilities designed by LLNL Site 300 personnel utilize ground water extraction and air sparging, or soil vapor extraction, both of which are followed by granular activated carbon (GAC) adsorption. Other methods include innovative technologies such as x-ray, high energy photon, and ozone treatment. Remediation began in 1988 and additional treatment facilities and capacity continue to be added. Because Site 300 is well characterized, hydrogeologically complex, and has a wide range of contaminants, it is used as a technology testbed by LLNL, university, and private researchers.



SITE CHARACTERISTICS

LLNL Site 300 has been divided into 6 Study Areas: 1) the General Services Area (GSA) – administration and maintenance, 2) Pit 6 Area – mixed-waste landfill and vicinity, 3) the High Explosives Process Area (HEPA) – HE formulation and testing, 4) Building 834 (B834) Complex – heat/cold and pressure testing, 5) Building 833 Area – testing similar to Building 834, and 6) the East and West Firing Area (EWFA) – explosives testing. The U.S. Department of Energy (DOE) and LLNL defined study area boundaries based on programmatic, topographic, and hydrological considerations.



Locations of study areas at LLNL Site 300.

Site History/Release Characteristics

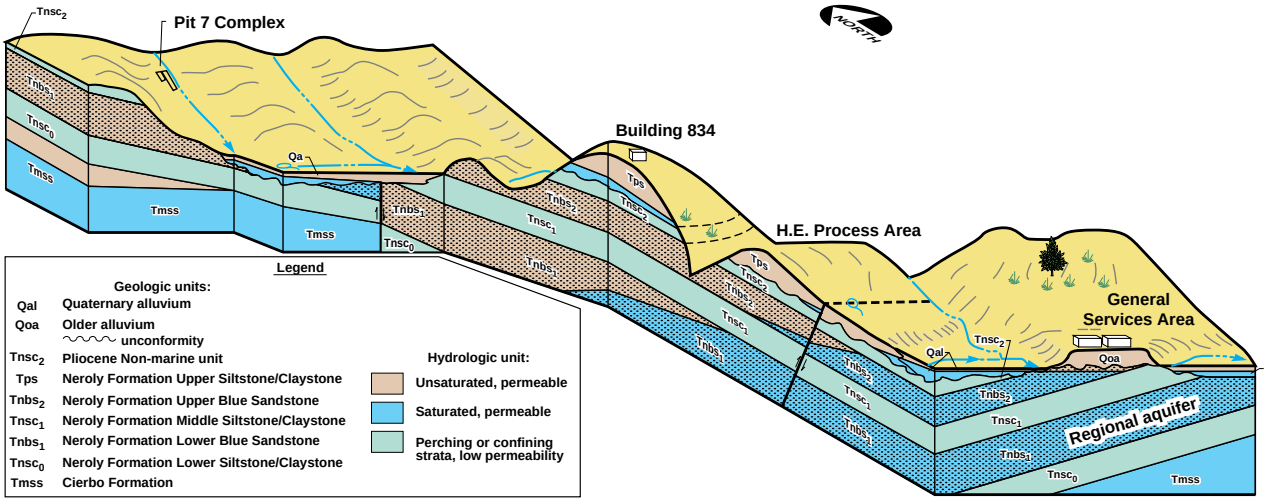
- The 10.4 mi^2 Site 300 property consisted of ranch land until 1955, when it was purchased by the Atomic Energy Commission (AEC) and converted to fulfill the present mission of high explosives formulation and testing. Other activities include tests exposing prototype weapons parts to extreme pressures and temperatures, and other experiments that require more space than may be available at the 1 mi^2 LLNL Livermore Site 13 miles to the west.
- DOE/LLNL have conducted environmental investigations at Site 300 since 1982. Over 700 boreholes have been drilled and 460 monitor wells installed.
- More than 8,500 ground water samples, 5,500 soil samples, and 900 soil vapor samples have been collected and analyzed.

• Hazardous material releases were initially identified in the early 1970s when tritium was found at elevated activities in spring water samples in the northern part of Site 300. Tritium was released to ground water from one explosives testing firing table and two landfills containing explosives debris. VOC contamination was initially identified in 1982 when detected in ground water from an onsite water-supply well. HE compounds were initially detected in soil and ground water [up to 350 parts per billion (ppb)] in 1986 during the closure of several disposal lagoons.
• Twelve distinct ground water contaminant plumes have been identified.
• Trichloroethylene (TCE) and other VOCs (up to 800,000 ppb in ground water) have been released to soil and ground water from drum storage areas, debris piles, two mixed waste landfills, several disposal dry wells (sumps), pressure and temperature effects testing facilities, and explosives formulation and machining facilities.
• Tritium and depleted uranium are in ground water in the northern part of Site 300 with maximum activities of 1,200,000 and 100 picocuries per liter (pCi/L), respectively.
• Site 300 was placed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) in 1990 due to high concentrations of TCE in ground water at one location (Building 834) and two offsite VOC ground water plumes at the GSA.
• A Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Federal Facility Agreement (FFA) was negotiated between DOE/LLNL, US EPA, the State Department of Toxic Substances Control, and the California Central Valley Regional Water Quality Control Board in 1992.
• Removal actions commenced in 1988 at the Building 834 VOC release site, in 1991 at the eastern GSA VOC release site, and in 1993 at the central GSA VOC release site.
• Past and ongoing remedial activities include three soil vapor and/or ground water extraction and treatment systems, landfill and lagoon capping, excavation of VOC-bearing soils, inactive water-supply well and dry well closures, and a number of innovative remedial technology projects such as soil heating, bioremediation, and the use of an electron accelerator and ultraviolet (UV) light to treat VOCs in soil vapor and water.
• More than 270 kilograms (kg) of TCE have been recovered to date. The remedial program also addresses potential impacts of contamination on two nearby private water-supply wells, which are in hydraulic communication with contaminated aquifers.

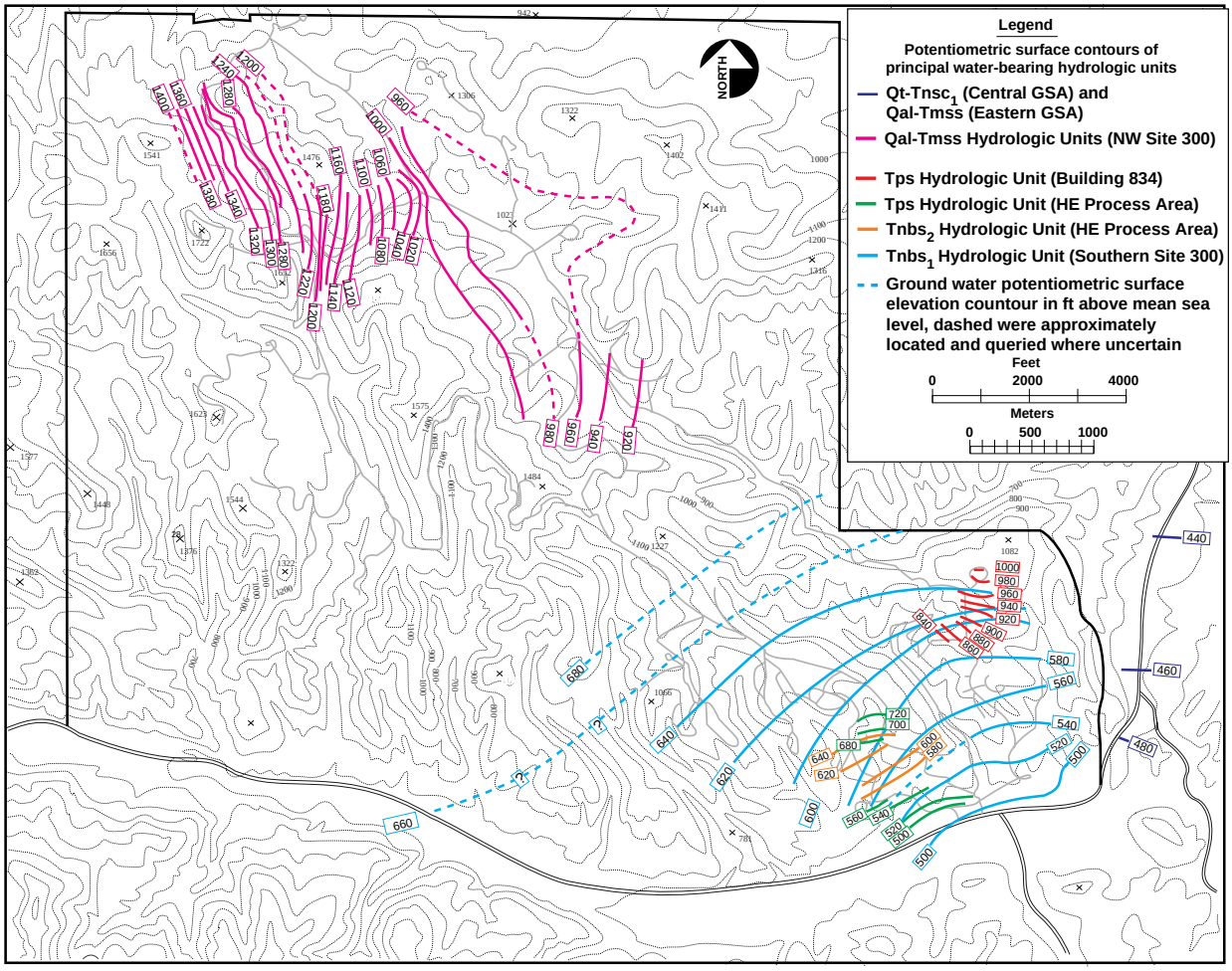
Site Conditions

LLNL Site 300 is located 30 miles southeast of San Francisco in the semi-arid Altamont Hills. Ground elevation ranges from to 500 ft in the southeast to 1,700 ft in the northwest.

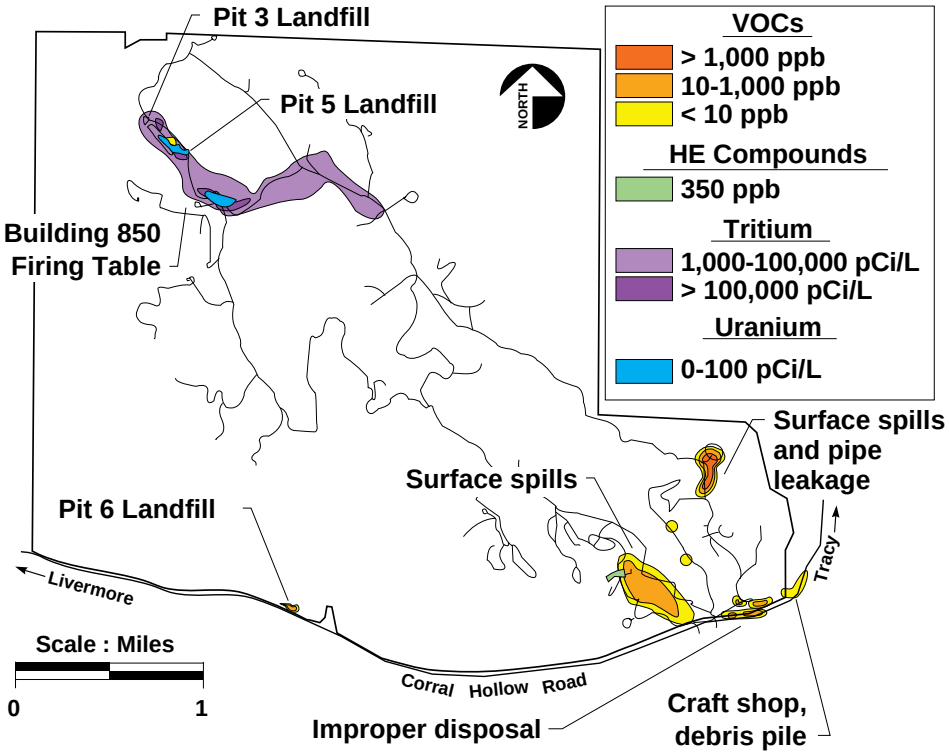
• Vegetation consists of seasonal grasses with rare small trees and bushes at springs and in valleys.
• Climate is semi-arid with average annual precipitation of 10 in./yr. Potential evapotranspiration is 60 in./yr.
• There are 20 springs at Site 300, but there are no permanent surface water drainages.
• Land north and west of Site 300 is used for cattle grazing and light agriculture. Land to the east is used for these purposes and for a privately-owned explosives test facility. Land to the south is used for ranching and for Carnegie State Vehicle Recreation Area (SVRA).
• Ground water provides the properties surrounding Site 300 with potable and stock water. Onsite water needs are currently met by ground water; however, beginning in 1996, onsite potable water will be provided by the Hetch-Hetchy aqueduct.



Site 300's hydrogeology is dominated by the Miocene Neroly Formation siltstone, claystone, and variably saturated sandstone. Thin veneers of colluvium and variably saturated alluvium locally overlay bedrock. Several regional faults transect Site 300 as does the broad northwest-southeast trending Patterson Anticline. Strata north of the anticline generally dip northeast; strata south of the anticline generally dip southeast. Ground water flow is generally dip-controlled.



More than 10 distinct water-bearing zones have been identified at Site 300. Faults, local folds, and permeability contrasts influence ground water porous and fracture flow.



Various contaminants have been released to the environment at Site 300. VOCs have been spilled and discharged through dry wells in the southern portion of the site, and tritium and uranium have been released through leaching from landfills and firing tables in the northern portion of the site.

VOCs:

• VOCs are found in ground water beneath all the Site 300 study areas. There are seven ground water VOC plumes; the longest plume is 2,500 ft long. Affected water-bearing zones range from 5 to more than 100 ft thick. The historic maximum VOC concentration is 800,000 ppb.

HE Compounds:

• The HE compounds RDX (cyclo-1,3,5-trimethylene-2,4,6-trinitramine) and HMX (cyclotetramethylene tetranitramine) occur in two aquifers in the HEPA in the southern portion of Site 300. Maximum ground water concentrations are about 350 ppb.

Radiological Parameters:

• Three tritium ground water plumes emanate from two landfills and a firing table in the EWFA in northern Site 300 and comingle into a plume 7,000 ft long. Affected aquifers range from 5 to 100 ft thick. Maximum tritium activities measured in 1983 were about 1,200,000 pCi/L. Current maximum activities are about 250,000 pCi/L.

• Also in the EWFA are three source areas (two landfills and a firing table) for depleted uranium in ground water. Uranium also occurs naturally at elevated activities in ground water. Maximum detected uranium activities in ground water are about 100 pCi/L.

Metals:

• In the EWFA, explosives tests have resulted in metal releases to soil. These metals include lead, beryllium, barium, copper, and zinc. Metal concentrations in ground water are slightly elevated, but below Maximum Contaminant Levels (MCLs).

Other Chemicals:

• Ground water in the HEPA contains nitrates at concentrations in excess of the 45 parts per million (ppm) MCL. The origin of this nitrate contamination is under investigation.

• In the EWFA, PCBs, dioxins and furans have been detected in surface soil around one explosives test firing table. Firing table debris was disposed of in several landfills. However, none of these compounds have been detected in the ground water.

• Diesel fuel and hydraulic oils have leaked from several underground tanks in the EWFA, GSA, HEPA, and Building 834 Area. Most of these releases have been excavated and the contaminated soils bioremediated.

Contaminants of Concern

VOCs:

Trichloroethylene	(TCE)
Perchloroethylene	(PCE)
1,1 & 1,2-Dichoroethylene	(DCE)
1,1 & 1,2-Dichloroethane	(DCA)
1,1,1-Trichloroethane	(TCA)
Chloroform	
Freon-113	

HE Compounds:

Cyclo-1,3,5-trimethylene-2,4,6-trinitramine	(RDX)
Cyclotetramethylene tetranitramine	(HMX)

Radionuclides:

Tritium	(^{3}H)
Depleted uranium	(D-38)
Thorium	(Th)

Metals:

Aluminum	(Al)
Chromium	(Cr)
Copper	(Cu)
Lead	(Pb)
Vanadium	(Va)
Zinc	(Zn)

Other chemicals:

Nitrates	(NO_3)
Polychlorinated Biphenyls Oils	(PCBs)

Site Characterization Methodology

Initial remedial investigation activities at Site 300 involved conventional geologic mapping, borehole sampling, geophysical logging, and well installation followed by ground water elevation measurement and chemical sampling and analysis, hydraulic testing and regional hydrogeologic analysis. Hydrogeologic cross sections showing stratigraphy, contaminant distribution, and affected water-bearing zones were constructed using these data. Investigations also included seismic reflection profiles, trenching across known or suspected active faults, ground penetrating radar and magnetic surveys, biotic assays, and aerial photograph analysis.

DOE/LLNL scientists use hydrostratigraphic correlation and time-series analysis to define discrete aquifer systems and to determine the influences of recharge and ground water flow on water level response and ground water chemistry. More recent site characterization activities have utilized data from additional methods, including:

- Active vacuum-induced soil vapor sampling
- Passive PETREX soil vapor surveys
- Neutron moisture density logging
- Downhole colloidal borescope (measures *in situ* flow azimuth and velocity
- *In situ* ground water chemical analysis fiber-optic probe
- Field bio-assay kits for soil chemical analysis
- *In situ* dissolved oxygen measurements
- Innovative application of stable and non-stable isotope analytical techniques

Once characterization was complete and a conceptual hydrogeologic model had been developed for each study area, chemical fate and transport mathematical models were applied to calculate conservative estimates of the exposure point concentrations for chemicals released to soil and ground water. DOE/LLNL scientists used the output from the fate and transport calculations to assess potential risks posed to human health and the environment by each chemical released.

Site 300 characterization results are presented in the LLNL Site 300 Site-Wide Remedial Investigation (SWRI) report. Chapters 1-8 of the SWRI document the site-wide history of operations and investigations, characterization methods, hydrogeology, nature and extent of contamination, fate and transport, remedial actions, and risk assessment. Chapters 9-14 contain in-depth analyses for each study area.

Remediation Plan

The overall long-term environmental remediation strategy for LLNL Site 300 integrates ground water extraction and treatment, source isolation, and hydraulic control based on the following:

- Completion of detailed characterization, including hydrostratigraphic unit analysis
- Validated contaminant modeling
- Phased implementation of remediation as CERCLA Removal Actions
- Directed ground water and soil vapor extraction and treatment
- Adaptive time-managed pumping
- Innovative technologies testing
- Subsurface interceptor drains and landfill/source capping

This unique approach will enable testing and optimization of extraction, injection, and treatment system designs.

STATUS OF CLEANUP

Objectives

The objectives of cleanup at Site 300 are to 1) reduce exposure risk (the US EPA acceptable incremental cancer risk is 10^{-4} to 10^{-6}), 2) reduce VOC mass in soil and ground water, 3) control plume migration, and 4) prevent contamination of offsite water supply wells. CERCLA Removal Actions have enabled acceleration of cleanup prior to the completion of the Record of Decision (ROD).

Current Strategy

Location		Cleanup strategy
OU 1	GSA	Prevent further source release. Soil and ground water remediation.
OU 2	B834	Soil and ground water remediation to prevent worker exposure.
OU 3	Pit 6	Cap landfill to prevent further contaminant releases. Monitor natural attenuation of VOC plume to ensure no offsite migration.
OU 4	HEPA	Monitor guard wells to detect contaminants before they migrate offsite.
OU 5	EWFA	Cap landfill Pits 3 and 5, and upgrade drainage systems at the Building 850 firing table to prevent further tritium releases. Building 854 cleanup strategy to be determined based on results of the ongoing Remedial Investigation (RI).
OU 6	B832	To be determined based on results of the ongoing RI.

REMEDIATION PROJECT PROFILE

General Services Area

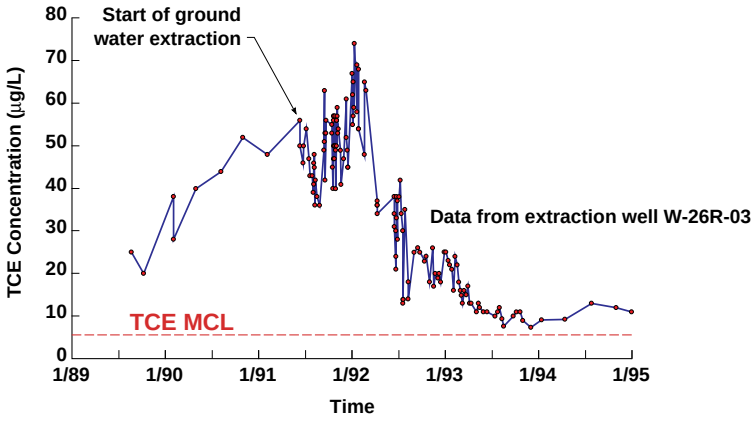
Dry wells (sumps) were commonly used at Site 300 in the past to dispose of waste fluids, primarily rinse water. Several dry wells were located in the GSA. Directly beneath the dry well area, preremediation VOC concentrations were as high as 240,000 ppb in ground water and 360,000 ppb in soil and bedrock, and Dense Nonaqueous Phase Liquids (DNAPLs) are inferred to be present. Although the dry wells received a wide variety of fluids and solvents, the primary contaminant of concern is TCE. In several eastern GSA areas, craft shop debris was buried in shallow trenches. This debris consisted primarily of electrical, plumbing, and construction waste, but also contained small quantities of degreasing solvents, primarily TCE. Contaminants migrated through permeable alluvium and extended a significant distance offsite prior to remediation.

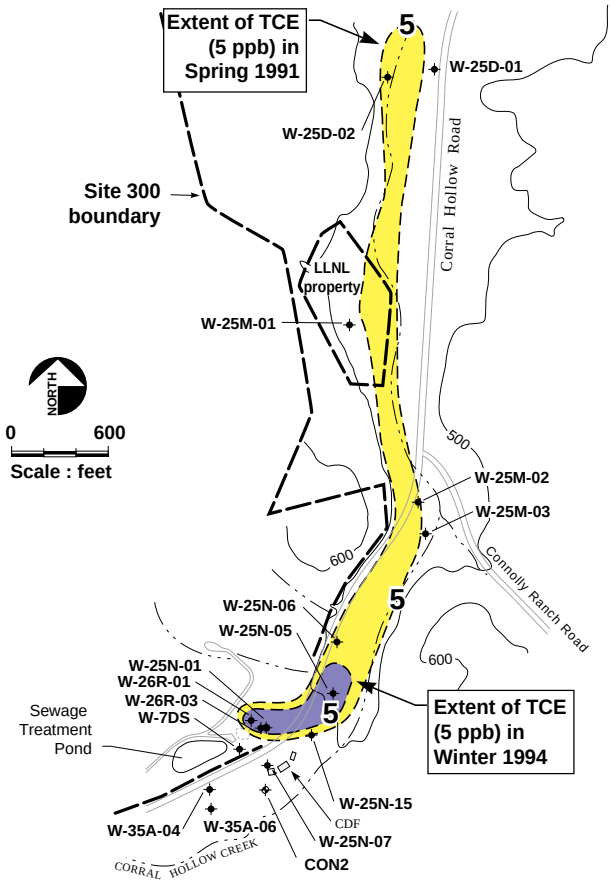
Project Highlights

- One soil vapor extraction treatment and two ground water extraction treatment systems are in operation.
- In the eastern GSA, ground water extraction and air sparging/GAC treatment has been conducted since June 1991. To date, over 64 million gallons of ground water have been extracted and treated in the eastern GSA, removing over 4,000 grams of VOCs.
- Since April 1993, an air sparging/GAC ground water treatment system has operated in the central GSA. To date, over 270,00 gallons of ground water have been extracted and treated. Ground water VOC concentrations in this area have decreased from a historical maximum of 240,000 ppb to a maximum of 10,000 ppb in the third quarter 1994. Following dewatering of the dry well area through ground water extraction, soil vapor extraction and GAC treatment was initiated in July 1994. VOC mass removed from ground water and soil in this area to date is 25,000 grams.
- The extent of offsite contamination has been reduced from 4,750 ft to only 500 ft.
- Ground water TCE concentrations at the central GSA dry well release area have been reduced from 240,000 ppb to less than 10,000 ppb. At the site boundary, TCE concentrations in ground water have been reduced to near MCLs.
- The eastern GSA ground water remediation system was formally designated "Best Project" status in a DOE study of over 500 DOE, Department of Defense, and private sector projects. The eastern GSA was one of only seven nation-wide projects to earn this distinction. The evaluation criteria included cost effectiveness, performance, and design.

Air sparging is used to treat extracted ground water in the central GSA.

TCE concentrations in ground water in the eastern GSA have been successfully reduced from 74 ppb to near MCLs.





The extent of offsite contamination has been significantly reduced at the eastern GSA.

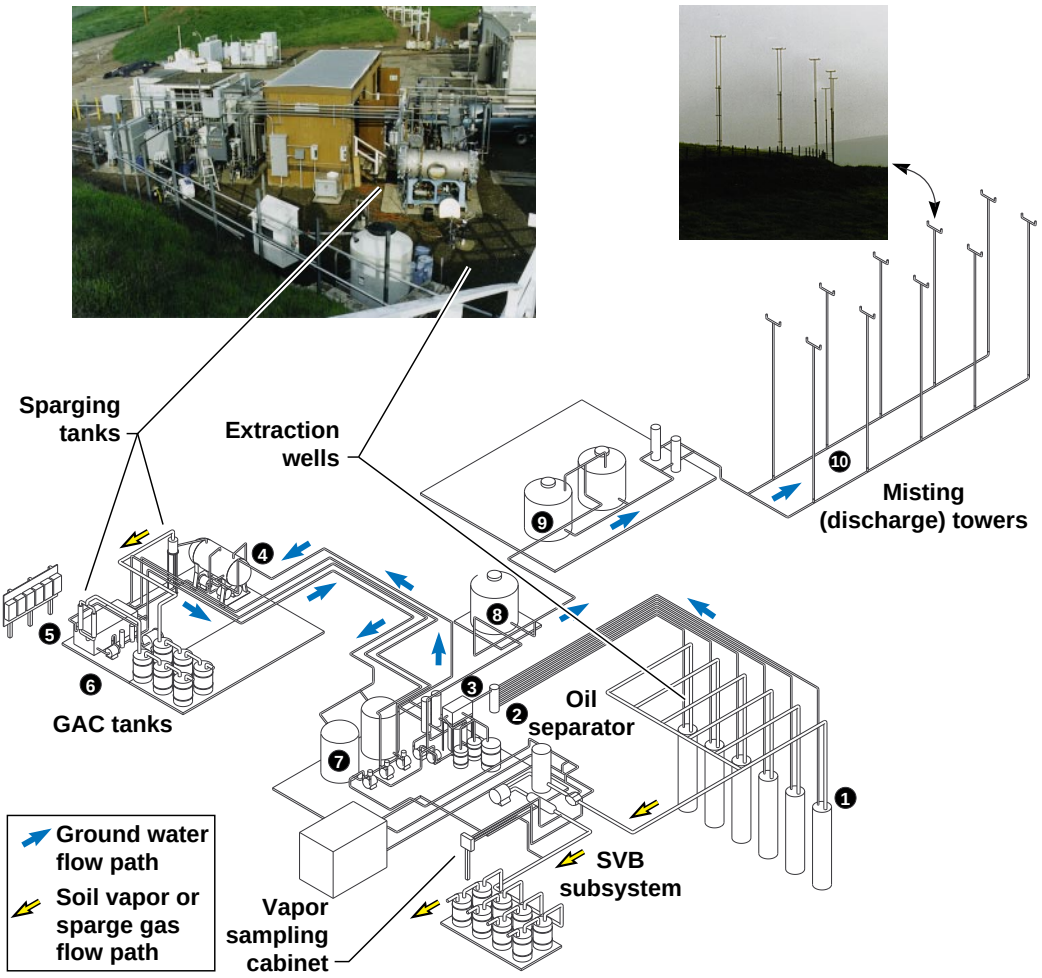
Simultaneous soil vapor and ground water extraction has effectively reduced VOC concentrations at the central GSA dry well release area.

Building 834

The Building 834 Complex houses facilities for thermal stress testing of prototype weapons components. The facility contains a control building, three heat fluid transfer and storage buildings and seven test cells. Past spills of TCE, which was used as a heat exchange fluid, have resulted in soil, bedrock, and ground water contamination. The affected ground water is confined to a perched water-bearing zone; the deeper regional aquifer has not been affected. The historical maximum total VOC concentration detected in perched ground water is 800,000 ppb. DNAPLs are known to be present. Tetra t-butylorthosilicate (T-BOS, a pump and seal lubricant similar to mineral oil) and diesel fuel contamination are also present as Light Nonaqueous Phase Liquids (LNAPLs).

Project Highlights

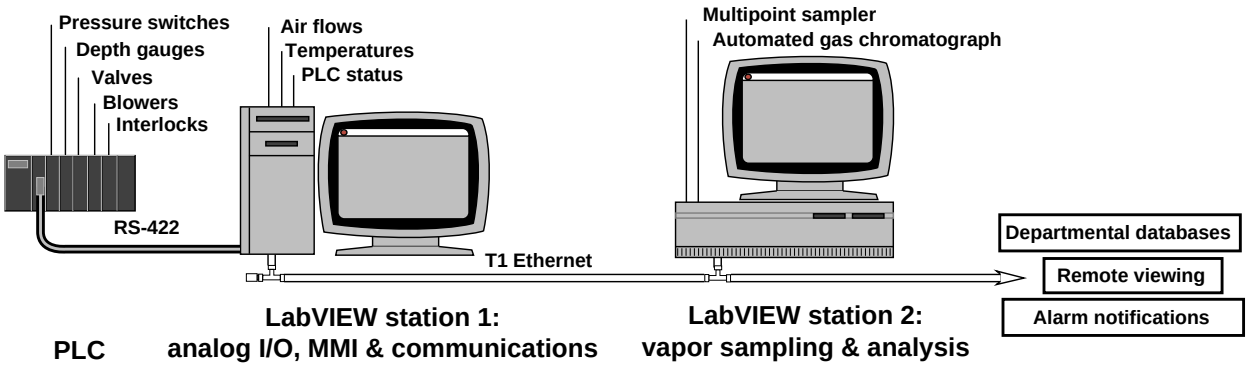
- Removal actions using simultaneous soil vapor and ground water extraction were initiated in 1988 to reduce VOC vapor exposure risk and reduce VOC mass in the subsurface.
- To reduce costs, equipment and components were recycled from the original Building 834 Complex heat-exchange system, and from surplus equipment from former LLNL Weapons Program projects.
- The site is equipped with computer-controlled gas analysis equipment for direct and remote monitoring of soil and ground water chemistry; treatment process parameters can also be monitored remotely.
- The modular facility design and well-equipped infrastructure allows testing of new technologies to expedite remediation and reduce the quantity of hazardous wastes generated by remedial activities.
- DOE/LLNL have tested several innovative technologies at Building 834, including the application of electron beam destruction of VOC vapor, and UV oxidation of TCE using flashlamps.
- An Interim ROD was finalized in September 1995 that allows renewed testing and implementation of innovative remedial technologies for a three year period while continuing the operation of the existing soil vapor and ground water extraction and treatment system.
- In 1996, LLNL will test dual tracer methods for identifying and locating DNAPLs and has plans to test the application of surfactants for removing DNAPLs from the subsurface.



The stages of the Building 834 ground water treatment process: 1) ground water extraction using air displacement pumps; 2) oil separation in a coalescing skimmer; 3) particulate removal (to 20µ); 4) primary sparging; 5) secondary sparging; 6) T-BOS and residual VOC removal (primarily Freon-113) with woven carbon-impregnated filters; 7) pumping to short-term storage in two 500-gallon stainless steel tanks at the treatment pads, 8) freeze drain storage tank, 9) pre-air misting storage tanks, and 10) discharge of treated ground water by air misting.

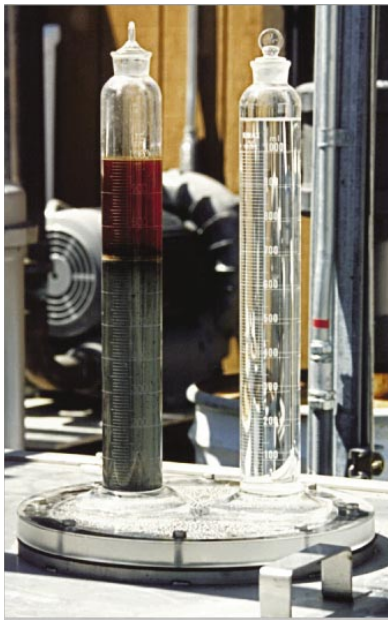
For more than 20 years, TCE was used as a heat-exchange medium for heating and cooling test cells. Because TCE is an extremely effective solvent, it dried seals and other components in the temperature control system, producing leaks and spills. To retard this action, a synthetic oil, known as T-BOS, was added to the TCE. TCE degradation products are also present (e.g., cis-1,2-DCE).

Bailed ground water from Building 834



A comprehensive control and data acquisition hardware system was developed for operation of the Building 834 ground water and soil vapor extraction treatment system. A programmable logic controller (PLC) was selected over a dedicated microcomputer for reliability and resistance to system crashes or lockup conditions. A man-machine interface (MMI) for system status display will be provided by a desk-top computer serially linked to the PLC.

Ground water before and after treatment.



By adhering to the concept of modular design, the Building 834 ground water treatment facility has become an economical and flexible testbed that 1) supports routine conventional pump-and-treat cleanup of a highly contaminated site, 2) provides a performance background against which new treatment technologies can be compared, and 3) is easily modified to incorporate new extraction and treatment technologies for field testing.

East and West Firing Areas

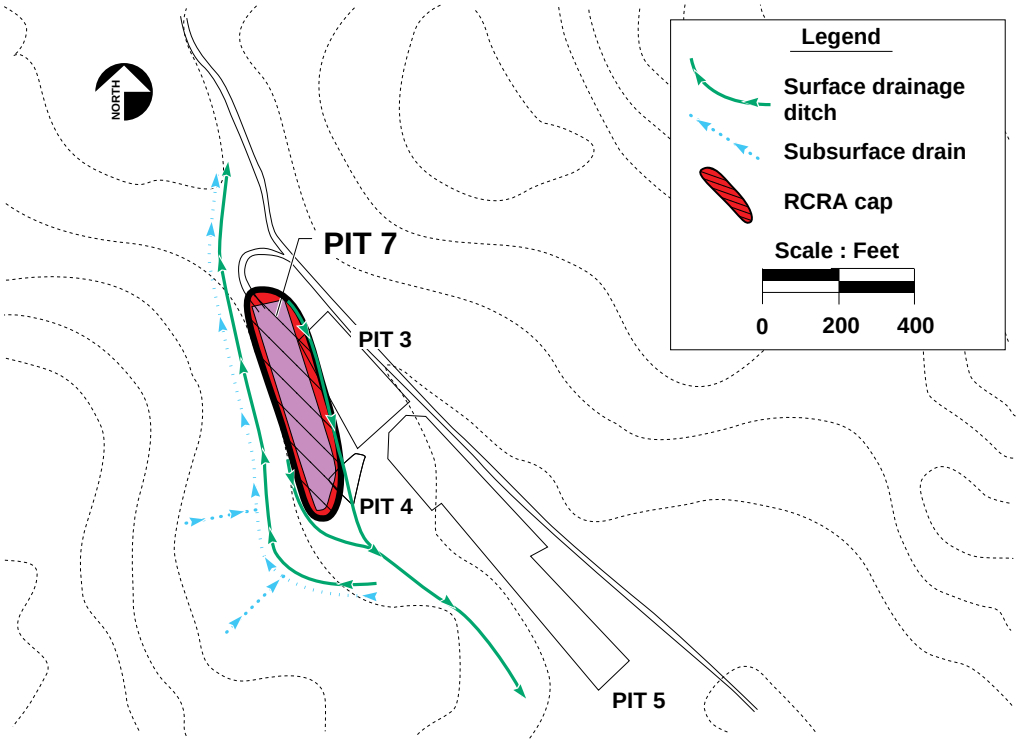
Seven HE testing firing tables, nine landfills (all closed), and a small analytical linear accelerator are located in the EWFA. Explosives experiment debris contains tritium, depleted uranium (D-38), metals, and PCBs. No fissile material was used in the experiments. The debris was disposed of in adjacent unlined mixed waste landfills. Two comingling tritium plumes emanate from landfill Pits 3 and 5. Tritium was mobilized during the 1982-83 wet winter from direct infiltration and ground water inundation of the pits. The Building 850 firing table is the source of a third ground water tritium plume. Maximum tritium activities were 1,200,000 pCi/L in water samples collected in 1982; current maxima are about 250,0000 pCi/L. Building 850 and Pits 3 and 7 are also release sites of depleted uranium to ground water. Three small plumes exist and the maximum detected total uranium activity is about 100 pCi/L.

Project Highlights

- Resource Cocervation and Recovery Act (RCRA) caps have been installed on two landfills (Pits 1 and 7). The caps consist of eight feet of natural earth materials, including two feet of compacted low permeability clay. The caps and associated surface and ground water control measures are designed to prevent release of tritium, depleted uranium, barium, lead, beryllium, and other metals from the landfills to the ground water. At Pit 7, DOE/LLNL installed an upgradient interceptor trench to direct recharge water away from the local hydrologic system.
- Conservative ground water modeling indicates that by the time the tritiated ground water reaches the site

boundary, tritium activities will be only slightly above background.

- DOE/LLNL may install additional capping material and drainage control at adjacent landfills (Pits 3 and 5).
- Gravel and soil containing tritium, uranium, and metals from six high explosive firing tables were removed. At three active firing tables, the tritiated gravels were replaced with fresh material.



Pit 7 remediation design.

Pit 7 RCRA cap and drainage system prior to vegetation seeding.

INNOVATIVE TECHNOLOGIES

Simultaneous Soil Vapor/Ground Water Extraction

In 1988, LLNL Site 300 designed, demonstrated and implemented simultaneous soil vapor and ground water extraction from six extraction wells completed in a shallow zone containing soil and ground water TCE contamination. Successful design and demonstration involved programming extraction pumps and adjusting soil vapor air flow rates to prevent pulling shallow ground water into the vapor extraction manifold system. The current Removal Action at the GSA follows the demonstration design.

Colloidal Borescope

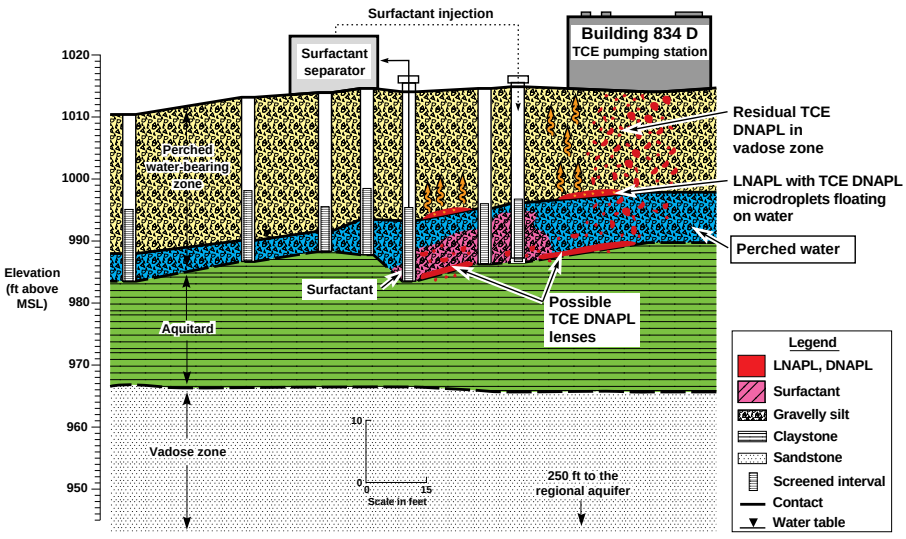
The colloidal borescope is a downhole tool capable of directly observing suspended colloidal size particles (1 to 10 µm) and determining ground water flow velocity and direction in an open borehole or monitor well in real time. LLNL Site 300 is using the borescope to characterize local ground water flow patterns, site monitor wells, and assess the efficiency of ground water extraction well fields. This is one of the first applications of this innovative technology to a real-world field situation.

Figure 20. LLNL is using the colloidal borescope to aid in well placement and to evaluate the progress of ground water remediation.

DNAPL Tracer Testing and Surfactant Remediation

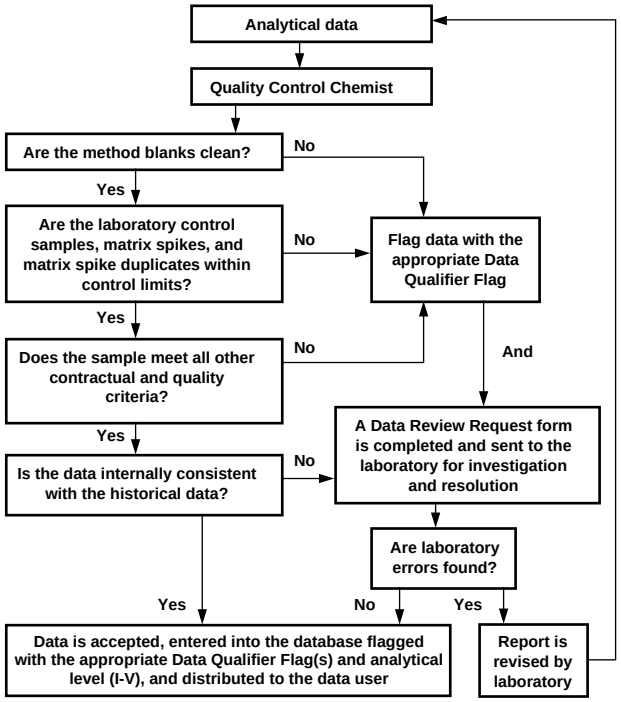
A major component of the Building 834 OU Interim ROD is applying innovative technologies for the identification, delineation, and remediation of NAPLs. LLNL will be demonstrating the application of partitioning tracers to identify and delineate the extent of NAPL contamination in a shallow perched water-bearing zone. A surfactant injection and extraction demonstration will follow the partitioning tracer test to solubilize residual NAPL and expedite VOC mass removal at the OU.

A surfactant remediation demonstration has been proposed for TCE DNAPL contamination in the perched water-bearing zone beneath the Building 834 Complex. Federal and State regulatory agencies committed their support for innovative technology demonstrations in a recently completed Interim ROD for the Building 834 OU.



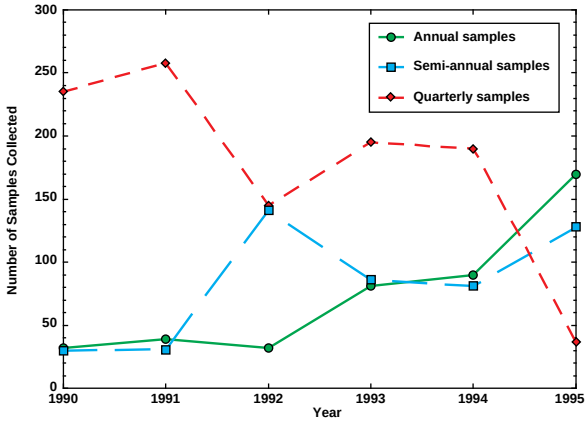
Sampling

- Site 300 has implemented a sampling, analysis, and data validation program which is both cost-effective and provides data of known and adequate quality.
- Rather than require our contract laboratories to participate in the US EPA's Contract Laboratory Program (CLP), we have implemented a streamlined data-validation procedure (outlined below) which requires our own contract laboratories to provide summaries of their Quality Control (QC) data. This has saved us several hundred dollars per sample in analytical costs without sacrificing data quality.
- Each laboratory analytical and QC data package can be reviewed by our QC chemists using the streamlined data-validation procedure in less than 15 minutes, rather than several hours required by the CLP. In conjunction with this procedure, we have further reduced data validation time by implementing an electronic data validation program that prepares a report for the QC chemist.
- In addition to reducing analytical costs and data validation time, we developed a Cost Effective Sampling (CES) algorithm to reduce the ground water sampling frequency without sacrificing data quality or jeopardizing human health or the environment. The CES algorithm permits us to evaluate all available analytical data variability trends with respect to proximity to sensitive receptors. Using this algorithm, we have successfully reduced the percentage of quarterly monitor well samples from almost 80% to about 10%, increased the annual monitor well samples from 10% to 50%, and increased the percentage of semi-annual monitor well samples from 10% to nearly 40%. This integrated sampling, analysis, and data validation program has saved DOE/LLNL several hundred thousand dollars per year while still providing the quality data required to make meaningful remediation decisions.



Streamlined data validation procedure flow chart.

LLNL Site 300 significantly reduced the number of ground water samples collected each year using the Cost Effective Sampling algorithm, saving several hundreds of thousands of dollars every year.

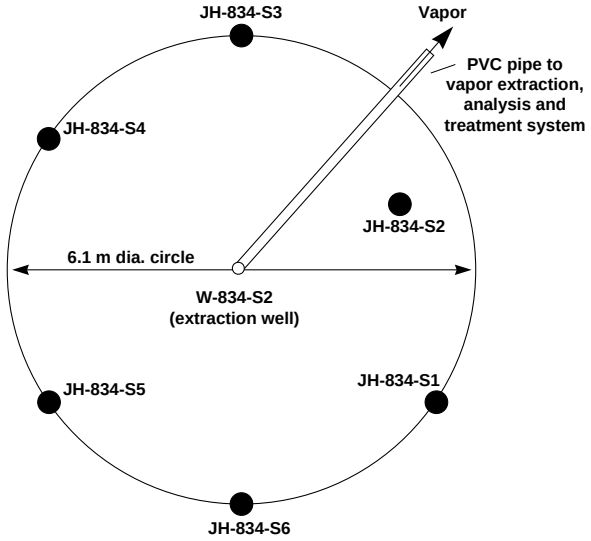


VOC UV/Oxidation

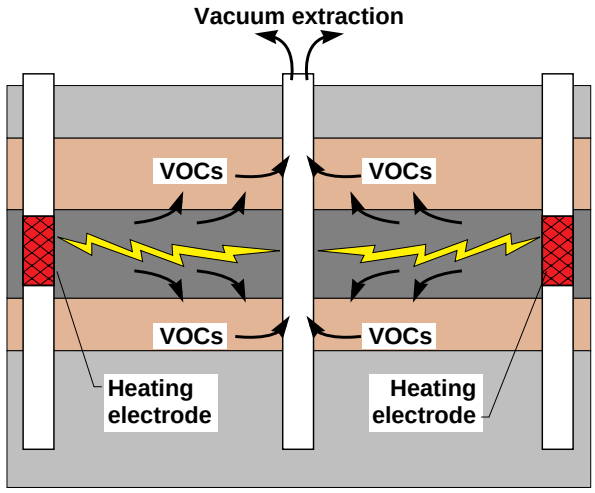
In 1992 LLNL Site 300 was selected by the US EPA SITE Program to demonstrate a full scale Perox-Pure™ UV/oxidation system. Over a three week period, scientists from LLNL and Perox treated nearly 40,000 gallons of VOC (primarily TCE) contaminated ground water extracted from the central GSA dry well pad area using a chemical oxidation process involving UV light and hydrogen peroxide to oxidize the VOCs. Efficiencies of 99.7% were achieved for the TCE removal and 97.1% for PCE. UV/oxidation systems are now in use at permanent ground water treatment facilities at the Livermore Site.

Electrical Heating and Air Stripping

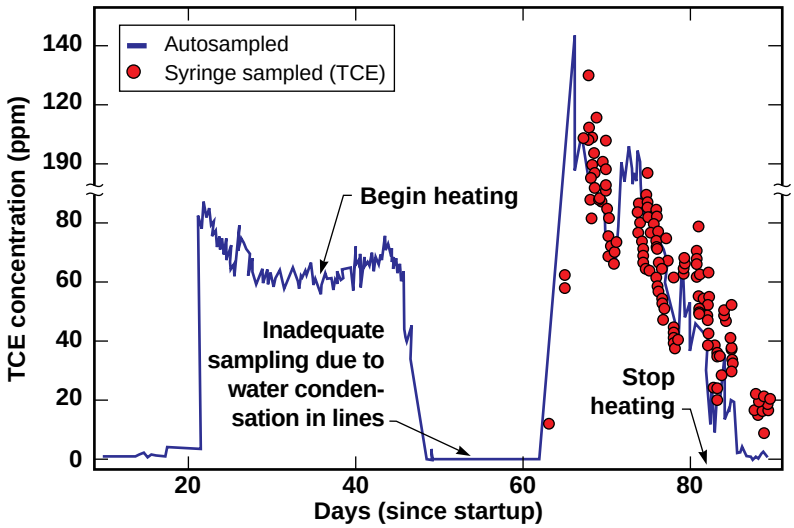
Six electrodes were buried to a depth of 4 meters in a circular pattern with a diameter of 6.1 meters (120 m^3 target volume) to demonstrate the effectiveness of enhanced vapor volatilization in TCE contaminated soil using 60 hertz (Hz) ohmic dissipation. Soil vapor was extracted from a single well located at the center of the array. The soil vapor extraction system initially ran for 36 days prior to soil heating. Soil vapor concentrations stabilized at about 60 parts per million by volume (ppmv) when soil heating was initiated. Soil vapor concentrations increased from 60 ppmv to 130 ppmv after 16 days of soil heating and rapidly decreased to about 5 ppmv after 51 days when the demonstration was terminated. Soil vapor temperatures increased from 16˚ C at the beginning of the demonstration to 38˚ C at the end. A total of 12 kg of TCE is estimated to have been extracted during this demonstration, requiring a total of 9,600 Kilowatt hours (kWhr) (3.46×10^6 joules) of electrical energy.



Field layout of soil heating electrodes (JH-834-S1 through -S6) and soil vapor extraction well (W-834-S2).



Electrical heating volatilizes contaminants in low permeability soils into more permeable zones where they can be more easily removed by soil vapor extraction.



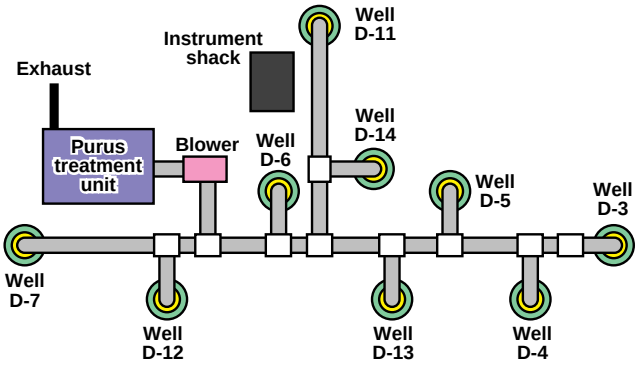
TCE vapor concentrations during the electrical heating demonstration.

VOC Vapor Destruction Using UV Flashlamp Photo-Oxidation

LLNL Site 300 was selected by the US EPA SITE Program to demonstrate two full scale Purus™ xenon UV flash-lamp photo-oxidation systems to destroy VOCs in extracted soil vapor. The photo-oxidation systems were tested at flash frequencies of 1 - 30 Hz, temperatures of 33 - 60˚ C, vapor flow rates up to 300 standard cubic feet per minute (scfm), TCE concentrations up to 10,600 ppmv, and residence times of 5 - 75 seconds.

TCE removal rates greater than 99.9% were achieved in all tests using a flash frequency greater than 1 Hz. Some photo-oxidation byproducts measured during the demonstration were: dichloroacetyl chloride [which further converted

to dichlorocarbonyl (phosgene)], possibly formyl chloride, hydrochloric acid and carbon dioxide. The demonstration was discontinued due to the formation of phosgene; further treatment of the photo-oxidation byproducts is recommended prior to continuing operations.



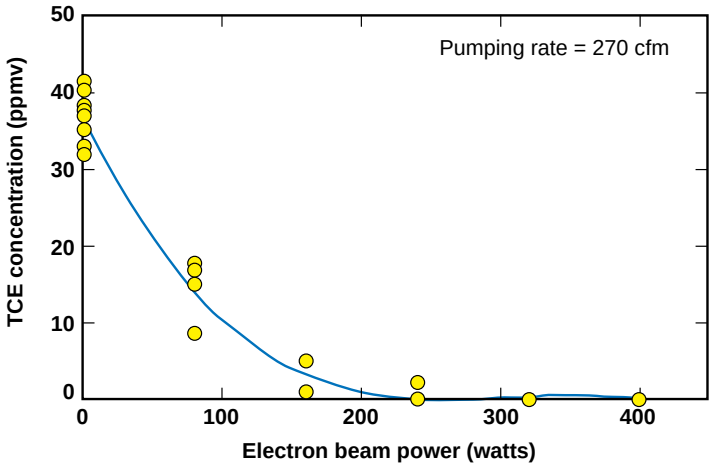
Schematic of UV flashlamp photo-oxidation demonstration.

Well ID	Maximum flow rate (scfm)	Maximum TCE concentration (ppmv)
D3	70	420
D4	9	30
D5	15	14
D13	19	19
D14	19	10
D3, D4, D5	23	150
D3, D4, D5, D14	30	100
D13, D14	35	25
All	>250	11

Maximum vapor flow rates and influent TCE vapor concentrations observed during the UV photo-oxidation demonstration.

VOC Vapor Destruction Using Bremsstrahlung Irradiation

The soil vapor extraction system at Building 834 was used to demonstrate the destruction of VOC contaminated vapor effluent using bremsstrahlung irradiation. A 2 MeV electron accelerator with 1 kW maximum beam power was installed in-line with the vapor extraction system. The electron beam accelerator was ramped up at 80 W steps to 400 W, where TCE vapor concentrations were reduced from 40 ppmv to 0.1 ppmv at 270 cfm at 70˚ F. The resultant dose deposited into the vapor was 88kR. Five reaction products were detected: chloromethane, dichloromethane, chloroform,acetone, and trimethylbenene. Though this test was technically successful, a cost analysis indicated that the technology would be more efficient at concentrations ≥500 ppm and flow rates ≥500 cfm.



TCE effluent vapor concentrations at 270 cfm as a function of electron beam power.

A New Approach to CERCLA

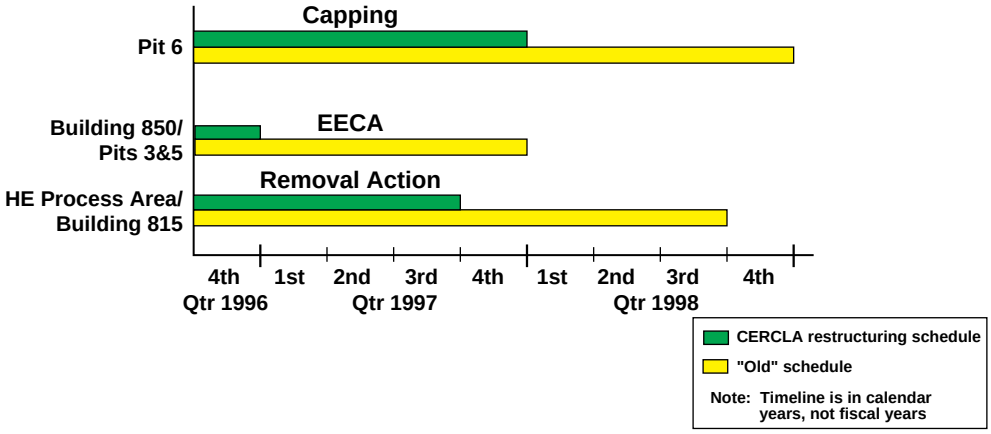
LLNL initiated a new approach to the CERCLA process during Fiscal Year 1995. Through months of discussion, the regulatory agencies, DOE, and LLNL agreed to changes to the FFA that significantly reduce the time and resources required for document preparation prior to Site 300 cleanup. The purpose of the FFA schedule revision is to accelerate the environmental restoration of Site 300 to provide protection to human health and the environment. The result is the mutual agreement that some work elements originally required under the Site 300 FFA could be reduced and streamlined to be more cost effective and eliminate unnecessary delay in contaminant cleanup initiation. DOE/LLNL and regulatory agencies believe this new approach to be a more efficient and effective environmental restoration process.

The Site 300 FFA restructuring provides for:

- Continued protection of human health and the environment
- Continued ground water monitoring in all OUs
- Continuation of existing Removal Actions at GSA and B834 OUs
- Continuation of the schedule for preparing the GSA and B834 RODs
- Addition of non-time-critical Removal Actions where warranted

- Preparation of contingency plans
- Creation of a Site 300 Monitoring OU, including all areas requiring monitoring only
- Preparation of a Site 300 Monitoring ROD that will incorporate the results of non-time-critical Removal Actions
- Incorporation of three existing OUs into the Site 300 Monitoring OU, if warranted

Improvements to the Site 300 deliverable schedule as a result of the new approach to CERCLA



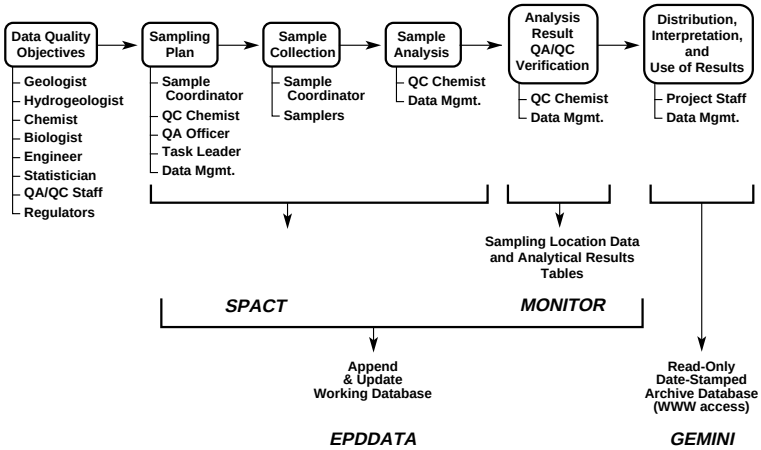
	Draft FS	Draft Final FS	Draft PP	Draft Final PP	Target Public Meeting Date	Draft ROD	Draft Final ROD
GSA OU	Completed	Completed	12/1/95	2/15/96	6/1/96	7/15/96	12/1/96
Building 834 OU	Completed	Completed	Completed	Completed	Completed	Interim ROD	Interim ROD
Pit 6 OU *	Completed	Completed	~~7/30/95~~	~~10/15/95~~	~~12/15/95~~	~~4/15/96~~	~~9/1/96~~
HE Process Area/ B815 OU *	~~12/1/95~~	~~4/15/96~~	~~7/1/96~~	~~9/15/96~~	~~11/15/96~~	~~2/15/97~~	~~7/1/97~~
Building 850/ Pits 3&5 OU *	~~2/15/96~~	~~7/1/9~~	~~11/15/96~~	~~2/1/97~~	~~2/20/97~~	~~6/20/97~~	~~11/5/97~~
Building 832 Canyon OU	Characterization work to be completed by October 1, 1997; establish CERCLA pathway						
Building 854	Characterization work to be completed by April 1, 1998; establish CERCLA pathway						

*** Items crossed out are to be replaced by Removal Actions and ground water monitoring.**
FS = Feasibility Study
PP = Proposed Plan
ROD = Record of Decision
OU = Operable Unit

Data and Information Management

- The Data and Information Management Group (DMG) of the Environmental Restoration Division at LLNL provides integrated sample and data management services that support planning, collection, tracking, verification, validation, reporting, interpretation and use of data produced in characterization, remediation, self-monitoring, and surveillance monitoring.

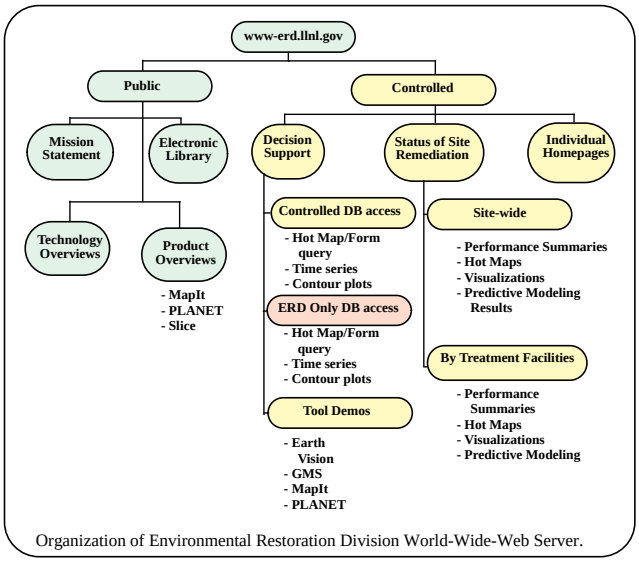
- This system has been in use at LLNL since 1986. Over 130,000 samples, 1.7 million analytes, and descriptive information, and geographic coordinates, for over 8,800 sampling locations are included in the system. Approximately 2000 sample records are added each month.



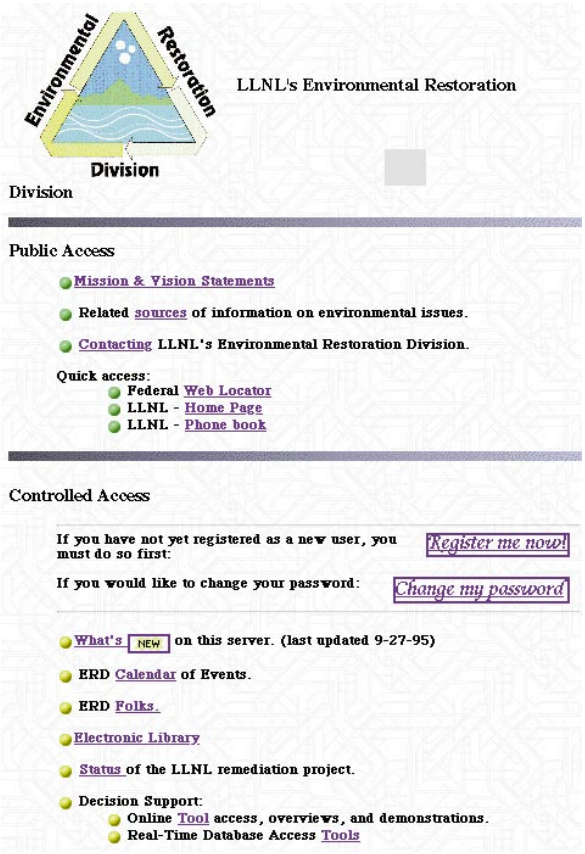
The DMG software tools are linked to the World Wide Web database access, have decreased labor-intensive overhead, and have increased the efficiency of the Ground Water Project.

The ERD Web

The LLNL Environmental Restoration Division (***ERD)*** has developed innovative new uses of the emerging World Wide Web (WWW) technology. In addition to the traditional use of providing access to static documents, reports, images, and product and technology overviews, our web-server also provides division personnel and DOE with dynamic access to project status by allowing form-based statistical processing, database access, and cost estimating tools. These new capabilities have demonstrated significant cost savings and, for the first time, have made the enormous amount of collected data available to scientists on their desk top in a timely fashion and in a form immediately useful.



Organization of Environmental Restoration Division World-Wide-Web Server.



LLNL ERD Home Page as shown on the WWW server.

Regulatory/Institutional Issues

- All treatment facilities comply with San Joaquin Valley Unified Air Pollution Control District standards for VOC release. Ground water discharges to the Corral Hollow stream channel are also controlled by National Pollution Discharge Elimination System (NPDES) requirements (currently in the eastern GSA).
- An active and ongoing public involvement program is encouraged through the LLNL Site 300 Community Relations Plan and newsletter.
- An extensive and detailed quantitative risk assessment involving fate and transport modeling of contaminants was performed for LLNL Site 300. Health conservative (reasonable maximum worst case) risk assessment produced cancer risks as high as 7×10^{-2} and Hazards Indices (HIs) as high as 540. These risks exceed EPA's acceptable cancer risk range at Superfund sites of 10^{-5} to 10^{-6} and indicate the potential for chronic health effects. No members of the public, or LLNL Site 300 employees are exposed to chemicals at Site 300 at health-threatening concentrations.
- Successful interactions with regulatory agencies include: (1) restructuring and re-negotiating FFA milestones to increase efficiency, reduce costs, and accelerate site cleanup, (2) negotiating reduced reporting requirements, and (3) negotiating reduced sampling and analysis.
- DOE/LLNL are working to resolve issues regarding the State of California's non-degradation policy, Resolution 92-49. This policy is interpreted by the Central Valley Regional Water Quality Control Board (CVRWQCB) as requiring the cleanup of contamination of "waters of the state" to "background" concentrations. Unlike US EPA and the California Department of Toxic Substances Control, the CVRWQCB does not base cleanup levels on risk reduction.
- At the GSA, DOE/LLNL have proposed cleanup of the VOC-contaminated drinking water aquifer to MCLs, citing the high cost and technical infeasibility of reaching background concentrations.
- At Building 834, DOE/LLNL are requesting that the shallow, contaminated aquifer be exempted from the non-degradation policy because the aquifer naturally does not meet the definition of a "potable drinking water-supply aquifer."

ENVIRONMENTAL RESTORATION SUMMARY

Accomplishments

- LLNL ground water extraction/treatment Removal Actions are significantly reducing offsite plume size, VOC concentrations, and vadose and saturated zone VOC mass.
- Restructuring of CERCLA FFA milestones with State and Federal regulators is leading to reduced costs and accelerated cleanup.
- LLNL designed and constructed treatment systems have successfully removed VOCs in vapor and water by air sparging, carbon adsorption, UV/oxidation, electron beam generated x-ray destruction, and other innovative technologies.
- Cost-effective decision support sampling selection techniques developed at LLNL have resulted in a significant reduction in ground water sampling, analysis, and data management costs.
- Effective use of the WWW allows for rapid access and analysis of data such as contaminant and potentiometric surface trends, data validation, and 3-D viewing of hydrogeological data, which allows decisions to be made in minutes rather than weeks.

Lessons Learned

- Integration of hydrogeologic data from the various study areas has allowed LLNL to develop a site-wide working hydrogeologic model necessary for targeting specific contaminant plumes, leading to accurate fate and transport modeling, accelerated VOC mass removal, and cleanup optimization.
- Design and application of innovative assessment techniques, some designed at LLNL, have enabled efficient determination of hydrogeology, chemical extent, and risk assessment.
- Advanced ground water and vadose zone fate and transport modeling techniques allowed for in-depth analysis of regulatory cleanup objectives and remedial alternatives.
- Phased implementation of treatment system capacity and the use of modular design was compatible with the need to optimize remedial actions and achieve cleanup objectives.
- Integration of hydrogeologic and engineering design for treatment and waste isolation systems is essential to properly place extraction wells or interceptor trenches and to construct high performance treatment systems in a cost-effective manner.
- Conducting pilot-scale or field treatment tests prior to full-scale construction of ground water treatment systems proved useful and cost effective.
- Remote control techniques for treatment system operations and monitoring, developed at LLNL, can accelerate cleanup and reduce operating costs.
- Salvaged equipment can be used to build treatment system equipment at great savings.
- Open dialogue with regulatory agencies and other Stakeholders has enabled DOE/LLNL to “restructure” the original FFA to accelerate site cleanup by putting the available funds into Removal Actions at the higher risk areas.
- LLNL Site 300 continues to be an effective testbed for environmental assessment and cleanup technologies.

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