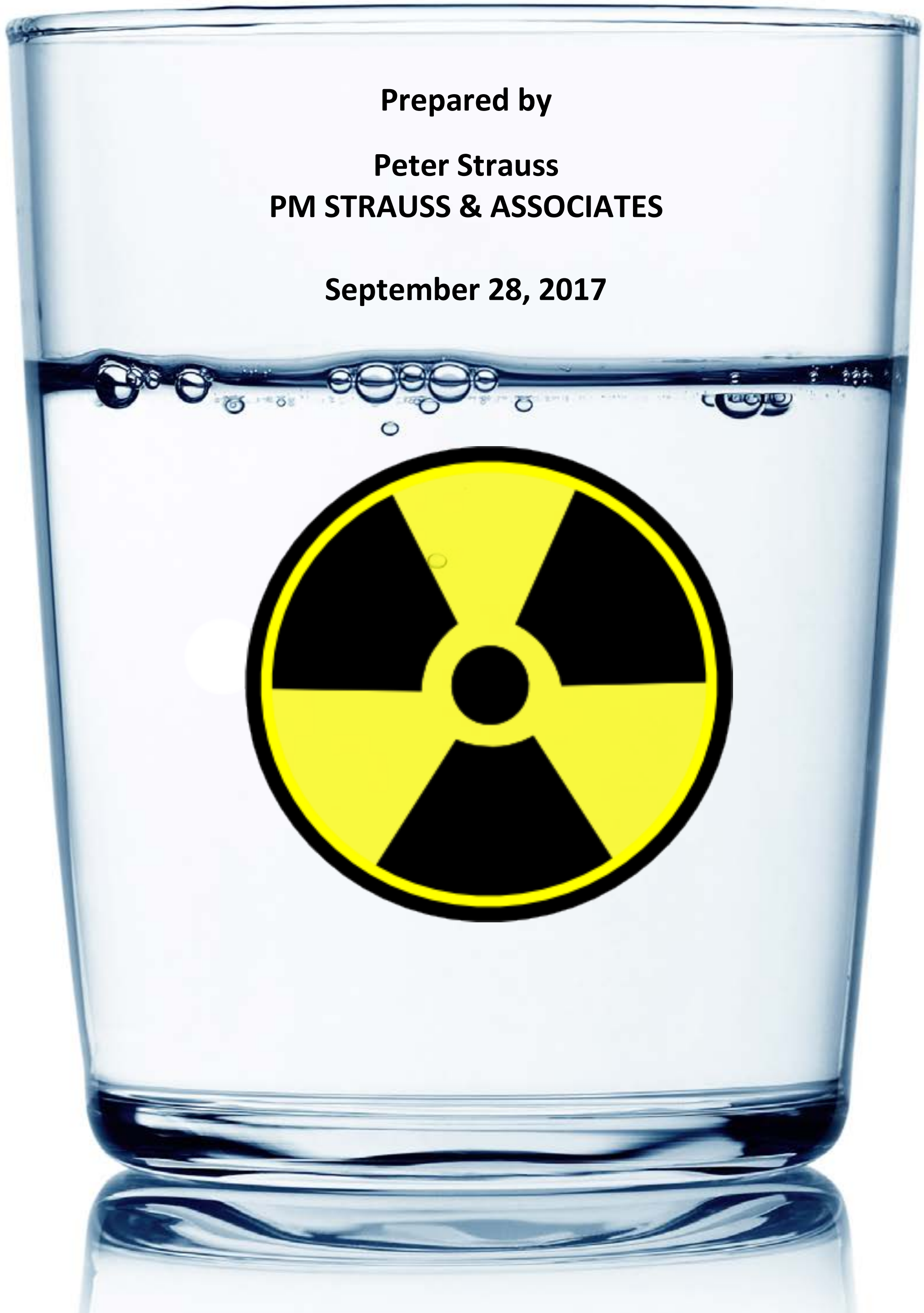
STATE OF THE SUPERFUND CLEANUP

Hazardous and Radioactive Pollution Issues at the Lawrence Livermore National Laboratory Main Site & Site 300



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September 28, 2017

A Tri-Valley CAREs Report

STATE OF THE SUPERFUND CLEANUP

Hazardous and Radioactive Pollution Issues at the Lawrence Livermore National Laboratory Main Site (Site 200) and Site 300

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Discussion Draft for Community-Wide Meeting

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STATE OF THE SUPERFUND CLEANUP

1. Introduction

The purpose of this report is to familiarize the community members about the status of the Superfund cleanup at the two Superfund Sites managed by Lawrence Livermore National Laboratory (LLNL). The information in this report is based on extensive review of documents obtained from the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the State of California Department of Toxic Substances Control (DTSC), and the Lawrence Livermore National Laboratory Environmental Restoration Division, as well as meetings with the regulatory agencies and the Department of Energy. It also incorporates information obtained through our role as Technical Assistance Grant recipient and other research projects.

LLNL was founded in 1952 by Edward Teller and E.O. Lawrence to develop the hydrogen bomb, thus becoming the United States' second nuclear weapons design lab after Los Alamos National Laboratory in New Mexico. Prior to this, the land was used by the Navy as an aircraft maintenance facility. The Main Site stretches over one square mile; located on the eastern edge of the City of Livermore. Homes, apartments, little league fields and more are built up to the fence line. There are approximately 50,000 people living within 2 miles of the main site, and 7 million within a 50-mile radius. The second Superfund site, known as "Site 300", is LLNL's high explosives testing range near the City of Tracy. Both sites have soil and groundwater that are contaminated with toxic and radioactive materials. Cleanup of both is projected to last until the end of the 21st century.

This summary highlights some of the progress and issues involved in cleaning up these two sites.

II. Site 300

Site 300 is Livermore Lab's high explosives testing facility. It is located in the Eastern Altamont Hills 17 miles east of Livermore and about 10 miles west of downtown Tracy. It encompasses 11 square miles along Corral Hollow Road. Over the years, Tracy has expanded and a major residential development is proposed near Site 300. Highly permeable channels carry groundwater, each separated from one another by a layer of non-saturated material that restricts vertical groundwater flow. These channels are known as hydrostratigraphic units (HSUs). Sediment layers that have hydraulic communication are grouped together as one HSU. The lower HSUs make up the regional groundwater system.

Since it was founded in 1955, Site 300 operations have included open-air blasts with high explosives and radioactive materials used in nuclear weapons. Site 300 activities have polluted soil, surface water, springs and regional groundwater aquifers with chemical and radioactive wastes including solvents, dioxins, furans, PCBs, perchlorate, high explosive compounds, metals, and radionuclides (namely tritium and depleted uranium). An off-site groundwater plume contaminated with solvents has migrated from Site 300, and traveled under Corral Hollow Road and the nearby Corral Hollow Creek.

Releases to the environment occurred from a variety of spills, leaking pipes, leaching from unlined landfills and pits, high explosive test detonations, and disposal of waste fluids in lagoons and dry wells (sumps). Current operations at Site 300 include contained detonations, open-air blasts, explosive and hazardous waste burning, and radioactive and hazardous waste storage. Prevailing winds blow contamination into the Central Valley, and, particularly, toward Tracy and surrounding communities.

In 1990, because of the magnitude of this contamination, Site 300 was added to the federal Superfund site. LLNL recently acknowledged that it is uncertain when cleanup at Site 300 will be completed, if ever. The contamination is widespread and complex, and Livermore Lab estimates that its cleanup at Site 300 will cost around $1.8 billion.

To better manage the cleanup, Site 300 was divided into nine Operable Units (OUs). These are:

- General Services Area (GSA) (OU 1)
- Building 834 (OU 2).
- Pit 6 Landfill (OU 3).
- High Explosives (HE) Process Area (OU 4).
- Building 850/Pit 7 Complex (OU 5).
- Building 854 (OU 6).
- Building 832 Canyon (OU 7).
- Site-Wide (OU 8) including Buildings and Pits that have not been characterized or don't pose a risk.
- Building 812 (OU 9).

Figure 1 shows the relative location of each OU along with the contaminants of concern.

A. Accomplishments

By the end of 2016, 433 million gallons of groundwater had been treated to remove contaminants at Site 300. During 2016, 10 million gallons of groundwater and 81 million cubic feet of soil vapor were treated. VOCs, perchlorate, nitrate, RDX (an explosive), silicon oil, and total uranium were removed. However, almost 99 percent of the contaminant removed was nitrate, while VOCs accounted for only 6.8 kilograms (kg) and all other additional compounds accounted for less than a kilogram. **Table 1** shows the cumulative amount of contaminants removed by Operable Unit through 2016.

Table 1: OUs and Gross Cumulative Volume of Contaminants Removed (2016)

Operable Unit	Volume of Groundwater Treated (thousands of gallons)	Volume of Contaminant Removed from Groundwater (kg)	Volume of Contaminant Removed from Soil (kg)*	Total Mass Removed (kg)
GSA	333,500	35	78	113
B-834	1,366	47	360	407
Pit 6	NA	NA	NA	NA
High Explosives Area	39,424	3,493	NA	3,493
B-850/Pit 7	222	42	NA	6
B-854	22,255	4,174	14	4,188
B-832	31,900	3,995	56	4,051
Site-Wide	NA	NA	NA	NA
B-812	NA	NA	NA	NA
Total	**443,465**	**18,814***	**508**	**19,222***

* These amount may be somewhat misrepresentative because nitrate accounts for approximately 17,000 kg removed from groundwater.

1. GSA

Eastern GSA reduced TCE to below MCLs, and in 2012 the cleanup was declared complete and closed out. The central GSA operates a groundwater treatment system (GWTS) and a soil vapor treatment system (SVTS). The former is an air stripper that then mists the water for vegetation. The latter uses a carbon-based filter known as granulated activated carbon (GAC), to remove solvents from the vapor. Both systems are effective, although the GWTS was inhibited by the drought. Seventeen monitoring wells are installed south of the Site 300 boundary in three water-bearing zones. Historically, Volatile Organic Compound (VOC) concentrations have been reduced by about 272,000 part per billion (ppb) in 1992 to a maximum of 1,360 ppb (at the source) in 2016. In 2016, VOCs were detected south of the boundary in two monitoring wells (83 ppb and 28 ppb respectively)

2. B-834

Contaminants of concern are VOCs, TBOS/TKEBs (a silicate oil), and nitrate. B-834 has a GWTS and a SVTS. The contaminants have been identified in two HSUs. VOC concentrations have decreased from 1,100,000 ppb in 1988 to 50,000 ppb in 2016. TBOS/TKEBs concentrations have decreased from historic maximum of 7,300,000 ppb to 50 ppb. Nitrate concentrations were 380,000 ppb, in contrast to the 45,000 ppb drinking water standard. An enhanced in-situ (in place) bioremediation study treatability study for VOCs has been ongoing since 2005. Concentrations have decreased by two orders of magnitude. Besides groundwater risks, there is a risk from indoor air exposure, and building occupancy restrictions and monitoring are in place.

3. Pit 6

Pit 6 is near the southern boundary of Site 300. It was used from 1964 to 1973 to bury waste in nine unlined trenches. Waste included shop waste and animals. It was capped in 1997. The remedy for nitrate and VOCs in groundwater near Pit 6 is monitored natural attenuation (MNA). There are two active water supply wells across Coral Hollow Rd. that provide water for the Carnegie State Vehicular Recreation Area. These wells are monitored on a monthly basis. VOCs in monitoring wells on site had only one occurrence of a well above drinking water standards. Nitrate was also detected in groundwater above MCLs, possibly due to a nearby septic system. This drinking water well is used to fill a pond off-site. The VOCs emanating from Pit 6 need to be carefully monitored. Based on the latest data, these levels meet drinking water standards. Spring 7 in this OU is contaminated by VOCs and poses an inhalation risk.

4. High Explosive Process Area (HEPA)

The HEPA Operable Unit (OU), located near the southern boundary of the site, covers a large area. HEPA was used for chemical formulation, mechanical pressing and machining of explosive detonators. Groundwater contamination is attributed to high explosive discharges into unlined lagoons, as well as a minor source from leaking waste stored at a waste accumulation area. Five groundwater treatment systems (GWTSs) operate at the site, removing VOCs, high explosive (HE) compounds, perchlorate and nitrate. Contaminants were found in the upper three HSUs. All of the wells sampled for VOCs had relatively low detections – none exceeding 50 ppb. HE contaminants and perchlorate have been reduced by over 50% from historic maximums, and nitrate has been reduced by one-third. VOCs were not detected in the off-site water supply well (GALLO1), and VOCs in guard wells remained low and stable. Spring 5 in this OU is contaminated by VOCs and poses an inhalation risk.

5. Building 850/Pit 7 Complex

High explosive experiments were conducted at the B-850 firing table from the 1950s through 2008. It was set in a topographically low area, so that debris from experiments would be contained within the walls of the surrounding hills, as well as reducing air pressure waves. The firing table was used to test detonators for nuclear weapons and armor piercing projectiles. Over 95% of the 22,670 curies of tritium used at Site 300 were used at the B-850 firing table.

Firing tables were covered with gravel to absorb shock. They were rinsed after each experiment to reduce dust. Infiltrating water mobilized chemicals from the gravel to the underlying groundwater and bedrock. Until 1988, the contaminated gravels were removed every 3 months and disposed of in unlined pits to the north, know as the Pit 7 Complex. This complex is a series of pits approximately one-half mile from the northern boundary of the site. (After 1988, gravel from B-850 was transported to the Nevada Test Site.)

This OU is easier to understand if it is subdivided into the B-850 area and the Pit 7 Complex.

B-850

In 2009, at B-850, 27,592 cubic yards of soil containing PCBs, dioxin and furan were scraped from the hillsides and solidified into a 20-foot high monolith. Other contaminants in the soil including depleted uranium (DU), high explosive materials, and metals were also collected. This monolith is inspected after each storm event, and twice per year. It has not shown any signs of deterioration.

Two groundwater HSUs beneath B-850 are primarily contaminated with tritium and perchlorate. There is also some nitrate, HE compounds and DU. There is no aboveground GWTS. During 2016, the following has taken place:

- Tritium degraded from a historical maximum of 566,000 pico curies per liter (pCi/L) to below 20,000 pCi/L in 2016.
- DU has remained stable, and only one well contained groundwater slightly exceeding the 20 pCi/L cleanup standard for uranium.
- At B-850, there was a pilot study begun in 2011 to treat perchlorate by in-situ bioremediation. In the treatment zone there were a number of detections around 40 ppb (the reporting limit is 4 ppb and the California drinking water standard is 6 ppb), although most detections have been reduced to below 6 ppb. In the source area, perchlorate levels ranged from 10 ppb to 65 ppb.
- In 2017, the B-850 Focused RI/FS proposed that perchlorate be treated naturally by monitored natural attenuation. This proposal followed EPA Guidance, including that it does not affect drinking water sources, and that there is evidence of perchlorate reduction. However, until a final decision is reached, LLNL will continue to use in-situ bioremediation to further reduce perchlorate.
- Nitrate is also being studied for in-situ bioremediation, in the same treatment zone as perchlorate. Concentrations decreased from pre-test 57 parts per million (ppm) to 0.5 ppm. Uranium in this treatment zone was also reduced to approximately 3 pCi/L.

- Groundwater samples for the HE compound RDX is slightly above the MCL (1 ppb

In 2015, a draft Five Year Review was prepared for this area. Because of the success of the treatability study, a work plan is being prepared to study the results, to be followed by a Focused Feasibility Study. Additionally, HE compounds were detected in groundwater during this review. There will be additional characterization, with possible follow-up actions. In September 2015, LLNL submitted a work plan to further characterize subsurface soil and groundwater in the B-850 area. The Five-Year Review also recommended an extraction well at Pit 7 be installed to optimize uranium extraction.

In this OU Spring 8 is contaminated by tritium. In 1972, levels were 770,000 pCi/L. Although tritium activity levels have decreased over the decades, in 2009, the monitoring indicated a potential inhalation risk. Surface water is sampled semi-annually. In 2014, because of drought conditions, surface water was not present.

Pit 7 Complex

The Pit 7 Complex is a series of unlined pits that was filled with gravels from firing tables and other debris. After these pits were filled, they were covered with soil. During some heavy storm events, groundwater levels rose as much as 10 feet, inundating the pits and washing contaminants out. The pits have leaked uranium, tritium (radioactive hydrogen), perchlorate and other contaminants into the groundwater at high concentrations. Historic highs of tritium reached 2,660,000 pCi/L. Maximums in 2016 were 281,000 pCi/L. These levels, while greatly reduced, are still an order of magnitude greater above the federal drinking water standard (20,000 ppb). Because tritium in water is difficult and extremely costly to remove from water, the remedy that addresses tritium most directly is called Monitored Natural Attenuation (MNA). Tritium has a half-life of a little more than 12 years, so this contaminant is allowed to stay in the groundwater while it decays.

In addition to MNA, in 2005, LLNL constructed a series of drains upstream from the pits and diverting runoff into another area. This is intended to mitigate the groundwater level rise, thus hydraulically controlling the migration of tritium. Prior to 2005, for every inch of rainfall, the groundwater level at the pits would rise an average of 5 inches. In 2011, data indicated that it reduced the rise in groundwater by 20%. In 2016, the 2016 Annual Report states that groundwater levels "remained well below the bottoms of the Pit 7 Complex Landfills." However, the beginning of 2017 had higher than normal rainfall, and we will wait until all reporting is done to see if this remedy hydraulic control prevented saturation of the Pits. Our informal conversations with staff indicate that it has.

The remedy uses a GWTS to extract and treat uranium, and perchlorate. Uranium activities have been reduced to historical highs of 781 pCi/L to 132 pCi/L in 2016. Perchlorate has been reduced from 40 ppb in 2009 to 14 ppb in 2016. Nitrate has been reduced from a historic high of 363 parts per million (ppm) in 2003 to a maximum of 65 ppm in 2016.

6. Building 854

This building complex was used to test the stability of weapon components under various environmental, mechanical and thermal conditions. Contaminants at this site include VOCs, nitrate and perchlorate. The remedy for this site involves 3 GWTSs and one SVTS. VOCs have been reduced from a high of 2,900 ppb to 69 ppb in 2016. Perchlorate was reduce from a maximum of 27 ppb to 15 ppb in 2016. Maximum nitrate in 2016 was 200 ppm. In 2017 an enhanced in-situ bioremediation treatability study will be initiated to reduce perchlorate at this OU.

7. Building 832 Canyon

Much like B-854, B-832 facilities tested stability of weapons components under various conditions. Contaminants were released through leaking pipes and spills. Three GWTSs and 2 SVTS are operated. VOCs are primary contaminants, with perchlorate and nitrate being secondary contaminants. As this area drains south, it has contaminated 5 HSUs. B-830 in this OU has a risk from indoor air exposure, and building occupancy restrictions and monitoring are in place. Since remediation began in 2000, in the B-830 source area, VOC concentrations have been reduced from a maximum of 10,000 ppb to a 2016 maximum of 660 ppb in the upper HSU, and 1,900 ppb.

8. Site-Wide OU

The Site-Wide OU is comprised of sites where there have been releases, but LLNL has not found unacceptable risks to health or the environment "at present". This may be due to under-characterization, or there is in fact no unacceptable risk. This OU contains a firing table (B-801) and a nearby landfill (Pit 8, covered in 1974), B-833 (where TCE was released), B-845 firing table and nearby Pit 9 (DU and HE compounds), and B-851 Firing Table (DU releases). At present, only nitrate slightly exceeds drinking water standards at Pit 8. At B-833, TCE has been reduced substantially to 110 ppb. At B-845 and Pit 9, contaminants were all below cleanup levels. At B-851, several monitoring wells were drilled. Soil and rock samples indicated depleted uranium at the surface to 2.5 ft. As a consequence, staff is conducting is conducting a surface-soil gamma radiation survey in several phases. Phase 1 was in a 700-foot radius of B-851. The 700 ft radius was determined because there are special status species and critical habitat in the vicinity. A larger radius would require a Biological Opinion from US Fish and Wildlife Service. Thus, the results are not conclusive.

Additionally, LLNL identified three potential release sites at the B-865 area. VOCs and insulating oil were used at this site and may have been released from tanks, storm drains or a surface impoundment. Although not officially part of this OU, the area overlaps Pits 1 and 2. After characterizing the site, a focused Feasibility Study will be prepared in 2017.

9. Building 812 Firing Table

B-812 and associated buildings were one of the last open-air firing tables used to detonate nuclear weapons experiments with Uranium-238. The area encompasses about 200 acres in the east-central part of Site 300. Four HSUs have been identified in this area, and the upper three had detections of uranium isotopes exceeding the MCL. The hillsides, canyons and groundwater in this area are contaminated, as is a nearby spring.

LLNL has undertaken an extensive soil survey in the Building 812 area to determine the extent of the Uranium-238 contamination, and a soil and biotic sampling effort to determine the radioactive material's deposition depth and uptake in plants and animals. The sampling has taken a long time, and there were many complications. Regulators have concurred that 11 potential release sites were adequately characterized. At two of these sites: the firing table and the gravel pile near the firing table, were deemed to be release sites. In 2017 DOE/LLNL agreed to conduct additional characterization at 10 additional sites. The status of characterization will be decided after this additional work has been completed.

Related to the work at B-812 and B-851, there is an ongoing study to determine background levels for uranium at Site 300. These background levels will be used in risk assessments at these firing tables.

B. Issues

1. Funding Commitments

A basic concern is whether funding commitments are sufficient to ensure long-term cleanup and achievement of project milestones. Cutbacks in funds only delay inevitable expenditures, and may make cleanup more costly. Long-term funding for clean up should be a major commitment, and DOE and LLNL should make all attempts to ensure future funding.

2. Complete Cleanup

Wherever possible, Tri-Valley CAREs (TVC) recommends that LLNL be cleaned up to a level that allows unrestricted use and avoids the need for long-term stewardship. We also recognize that at a few selected areas this may not be possible due to the nature of the contaminants. Where cleanup to such a level is not practical due to current technical constraints, commitments should be inserted into the final remedy decision detailing the stewardship plan and funding. DOE should develop a program to look for solutions that would minimize or eliminate the need for long-term stewardship.

3. Relaxing Policy for Cleanup

Historically, TVC is very concerned that there will be a relaxation of cleanup. This is especially true in 2017 as there is a concerted push to re-evaluate cleanup at major sites. We are concerned that active remediation will shift to passive remediation or that sites will receive waivers from meeting cleanup standards. DOE, because of its massive cleanup around the country is currently searching for new rationales regarding relaxation of current cleanup standards and methods.

4. Long Term Stewardship (LTS)

A working definition of LTS is "the physical controls, institutions, information and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed plans for cleanup (e.g., landfill closures, remedial actions, removal actions and facility stabilization). The concept of long-term stewardship includes land use controls, monitoring, maintenance and information management".[1] TVC is concerned about DOE's commitment to implement the necessary plans and activities that this will entail, and maintain steady and necessary levels of funding. Because of the long-term nature of contaminants found at many of the sites, DOE should develop a record management system that will always be accessible near the location of the stewardship activities (such as the state archive or library) and from the National Archive system.

5. California's Drought

Because of limited recharge due to the drought combined with continued groundwater pumping, there were declining ground water levels and yields at many extraction wells. Although we gained significant relief in the drought in the 2016-2017 rain year, long-term prognosis is that we will continue to experience declining rainfall. This makes the development of the in-situ technologies ever more critical, as well as making sure that all water that is treated above ground be recharged in the aquifer zone or HSU from which it was extracted.

6. Remediation of open air firing tables (Building 812)

The Superfund cleanup at Site 300 is entering a new and important phase extending well beyond 2015. Cleanup is starting at one of the last open-air firing tables that had been used often to detonate nuclear weapons experiments with Uranium-238. The area encompasses about 200 acres in the east-central part of Site 300. The firing table is located almost directly over an earthquake fault. The hillsides, canyons and groundwater in this area are contaminated, as is a nearby spring.

In soil samples taken 5 feet below the firing table, total uranium has been measured at a concentration of 22,700 picocuries per gram. For comparison, a DOE report lists the proposed soil cleanup standard for uranium at Building 812 as 3.1 picocuries per gram. This may have been an anomaly, as the sampling method may have detected a piece of DU.

In 2008, LLNL prepared a draft RI/FS for this OU. This document was tabled in order for LLNL to undertake an extensive soil survey in the Building 812 area to determine the extent of the Uranium-238 contamination, and a soil and biotic sampling effort to determine the radioactive material's deposition depth and uptake in plants and animals. The sampling has taken a long time with many complications. Because of the steep slopes surrounding the firing table, LLNL used a robot to detect

1 Long-Term Stewardship Study, DOE 2001.

radiation for much of the hillsides surrounding the firing table, supplemented by hand-held detectors in areas where the robotic detectors could not access. As mentioned above in the description of B-812, DOE/LLNL have agreed to characterize 10 additional potential release sites.

7. The Pit 7 Complex

The "Pit 7 Complex" has leaked uranium, tritium (radioactive hydrogen) and other contaminants into the groundwater at high concentrations. A remedy has been selected at that area, but the remedy allows the most contaminants to be left in place, with others (e.g., uranium) being removed from groundwater. A series of drains and other engineered features have been installed to prevent rainwater from entering the pits and further dispersing the pollutants. Continued vigilance is needed to ensure that the remedy works as intended and that the pollutants do not continue to leach into the groundwater and/or migrate further.

8. Remediating Perchlorate in Numerous Areas

Perchlorate is used in explosives and is found in several locations throughout the site. Perchlorate was an emerging contaminant approximately 7 years ago, and the remedy for the site did not necessarily involve cleanup of this contaminant. In 2011, after the remedy for B-850 was completed, an in-situ Bioremediation Treatability test began to determine if this technology would remediate perchlorate in the groundwater. A Focused Feasibility Study and a proposed plan will be issued, likely in the 2018 timeframe. The proposed remedy for B-850 is MNA, while at other sites, treatability studies are being proposed.

9. Fire Hazard and Controlled Burns

Site 300 normally uses controlled burns to prevent wildfires. In April 2015, LLNL submitted its revised Prescribed Burn/Smoke Management Plan. Objectives include minimizing occurrence of wildfires, managing smoke so that burns conform with CA Air Quality Board and San Joaquin Valley Air Pollution Control District regulations, and managing and protecting biodiversity at Site 300. Burns take place from May through August. Because of the drought and exceedingly dry vegetation, a wildfire can rapidly spread beyond the boundaries of Site 300. Contaminants on the surface, such as depleted uranium and PCBs, could be mobilized by a fire and windstorm, with potential deposition off-site. Heat from controlled burns can turn PCBs and other types of compounds into highly toxic dioxin and furan. Other on-site activities such as drilling new wells, or even routine monitoring could set off a spark that initiates a fire.

III. The Main Site

LLNL conducts experiments with hazardous substances, including weapons grade plutonium, enriched uranium, and tritium (radioactive hydrogen used in the hydrogen bomb). Since the 1960's, LLNL has released approximately one million curies of radiation into the environment. Tritium gas has been released in substantial quantities over the years through normal operations and accidental releases. Tritium releases are especially a concern because of Livermore's large agricultural sector; where it can enter the food supply.

Also, laboratory processes used and released a variety of other non-radioactive chemicals. Much of the cleanup to date has focused on other chemicals that were used in experiments or were byproducts of laboratory work, or residuals from the previous landowner – the Navy. These chemicals include fuel hydrocarbons (mostly gasoline), metals, PCBs and volatile organic compounds (VOCs), most often trichloroethylene (TCE). TCE is an industrial solvent that is known to cause cancer in humans and other non-cancer health effects such as impacts to the liver and kidneys, and negative neurological, immunological, reproductive, and developmental impacts. TCE is a factor in congenital fetal heart defects during the first trimester of pregnancy. In operating the facility over 60 years, LLNL has had accidental releases of these substances, as well as extensive groundwater pollution that threatened the City of Livermore's water supply.

In 1987, the Main Site was placed on the Environmental Protection Agency's (EPA) "Superfund" list, a list of the most contaminated sites in the nation. In 1992 a Record of Decision (ROD) was signed and full cleanup began in 1995. It had a priority to capture the off-site plume and reduce it to safe drinking water standards known as Maximum Contaminant Levels (MCLs). At the same time, a plan was developed to treat the most heavily contaminated source areas. For the most part, LLNL pumps the contaminated groundwater to the surface, treats it through air strippers or granular activated carbon (GAC), and discharges the treated water. In some areas, highly contaminated soil is treated using soil vapor extraction technology. Originally, estimated cleanup time was 53-years: in 2011, LLNL estimated cleanup would not be completed until the year 2080 with a remaining cost of one billion dollars.

Depth to groundwater at the site varies from 130 feet in the southeast corner to 25 feet in the northwest corner. Municipal wells about two miles from the site supply Livermore residents; groundwater to the south and west is used for irrigation. Highly permeable channels carry groundwater, each separated from one another by a layer of non-saturated material that restricts vertical groundwater flow. These channels are known as hydrostratigraphic units (HSUs). Sediment layers that have hydraulic communication are grouped together as one HSU. As active remediation began and as time, experience and knowledge have progressed, LLNL has exceeded expectations about plume capture and mass removal. This is due in part to a much better understanding of the hydrogeology underlying the site and innovations in well-field management that allows LLNL to target source areas.

The site is currently divided into seven treatment areas. They are named Treatment Facility A (TFA), TFB, TFC, TFD, TFE, TFG, and TFH. Within TFH, there are three distinct treat areas: TF 406, TF 518, and TF Trailer 5475. [2] Four areas have soil

[2] Note that TF F was contaminated by fuel hydrocarbons in the soil, and was cleaned up by 1996. It is therefore not included in tables and charts

vapor extraction facilities. These facilities are designated Vapor Treatment Facility (VTF) D Helipad, VTFE Eastern Landing Mat, VTF518 Perched Zone and VTF5474. **Figure 2,** attached at the end of this paper, provides a diagram of the location of the treatment facilities. **Table 2** provides the cumulative volume of contaminants removed in each treatment area. Note that in 2016, about 44 kilograms (kg) of volatile organic compounds (VOCs) were removed from the subsurface, including 30 kg VOCs from groundwater and 14 kg of VOCs from soil vapor. Approximately 255 million gallons of groundwater were treated. The amount of contaminant mass removed accounts for less than two percent of the total mass removed since initiation of remedial action at the site.

Table 3: Treatment Facilities and Volume of Contaminants Removed (Cumulative)

Treatment Facility Area	Volume of Groundwater Extracted (Mgal)	Volume of VOC Removed from Groundwater (kg)	Volume of VOC Removed from Soil Vapor (kg)	Total Mass Removed (kg)
TFA	2,384	225	NA	225
TFB	585	90	NA	90
TFC	652	122	NA	122
TFD	1,328	933	105	1,038
TFE	492	253	162	415
TFG	103	13	NA	13
TFH*	202	45	1,315	1,364
Total	**5,746**	**1,681**	**1,586**	**3,269**

*TFH includes TF-406, TF-518, and TF-5475

A. Accomplishments in 2016

LLNL remediation activities in 2016 focused on enhancing and optimizing ongoing operations at treatment facilities. This included evaluation of technologies that "may" accelerate clean up of the source areas and address areas of co-mingled VOC and low-level tritium plumes.

Significant concentration declines were observed in several source areas where remedial operations have been performed for a decade or more, such as at the East Traffic Circle South source area. Elsewhere, elevated VOC concentrations remain, indicating areas where additional remedial efforts will likely be needed, such as in the southern TFD Hotspot source area. Major accomplishments are summarized below.

• Operated and/or maintained 28 groundwater treatment facilities and 8 soil vapor treatment facilities, 94 groundwater extraction wells, three groundwater injection wells, 13 dual extraction wells (i.e., both groundwater and soil vapor is extracted), and 34 SVE wells.

• Hydraulically controlled groundwater along the western and southern margins of the site, where concentrations declined or remained stable during the year.

• Installed 3 new soil vapor monitoring wells and 2 groundwater monitoring wells, as well as redeveloped 2 groundwater extraction wells.

• Continued the monitoring and analyzing treatability tests at TFD Helipad (bioremediation), TFE Eastern Landing Mat (thermally-enhanced remediation), and implemented a fourth treatability test at TFC Hotspot. This last treatability placed a thin matrix of zero-valent iron (ZVI) for in- situ VOC destruction. The emplacement used an innovative technique.

B. Issues

Issues 1 – 5 as described above also apply to the Main Site. In addition, the Main Site has the following unique issues.

1. Mixed Waste and Innovative Technology

In 2009, LLNL prepared a draft Feasibility Study on problems involving mixed chemical and radioactive waste. This problem came to light as some groundwater treatment facilities brought tritium-contaminated water to then surface together with water contaminated with chemicals. The treatment facilities, namely GAC, captured the chemicals and became radioactive at high enough levels to qualify as mixed waste. This FS was sent out for review, but it was later tabled: not because the problem was resolved, but because LLNL was experimenting with innovative technologies that may help resolve this problem. In 2010, LLNL began conducting treatability tests involving in-situ bioremediation, thermally enhanced remediation, pneumatic fracturing and in-situ chemical reduction using ZVI. TVC encourages investigation of small-scale experimental applications, as they may increase mass removal and may be more sustainable in the long run. The results of the treatability tests may identify alternative remedial approaches for other Livermore Site source areas. However, some of these technologies may not be appropriate for wider use and the community should be involved in those decisions.

Therefore, we think that the treatability studies should be concretely applied to the issue of resolving the mixed waste problem. Additionally, if treatability is going to be used, it must go through a fully transparent process.

TVC has brought this issue up numerous times with LLNL Environmental Staff and the regulatory agencies. We do not have any concrete commitments, as LLNL says that these studies take a long time, and may be tied to other issues than just the mixed-waste problem. Recognizing that the Treatability Studies do take some time to complete, we think that we are at a stage when the preliminary results can be tied together to develop a strategy for dealing with the mixed-waste issue.

2. Tritium

Tritium activities in ground water are largely below the 20,000 picocuries per liter (pCi/L) cleanup standard at Livermore Site wells.

In the Trailer 5475 area, tritium activities remained relatively high in two wells: one measuring 14,400 pCi/L in 2016 (down from a high of 21,400 pCi/L in 2012); a second measuring 11,800 pCi/L in 2016 (down from a high of 21,600 pCi/L in 2012).

In the Building 292 area, tritium activities continue to decline. Tritium where the highest activities onsite had previously been observed (24,000 pCi/L, October 2000), were 5,760 pCi/L in February 2013. The well has been dry since then. The most recent, highest tritium activity in the Building 292 area is less than100 pCi/L in 2014.

In the Building 419 area, DOE/LLNL installed a well to monitor tritium activities beneath the former Building 419 area. Tritium was detected in 2011 at approximately 60,000 pCi/L in bailed groundwater samples. In 2014, a same groundwater monitoring well detected tritium at 12,400 pCi/L. It has currently increased to 16,600 pCi/L (2016). In a piezometer, tritium was measured at15,500 pCi/L (2016).

In 2016, DOE/LLNL conducted a direct-push survey between former Building 419 and Building 511, and in the former Building 419 yard north of the monitoring well to delineate the distribution of tritium in soil and groundwater. One borehole sample measured 39,600 pCi/L, another boring had soil moisture tritium activities ranging from 72,885 and 18,381 pCi/L between the depths of 18 ft to 104 ft (LLNL states that if the pore space within the soil were fully saturated, these activities would range from 48,210 and 11,604 pCi/L). The highest detection occurred in a borehole at a depth of 15 ft, where the soil moisture activity was 93,347 pCi/L. (LLNL states the if the pore space within the soil were fully saturated, this activity would be 20,500 pCi/L).

IV. Community Involvement

For both sites, the remediation strategy must satisfy a number of criteria to be accepted by EPA. Among these criteria is Community Acceptance. However, community acceptance is not defined in the regulations. For community organizations such as Tri-Valley CAREs, this a powerful tool for effecting changes to the cleanup strategy. We developed acceptance criteria for the Site 300 and the Main Site, and we gauge remedial action plans and Records of Decision against these criteria. Below is a summary of community acceptance criteria.

- Complete the cleanup project in a timely manner.
- Cleanup levels should support many uses of the property that are unrestricted by environmental contamination.
- Cleanup levels should be set to the strictest state and federal government levels.

- Remedies that actively destroy contaminants are preferable.
- Radioactive substances should be isolated from the environment.
- Ecosystem protection should be balanced against the cleanup remedies.
- Decisions should not rely on modeling alone.
- Additional site characterization is needed and must be budgeted for over many years.
- DOE should establish a mechanism so that the public is involved in cleanup decisions until the site is cleaned up.
- Superfund factsheets, Proposed Plans and select other materials should be made available to the community in English and Spanish.
- Cleanup should be given priority over further weapons development.
- Any ongoing activities should be designed to prevent releases to the environment.

TVC meets regularly with the regulators and LLNL staff managing environmental cleanup at both sites. This provides us with a heads up on issues that are coming up, as well as providing an exchange where we can discuss technical and policy issues with the regulators. These meetings are extremely helpful for us; however, a wider community exchange is not available on a regular basis.

There are opportunities to get involved at both sites, and aside from listing them, we welcome your suggestions for increasing the level of involvement.

Opportunities include:

- The Superfund law allows public comment during the initial stages of study and the selection of a proposed plan to remediate the area. These are mostly complete. However, there are still areas for which public participation is legally required, including the selection of a remedy for the B-812 firing table at Site 300, the proposed plan to manage mixed waste at the Main Site, and any changes in the remedy. Changes in the remedy may include full implementation of one or more of the technologies that are under experiment at the Main Site.
- The Livermore Lab can conduct public workshops beyond those that are legally mandated.
- Every five years, a mandated Superfund Five-Year Review is compiled with the following general purpose: evaluate the implementation and performance of the selected remedy to determine whether it is protective of human health and the environment. In addition, the Five-Year Review identifies issues and/or deficiencies and identifies recommended actions, if necessary. Public comment is welcome for the Five-Year Reviews, although we do not believe that it is publicized.
- As a fundamental principle, it is important to ensure that cleanup remains a priority, and that the Livermore, Tracy and surrounding communities are consulted in decision-making.

Figure 1

Site 300 Site Map

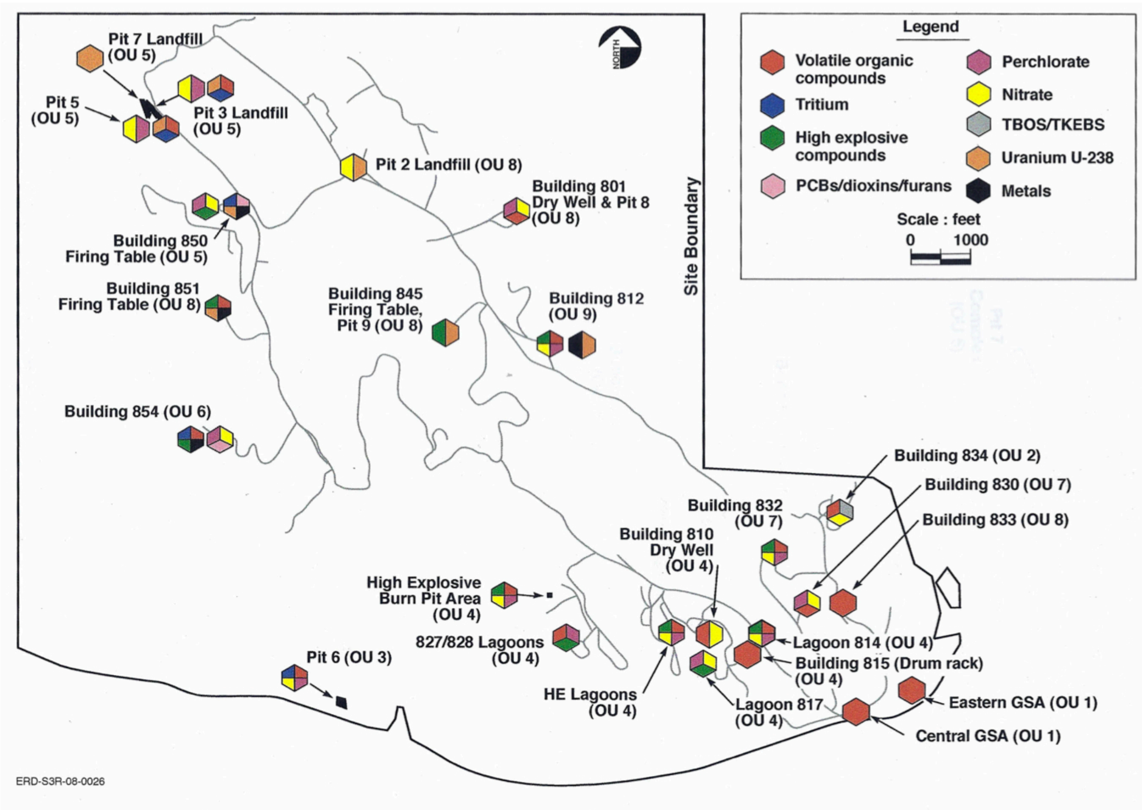
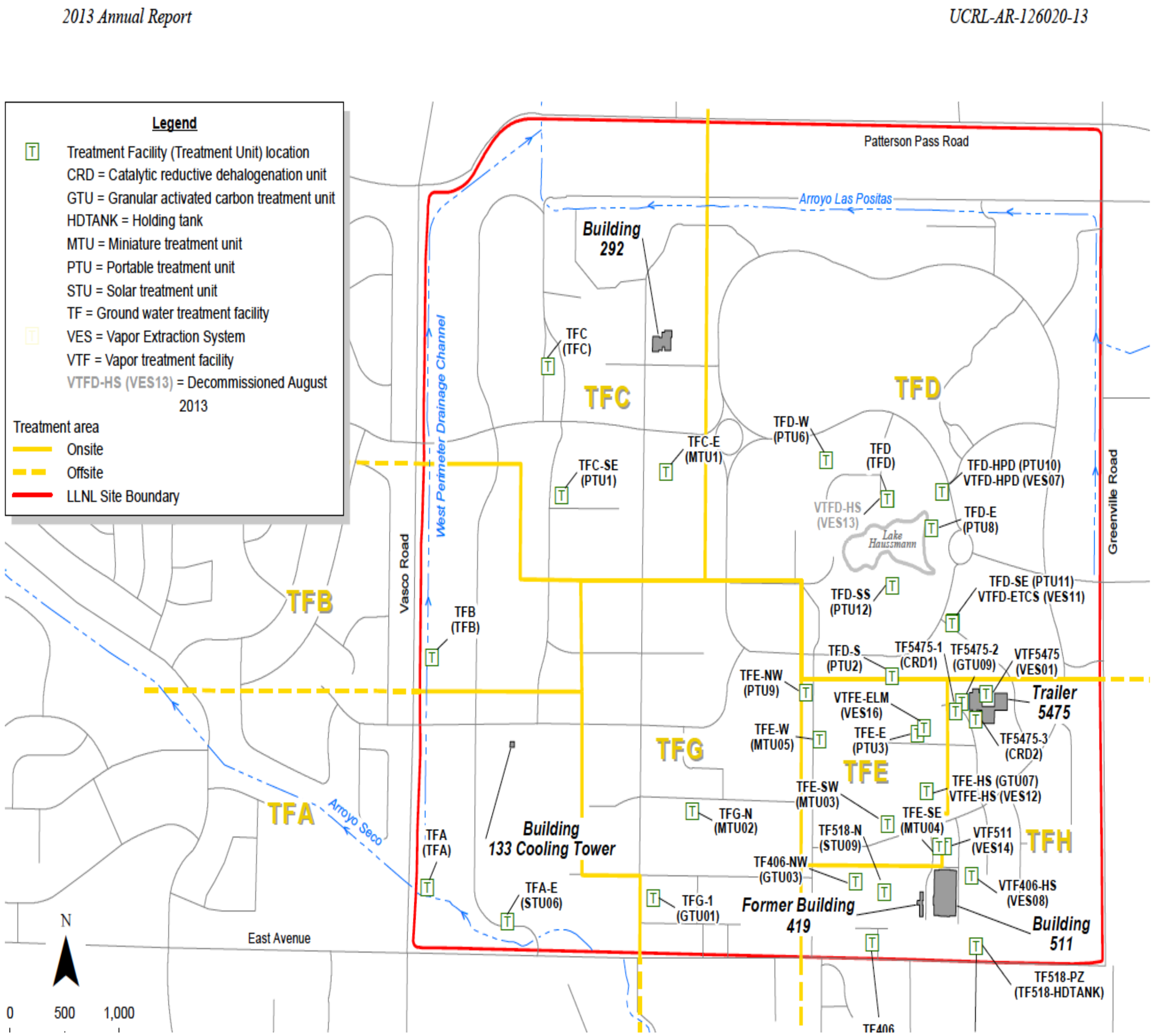


Figure 1-2. Site 300 release sites and Operable Units (OUs).

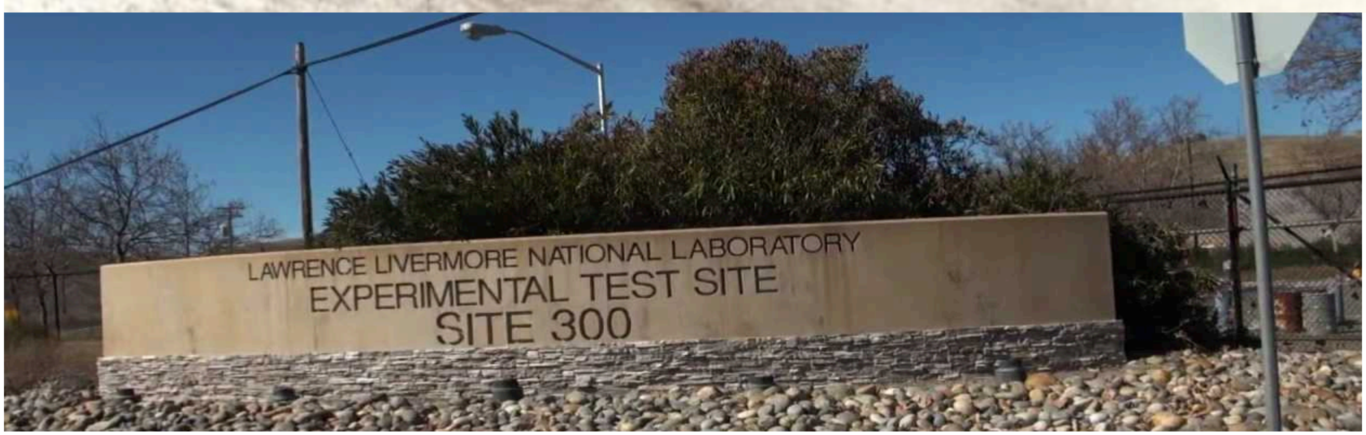
Release sites and contaminants of concern at Site 300 for surface soil, subsurface soil/rock, surface water, and ground water. UCAR 2009

Figure 2
LLNL Main Site Map



Hydrodynamic (bomb core) test on a firing table at Site 300, 1961. The bright "streaking" effect in the photo is likely from shards of pyrophoric metal, such as Uranium 238, hurtling through the air. U-238 is one of the contaminants of concern in the Site 300 Superfund cleanup. Photo: LLNL

This photo was obtained with permission from the Lawrence Livermore National Laboratory archivist by Tri-Valley CAREs, 4049 First St., Suite 139A, Livermore, CA 94551. More information at www.trivalleycares.org.



The above photo was obtained with permission from the Lawrence Livermore National Lab archivist by Tri-Valley CAREs, 4049 First St., Suite 139A, Livermore, CA 94551. Note the size of the buildings in the picture relative to the size of the test blast.

At left is a photo of the Site 300 sign on Corral Hollow Road near Tracy, CA. Note the drums to the right of the sign.