Appendix 1. Glossary of Environmental Health Terms

Absorption: How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.

Activity: The number of radioactive nuclear transformations occurring in a material per unit time. The term for *activity* per unit mass is specific activity.

Acute Exposure: Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.

Additive Effect: A response to a chemical mixture, or combination of substances, that might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

Adverse Health Effect: A change in body function or the structures of cells that can lead to disease or health problems.

Antagonistic Effect: A response to a mixture of chemicals or combination of substances that is **less** than might be expected if the known effects of individual chemicals, seen at specific doses, were added together.

ATSDR: The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.

Background Level: An average or expected amount or concentration range of a substance in a specific environment or, amounts that occur naturally in the-environment.

Background radiation: The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body.

Biota: Used in public health, things that humans would eat – including animals, fish and plants.

Body burden: The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP: See **C**ommunity **A**ssistance **P**anel**.**

Cancer: A group of diseases which occur when cells in the body become abnormal and grow, or multiply, out of control

Carcinogen: Any substance shown to cause tumors or cancer in experimental studies.

CERCLA: See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.

Chronic Exposure: A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Committed Effective Dose Equivalent (CEDE): The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues integrated over a specified time period (such as 50 or 70 years). The *committed effective dose equivalent* is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert—1 sievert equals 100 rem.)

Completed Exposure Pathway: See **Exposure Pathway**.

Community Assistance Panel (CAP): A group of people from the community and health and environmental agencies who work together on issues and problems at hazardous waste sites.

Comparison Value (CVs): Concentrations or the amount of substances in air, water, food, and soil that are, upon exposure, unlikely, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated. See Appendix 4 for the derivation of CVs.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): **CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. ATSDR was created by this act and is responsible for looking into the health issues related to hazardous waste sites.

Concern: A belief or question about substances in the environment that might cause harm to people.

Concentration: How much or the amount of a substance present in a certain amount of soil, water, air, or food.

Contaminant: See **Environmental Contaminant**.

Contaminant of (public health) concern: An environmental contaminant for which, (1) environmental concentrations exceed media-specific comparison values, or (2) has noted community health concerns, or (3) the quality and extent of sampling data with which to evaluate potential exposure and human health hazard is inadequate.

Curie (Ci): A unit of radioactivity. One *curie* equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product, daughter product, progeny: A new nuclide formed as a result of radioactive decay: from the radioactive transformation of a radionuclide, either directly or as the result of successive transformations in a radioactive series. A *decay product* can be either radioactive or stable.

Delayed Health Effect: A disease or injury that happens as a result of exposures that may have occurred far in the past.

Dermal Contact: A chemical getting onto your skin. (see **Route of Exposure**).

Dose: The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as “amount of substance(s) per body weight per day”.

Dose (for radioactive chemicals): The radiation *dose* is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment

Dose / Response: The relationship between the amount of exposure (dose) and the change in body function or health that result.

Duration: The amount of time (days, months, years) that a person is exposed to a chemical.

Environmental Contaminant: A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than that found in **Background Level**, or what would be expected.

Environmental Media: Usually refers to the air, water, and soil in which chemcials of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.

U.S. Environmental Protection Agency (EPA): The federal agency that develops and enforces environmental laws to protect the environment and the public's health.

Epidemiology: The study of the different factors that determine how often, in how many people, and in which people will disease occur.

Equilibrium, radioactive: In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

Exposure: Coming into contact with a chemical substance.(For the three ways people can come in contact with substances, see **Route of Exposure**.)

Exposure Assessment: The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.

Exposure Pathway: A model describing how a substance moves from its source (where it was released) to where and how people can come into contact with (or get exposed to) the chemical. ATSDR defines an exposure pathway as having 5 parts:

1. Source of Contamination,
2. Environmental Media and Transport Mechanism,
3. Point of Exposure,
4. Route of Exposure, and
5. Receptor Population.

When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.

Frequency: How often a person is exposed to a chemical over time; for example, every day, once a week, twice a month.

Half-life ($t_{½}$): The time it takes for half the original amount of a substance to decay or transform. In the environment, the *half-life* is the time it takes for half the original amount of a substance to change to another chemical form by bacteria, fungi, sunlight, or other chemical processes. In the human body, the *half-life* is the time it takes for half the original amount of the substance to change to another substance or by leave the body. In the case of radioactive material, the *half-life* is the amount of time necessary for one half the initial radioactive atoms to change or transform into other atoms (normally not radioactive). After two *half-lives*, 25% of the original radioactive atoms remain.

Hazardous Substance (Waste): Substances that have been released into the environment which could, under certain conditions, be harmful to people who come into contact with them.

Health Comparison Value: See Comparison Value.

Health Effect: ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Health Guideline: Doses such as MRLs and RfDs that are likely to be without any adverse health effects. Health guideline values are expressed in units of dose such as mg/kg/day or cancer risk values as inverse dose ($mg/kg/day^{-1}$).

Health Protective Dose: Doses calculated using health protective exposure factors and contaminant concentrations that are most likely greater than any real dose to a member of the community.

Indeterminate Public Health Hazard: The category is used in Public Health Assessment documents for sites where important information is lacking (missing or has not yet been gathered) about site-related chemical exposures.

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

Ionizing radiation: Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, gamma and x rays, and neutrons.

Isotopes: Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Identical chemical properties exist in *isotopes* of a particular element. The term should not be used as a synonym for "nuclide," because "isotopes" refers specifically to different nuclei of the same element.

LOAEL: **L**owest **O**bserved **A**dverse **E**ffect **L**evel. The lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.

Malignancy: See **Cancer**.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used as a predictor of adverse health effects.

NPL: The **N**ational **P**riorities **L**ist. (Which is part of **Superfund**.) A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious, uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

NOAEL: **N**o **O**bserved **A**dverse **E**ffect **L**evel. The highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.

No Apparent Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where exposure to site-related chemicals may have occurred in the past or is still occurring but the exposures are not at levels expected to cause adverse health effects.

No Public Health Hazard: The category is used in ATSDR's Public Health Assessment documents for sites where there is evidence of an absence of exposure to site-related chemicals.

Parent: A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Plume: A line or column of air or water containing chemicals moving from the source to areas further away. A plume can be a column or clouds of smoke from a chimney or contaminated underground water sources or contaminated surface water (such as lakes, ponds and streams).

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). For examples: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, the location where fruits or vegetables are grown in contaminated soil, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area; or a group of individual persons, or objects from which samples are taken for statistical measurements.

PRP: **P**otentially **R**esponsible **P**arty. A company, government or person that is responsible for causing the pollution at a hazardous waste site. PRP's are expected to help pay for the clean up of a site.

Public Health Assessment(s): See **PHA**.

Public Health Hazard: The category is used in ATSDR documents for sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects.

Public Health Hazard Criteria: PHA categories given to a site which tell whether people could be harmed by conditions present at the site. Each are defined in the Glossary. The categories are:

- Urgent Public Health Hazard
- Public Health Hazard
- Indeterminate Public Health Hazard
- No Apparent Public Health Hazard
- No Public Health Hazard

Quality factor (radiation weighting factor): The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses - on a common scale for all ionizing radiation - the approximate biological effectiveness of the absorbed dose.

Rad: The unit of absorbed dose equal to 100 ergs per gram, or 0.01 joules per kilogram (0.01 gray) in any medium [see dose].

Receptor Population: People who live or work in the path of one or more chemicals, and who could come into contact with them (See **Exposure Pathway**).

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is <u>not</u> likely to cause harm to the person.

Rem: A unit of dose equivalent. The dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by the quality factor. Rem is used only in the context of radiation safety, administrative, and engineering design purposes.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
- breathing (also called inhalation),
- eating or drinking (also called ingestion), and
- or getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The **S**uperfund **A**mendments and **R**eauthorization **A**ct in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from chemical exposures at hazardous waste sites.

Sample: A representative individual or item from a larger group or population, or finite part of a statistical population.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an Exposure Pathway.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Superfund Site: See **NPL**.

Survey: A way to collect information or data from a group of people (**population**). Surveys can be done by phone, mail, or in person. ATSDR cannot do surveys of more than nine people without approval from the U.S. Department of Health and Human Services.

Synergistic effect: A health effect from an exposure to more than one chemical where the combined effect of the chemicals together is greater than the effects of the chemicals acting by themselves.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Urgent Public Health Hazard: This category is used in ATSDR's documents for sites that have certain physical features or evidence of short-term (less than 1 year), site-related chemical exposure that could result in adverse health effects and require quick intervention to stop people from being exposed.

Appendix 2. Summary of Public Health Assessment on "Community Exposures to the 1965 and 1970 Accidental Tritium Releases"

http://www.atsdr.cdc.gov/HAC/PHA/livermore4/lms_toc.html

Summary

The Lawrence Livermore National Laboratory (Livermore site, hereafter referred to as LLNL) is a multi-program research facility owned by the U.S. Department of Energy (DOE) and operated by the University of California. LLNL was placed on the Superfund National Priority List (NPL) in 1987. The Agency for Toxic Substances and Disease Registry (ATSDR) is required to conduct a public health assessment of all facilities proposed for listing on the NPL. During the LLNL public health assessment process, potential off site exposure to tritium released by LLNL has been identified as a specific community concern (CDHS 2003). In response to this concern, ATSDR convened an expert panel to assess tritium monitoring and dosimetry issues at the Lawrence Livermore National Laboratory (LLNL) and Savannah River Site (SRS) facilities. Although the expert panel determined that approximately 80% of the total radiologic releases from the LLNL facility occurred during two accidents in 1965 and 1970, they did not explicitly evaluate potential short-term tritium doses from those accidental releases. This public health assessment will specifically evaluate potential short-term tritium doses from the accidental tritium releases to determine whether these releases presented a public health hazard to members of the Livermore community.

There are insufficient historic environmental sample data available to adequately evaluate the total tritium doses from these releases. Consequently, this evaluation will use modeled data combined with available measured data to estimate past exposure concentrations and doses. This evaluation focuses on exposure doses to maximally exposed individuals. Available meteorological data indicate that for the 1965 release winds were blowing to the east-northeast at about 3 meters per second (m/s). The maximally exposed residence is more than 1 mile from the tritium facility for the 1965 release (January 20, 1965) with an estimated maximum of 18 people living in the plume area to a distance of 2 miles from the tritium facility. During the 1970 release, winds were blowing to the north-northeast at about 1.5 m/s and the closest residence was also more than 1 mile from the tritium facility. An estimated maximum of 55 people were living in the area of the 1970 plume to a distance of 2 miles from the tritium facility.

Tritium is a radioactive isotope of hydrogen. As hydrogen, tritium might be present in the environment as any chemical form or compound of hydrogen, including hydrogen gas (HT), tritiated water (HTO), or as various organic compounds (known generically as organically bound tritium; OBT). The specific absorbed dose from tritium exposure depends on the chemical form of the tritium that is ingested or inhaled or absorbed. The radiologic dose is determined by how many tritium decays occur in the body after intake. As hydrogen gas, very little tritium is absorbed and retained in the body following exposure. Consequently, very few tritium decays occur in the body from HT inhalation. Conversely, most of the tritium taken in as water or HTO (including a lesser OBT contribution) is absorbed and retained in the body with an effective half-life that varies from 1 to about 40 days.

Both of the accidental tritium releases from LLNL occurred in the HT form. Consequently, there is very little radiologic dose from direct inhalation of the HT plumes. However, HT is converted by soil microbes into the HTO form of tritium. Subsequent exposure to HTO creates the potential for much more significant radiologic doses. This health assessment is based on potential exposures to each of the significant tritium forms as it moves through the environment. As there are insufficient environmental measurements of each of the tritium forms in air following the accidental releases, this health assessment relies on air dispersion and exposure models to evaluate potential historic short-term tritium exposures. Specifically, this assessment uses the RASCAL air dispersion model to determine concentrations of airborne HT in areas of potential exposure. The Industrial Source Complex air model is used to estimate concentrations of HTO in areas of potential exposure due to emission of HTO from the soil. To accommodate the uncertainty inherent in each of these modeling steps, a Monte Carlo simulation is conducted to determine the most likely tritium doses from each type of exposure.

The estimated total tritium doses include direct inhalation of the HT plumes, inhalation of HTO following emission from soil, direct absorption of HTO through skin, ingestion of foods containing HTO and OBT, and also sum potential chronic exposures from ongoing (past) LLNL tritium releases. The estimated maximum doses (to a child; 95^{th} percentile) are less than 149 millirem/year (mrem/year) for both the 1965 and 1970 releases. The more likely average doses are about 42 mrem/year. On the basis of current peer-reviewed scientific literature, the one-time exposure to tritium resulting in a committed effective adult dose of 42 mrem (0.42 mSv) or a child dose of 149 mrem (1.49 mSv) from the LLNL accidental HT releases is not expected to be a public health hazard.

While some public exposure to tritium probably did occur as a result of the accidental releases of tritium gas (HT), estimated maximum exposures are below levels of public health concern and no adverse health effects would be expected. This conclusion is based on tritium doses developed from analytical models and is supported by human biological samples that showed no detectable tritium from either LLNL workers or affected community members. The above doses represent the 95^{th} percentile doses on the basis of health protective exposure and dosimetry assumptions. It is unlikely that actual doses approached these conservatively estimated values.

All of the adverse health effects from exposures to tritium (or low-energy external gamma radiation or x-rays) that we found in the medical literature occurred at levels higher than the exposure levels we estimated for people living near the LLNL facility at the time of the accidental releases. Therefore, we conclude that inhalation and ingestion of tritium from the acute releases that occurred in 1965 and 1970, plus the annual contribution from chronic or long-term exposures, were never a public health hazard. Because these historic accidental releases are below levels of public health concern, no specific recommendations are warranted.

Appendix 3. Summary of Public Health Assessment on "Plutonium 239 in Sewage Sludge Used as a Soil or Soil Amendment in the Livermore Community"

http://www.ci.livermore.ca.us/CADHS/ATSDR_PHA_2-11-2003.pdf

Summary

Potential off site exposure to plutonium 239 (Pu 239) in sewage sludge released from the Lawrence Livermore National Laboratory (LLNL) to the Livermore Water Reclamation Plant (LWRP) has been identified as a specific community concern. This public health assessment will address that concern by evaluating the public health implications of potential radiological doses from exposures to the Pu 239-contaminated sludge. In order to evaluate the public health implications of the historical distribution of Pu-contaminated sludge to the Livermore community three specific questions are addressed: 1) What concentrations of Pu 239 in sludge would produce doses of public health concern? 2) Were the concentrations of Pu 239 in the sludge distributed to the public by LWRP greater than the levels of potential health concern? 3) Do the available data provide an adequate basis for this public health assessment?

Doses of public health concern are defined as the human intake of Pu 239 (or other radionuclides) via ingestion, inhalation, or external exposure at levels that are capable of causing adverse health effects, such as cancer, other illnesses, or death. The ATSDR minimal risk level (MRL) of 100 mrem/year (above background) is used as a basis for determining radiological doses of public health concern. No adverse health effects have ever been documented from radiological doses of 100 mrem/year or less (above background). The average background radiation dose throughout the US is about 360 mrem/year. The MRL represents a dose of less than 1/3 of normal background.

Several sources of historical monitoring data are available to assess the historic concentrations of Pu 239 in sludge produced at the LWRP. These data include gross alpha concentrations in LLNL effluent to the LWRP, gross alpha concentrations in both digester and processed sludge, and Pu 239 concentrations in soils of disposal areas for contaminated sludge. Past studies have evaluated the potential radiological doses from exposure to Pu 239-contaminated sludge. These studies have assumed different exposure scenarios, including LWRP workers responsible for tilling and spreading the contaminated sludge, residents living adjacent to the sludge disposal area, children playing in sludge-contaminated areas, and adults gardening in and consuming food crops grown in contaminated-sludge soils.

The Pu 239-contaminated sludge, released from the LLNL to the LWRP, and distributed to the Livermore community represents a completed exposure pathway. The route or process of human uptake of the Pu 239 occurs via incidental ingestion and inhalation during the use, transport, or handling of the sludge, or the soil where the sludge was placed, or ingestion of vegetation grown in the sludge-amended soil. The calculation of radiological doses from a long-lived isotope such as Pu 239 is very complex due to the partitioning, retention, and decay of the isotope and each of its decay products within the environment and the different organs in the human body. For this

health assessment, radiological doses from exposure to the Pu 239 contaminated sludge are calculated using RESRAD 6.2.1**.**

A soil Pu 239 concentration (100 percent sludge cover) of 816 pico Curies per gram (pCi/g; 1 pCi=1x 10^{-12} curies; averaged over an entire exposure area or residential yard) is required to produce a dose of 100 mrem/year, as calculated using RESRAD. This calculation includes health-protective exposure factors and includes ingestion of soil and garden crops, inhalation of dust, and external exposure. This calculation also assumes that the contaminated area covers an area of ½ acre to a depth of 6 feet, ½ of the area is unvegetated, and ½ of the resident's food is grown on the contaminated area. Considering that it would take 108 pick-up truck loads of sludge to cover a 1/2 acre lot (to a 3 inch depth), such an exposure scenario, although possible, is very unlikely.

A nearly complete historical record of LWRP gross alpha concentrations for the period of 1960 through 1973 (analyzed by the California Department of Public Health; CDPH) indicates that maximum digester sludge concentrations were less than 300 pCi/g (monthly average values). The average monthly gross alpha concentration of digester sludge measured by LLNL was 606 pCi/g (June 1967; average of digesters 1 and 2). The CDPH digester sludge values show two distinct peaks corresponding with the 1964 and 1967 release episodes (297 pCi/g and 258 pCi/g, CDPH data, respectively). Gross alpha concentrations of LLNL effluent into the Livermore sewer system show the same peaks and provide supplementary data for those periods during which digester concentrations were not collected or analyzed. Collectively, the measured digester sludge data and the LLNL analyzed effluent data indicate that the 1964 and 1967 release episodes represent the worst-case sludge concentrations.

As the concentrations of Pu 239 in processed sewage sludge following the 1964 episode of maximum digester sludge concentration were less than 816 pCi/g, it follows that the maximum Pu 239 concentrations in sludge were below levels of health concern. Although sludge concentrations following the 1967 event are not available, processed sludge gross alpha concentrations following the 1964 release (297 pCi/g digester sludge values) were approximately 60 pCi/g. This indicates that digester sludge gross alpha concentrations are considerably reduced during the treatment process. As processed sludge is further milled and mixed before disposal, it is expected that processed sludge concentrations would be additionally reduced before distribution to the public.

Several areas where contaminated sludge was placed have been sampled for Pu 239 concentrations. These areas include Big Trees Park, residential yards of former LLNL employees, and a test garden on the LLNL facility. Maximum Pu 239 concentrations of these locations were less than 2 pCi/g. Although the initial sludge concentration of most of these areas is unknown, sludge and soil sampling at the LLNL test garden indicated that Pu 239 concentrations in applied sludge are reduced by a factor of more than 5 in the resulting soil. This indicates that tilling and mixing of applied sludge will additionally reduce residential soil Pu 239 concentrations.

Assuming that the available gross alpha concentrations in LWRP sludge and LLNL sewer

effluent are a reasonable substitute for direct Pu 239 measurements, the available data clearly indicate that

the Pu 239-contaminated sludge does not result in radiological doses of public health concern. Monthly nuclide specific and gross alpha monitoring data for 1973 indicate that gross alpha concentrations overestimate Pu 239 concentrations. Consequently, the use of gross alpha concentrations as a proxy for Pu 239 concentrations is a health protective assumption.

No single data set is adequate for making the above public health determinations. There is not a consistent time series of Pu 239 or gross alpha concentrations in processed sludge. Similarly, there are gaps in the digester sludge measurements, and the LLNL effluent data do not provide specific levels of sludge contamination. However, collectively, the available data do provide an adequate basis for public health assessment. The trends in the different data values support and reinforce the individual data sets. Additionally, the health protective assumptions used in calculating doses provide additional assurance for the health conclusions. The following conclusions are based on our current knowledge of radiation health effects and the data reviewed and evaluated in this health assessment:

1. Pu 239 from LLNL was released to the Livermore sewer system and resulted in the contamination of LWRP sludge which may have been distributed to the Livermore community resulting in areas of above background soil concentrations of Pu 239.
2. Using health protective exposure assumptions, radiological doses from maximum measured concentrations of digester sludge are below levels of health concern. This evaluation assumes that digester sludge gross alpha concentrations represent Pu 239 concentrations and that digester sludge is spread uniformly over an entire residential yard. Pu 239 concentrations of processed sludge distributed to the Livermore community are estimated to be more than 10 times lower than digester sludge concentrations.
3. The available data and evaluations provide an adequate basis for these public health conclusions. Any additional sampling data will be subject to the same types of uncertainties as existing historical data.

Based on the above conclusions, the historic distribution of Pu-contaminated sewage sludge is determined to be **no apparent public health hazard**. No apparent public health hazard means that while exposure may have occurred, or may still be occurring, the resulting doses are unlikely to cause cancer, other illnesses, or death. As the potential maximum radiological doses from exposures to Pu 239-contaminated sludge are below levels of health concern, ATSDR has no recommendations concerning additional soil sampling in areas of known or unknown sludge distribution. Because the community may still have unresolved concerns about this issue, ATSDR offers the following recommendations:

1. Develop and present educational materials, based on the information included in this public health assessment, to the Livermore community.
2. Continue current monitoring of Pu 239 (and other contaminant) concentrations in LLNL effluent and the LWRP sewage treatment system (as stipulated by existing discharge permit requirements).

Appendix 4. Health Guidelines, Comparison Values, and Exposure Factors

When a hazardous substance is released to the environment, people are not always exposed to it. Exposure happens when people breathe, eat, drink, or make skin contact with a contaminant. People can also be exposed to radioactive contaminants by direct irradiation—if they get close to the radioactive material and if the contaminants are present at high concentrations.

Several factors determine the type and severity of health effects associated with exposure to contaminants. Such factors include exposure concentration, frequency and duration of exposure, route of exposure, and cumulative exposures (i.e., the combination of contaminants and routes). Once exposure takes place, individual characteristics—such as age, sex, nutritional status, genetics, lifestyle, and health status—influence how that person absorbs, distributes, metabolizes, and excretes the contaminant. These characteristics, together with the exposure factors discussed above and the specific toxicological effects of the substance, determine the health effects that may result.

ATSDR considers these physical and biological characteristics when developing health guidelines. Health guidelines provide a basis for evaluating exposures estimated from concentrations of contaminants in different environmental media (soil, air, water, and food) depending on the characteristics of the people who may be exposed and the length of exposure. Health guideline values are in units of dose such as milligrams (of contaminant) per kilogram of body weight per day (mg/kg/day).

ATSDR reviews health and chemical information in documents called toxicological profiles. Each toxicological profile covers a particular substance; it summarizes toxicological and adverse health effects information about that substance and includes health guidelines such as ATSDR's minimal risk level (MRL), EPA's reference dose (RfD) and reference concentration (RfC), and EPA's cancer slope factor (CSF). ATSDR public health professionals use these guidelines to determine a person's potential for developing adverse non-cancer health effects and/or cancer from exposure to a hazardous substance.

An MRL is an estimate of daily human exposure to a contaminant that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified duration of exposure (acute, less than 15 days; intermediate, 15 to 364 days; chronic, 365 days or more). Oral MRLs are expressed in units of milligrams per kilogram per day (mg/kg/day); inhalation MRLs are expressed in micrograms per cubic meter ($\mu g/m^3$). MRLs are not derived for dermal exposure.

RfDs and RfCs are estimates of daily human exposure, including exposure to sensitive subpopulations that are likely to be without appreciable risk of adverse non-cancer health effects during a lifetime (70 years). These guidelines are derived from experimental data and lowest-observed-adverse-effect levels (or no-observed-adverse-effect levels), adjusted downward using uncertainty factors. The uncertainty factors are used to make the guidelines adequately protective

of public health. RfDs and RfCs should not be viewed as strict scientific boundaries between what is toxic and what is nontoxic.

For cancer-causing substances, EPA established the cancer slope factor (CSF; EPA 2004). A CSF is used to determine the number of excess cancers expected from maximal exposure for a lifetime.

Health comparison values (CVs) are estimated contaminant concentrations that are unlikely to cause detectable adverse health outcomes when these concentrations occur in specific media. CVs are used to select site contaminants for further evaluation. CVs are calculated from health guidelines and are presented in media specific units of concentration, such as micrograms/liter (µg/l) or ppm. CVs are calculated using conservative assumptions about daily intake rates by an individual of standard body weight. Because of the conservatism of the assumptions and safety factors, contaminant concentrations that exceed comparison values for an environmental medium do not necessarily indicate a health hazard.

For nonradioactive chemicals, ATSDR uses comparison values like environmental media evaluation guides (EMEGs), cancer risk evaluation guides (CREGs), reference dose (or concentration) media evaluation guides (RMEGs), and others. EMEGs, since they are derived from MRLs, apply only to specific durations of exposure. Also, they depend on the amount of a contaminant ingested or inhaled. Thus, EMEGs are determined separately for children and adults, and also separately for various durations of exposure. A CREG is an estimated concentration of a contaminant that would likely cause, at most, one excess cancer in a million people exposed over a lifetime. CREGs are calculated from CSFs. Reference dose (or concentration) media evaluation guides (RMEGs) are media guides based on EPA's RfDs and RfCs.

EPA's maximum contaminant levels (MCLs) are maximum contaminant concentrations of chemicals allowed in public drinking water systems. MCLs are regulatory standards set as close to health goals as feasible and are based on treatment technologies, costs, and other factors.

For radiological contaminants, ATSDR uses information on radiation exposure and its effects prepared by federal agencies, including EPA, DOE, and the US Nuclear Regulatory Commission. The agency also uses other publicly available data sources and recommendations on radiation dose limits. The National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation are a few of the sources.

ATSDR uses standard or site specific intake rates for inhalation of air and ingestion of water, soil, and biota. These intake rates are specified in the pathway specific sections of the PHA. The dose calculation equations, and our assumptions about exposure factors, are derived from the ATSDR Public Health Assessment Guidance Manual (ATSDR 1992a) or from the EPA Exposure Factors Handbook (EPA 1999). For screening purposes, ATSDR often uses a health protective estimate of the maximum contaminant concentration (95^{th} percentile or maximum measured concentration)

detected in a specific medium at a site to identify contaminants requiring specific exposure evaluations; using the maximum concentration results in a more protective evaluation. When unknown, the biological absorption of a substance within the human body is assumed to be 100%.

Doses calculated using health protective exposure factors and environmental concentrations are considered "health protective doses" because it is unlikely that any real community exposures are greater than the calculated doses and are most likely to be less than the health protective doses.

After estimating the potential exposure at a site, ATSDR identifies the site's "contaminants of concern" by comparing the exposures of interest with health guidelines, or contaminant concentrations with comparison values. As a general rule, if the guideline or value is exceeded, ATSDR evaluates exposure to determine whether it is of potential health concern. Sometimes additional medical and toxicological information may indicate that these exposures are not of health concern. In other instances, exposures below the guidelines or values could be of health concern because of interactive effects with other chemicals or because of the increased sensitivity of certain individuals. Thus additional analysis is necessary to determine whether health effects are likely to occur.

Exposure doses via ingestion are calculated on the basis of the following equation:

Dose (Ingestion) = (Chemical Conc. x IR x EF x ED) / (BW x AT)

Where:

Chemical Conc.	=	concentration of each contaminant (in mg/g, μg/g, mg/L, or μg/L)
IR	=	ingestion rate (in grams/day or liters/day)
EF	=	exposure frequency in days per year
ED	=	exposure duration in years
BW	=	body weight in kilograms
AT	=	averaging time in days

For soil and sediment doses, we take an additional step to determine exposure via dermal absorption, with the total dose being the sum of the ingestion dose and the dermal dose.

Dose (Dermal) = (Chemical Conc. x ABS x TSA x EF x ED) / (BW x AT)

Where all factors are as above except:

ABS	=	a chemical-specific absorption or bioavailability factor (unitless)
TSA	=	total soil adhered in milligrams (skin surface area x soil adherence value)

Once we have calculated the dose (in mg/kg/day) for a contaminant, we evaluate that contaminant's non-cancer and cancer health effects. For the former, we compare the dose with studies that have investigated the health effects of exposure to the contaminant. For the latter, we multiply the dose by the pathway-specific CSFs which are expressed in units of inverse dose—that is, $(mg/kg/day)^{-1}$.

Excess Cancer Risk = Dose (mg/kg/day) x Cancer Slope Factor $(mg/kg/day)^{-1}$

The excess cancer risk is the expected increase in cancer risk due to contaminant exposure. All of the uncertainties and health-protective exposure assumptions associated with the dose calculations are included in the risk estimation, as well as the uncertainty in deriving the CSF.

Appendix 5. Background Data and Procedures Related to Evaluation of Ground Water Contaminants

Estimated Contaminant Concentrations for Past Ground Water Exposures

Volatile organic compound (VOC) contamination in ground water was discovered at LLNL in 1983. Twenty off site wells were sampled for VOCs in December 1983 with detectable concentrations in eight wells and four wells had concentrations exceeding drinking water guidelines (Weiss Associates, 1985). Residents were provided bottled water and several residences were later plumbed to the Livermore water system (Weiss Associates, 1985; Hoffman, 2000). This Appendix will evaluate the measured VOC distributions and trends to determine whether concentrations prior to 1983 could have been higher than the post-1983 measured values, and if so, provide estimates of the maximum concentrations and durations of exposure.

Several VOCs were detected in those analyses with only PCE and TCE exceeding ATSDR health comparison values. This evaluation will focus on PCE and TCE, however, it will also compare trends and distributions of other detected VOCs to determine if prior concentrations may have exceeded ATSDR health comparison values. In addition to TCE and PCE, boron, chromium, chromium-6, manganese, and nitrate have also been identified as contaminants of concern (Section 2). Even though these contaminants may result from off site or natural sources, it is necessary to determine if potential exposures were at levels of public health concern. Consequently, the distributions of all contaminants of concern will be evaluated to determine the highest probable exposure doses and exposure durations.

Boron, chromium (total), manganese, and nitrate have either high background concentrations or have multiple off site sources such that areas of high concentration are widely distributed and do not have a distinct LLNL source. There has also been less frequent monitoring of these contaminants such that most wells do not have a consistent time-series of analytical results. Upper-bound concentrations for calculating exposure doses are based on the 95^{th} percentile of both on and off site data values (Table A-1). A lifetime (70 year) exposure duration is assumed for these non site specific contaminants.

Hexavalent chromium also appears to have multiple on site and off site sources but high concentrations are assumed to be site-related due to its use and release from the LLNL cooling system. However, the most significant concentrations of off site chromium-6 are located in the vicinity of the Arroyo Los Positas plume and may be due to an off site source. The upper-bound concentration for calculating exposure doses is based on the 95^{th} percentile of both on and off site data values (Table A-1). Because exposure may be related to LLNL releases, the chromium-6 exposure duration cannot exceed the operational history of LLNL and is assumed to be 30 years.

Estimation of PCE and TCE exposure concentrations and durations is problematic due to the truncated nature of the monitoring data. No measured contaminant concentrations are available prior to 1983. For this health assessment, measured contaminant concentrations along the down-

-gradient trend of the contaminant plumes will be used to estimate upper bounds for calculating maximum potential exposure doses.

Health-conservative variables for all parameters such as ingestion amounts, duration of exposure, and proportion of water from the contaminated wells will be used in all calculations. Estimation of contaminant concentrations prior to establishment of measurements will be accomplished by including measured contaminant values from on site wells that are closer to the contaminant sources than off site drinking water wells. Exposure doses will be calculated from the 95th percentile distribution (lognormal probability distribution) of measured contaminant concentrations. This procedure assumes that the maximum contaminant concentration in a down-gradient drinking water well cannot be higher than the measured concentrations in up-gradient wells closer to the contaminant sources. If the worst-case exposure estimates from this procedure identify exposures of health concern, additional dose evaluation techniques will be employed.

PCE and TCE have different off site concentrations distributions as illustrated in Figures A-2 and A-3 (respectively). While TCE is much more widespread and has higher on site concentrations than PCE, the primary off site TCE plume is located along Arroyo Los Positas and probably originates in the industrial park north and west of Vasco and Patterson Pass Roads. A smaller, lower concentration plume that originates from an LLNL source, joins or underlies the off site plume (these plumes may be vertically separated with the LLNL plume underlying the Richmond Lox plume). Another LLNL-originated TCE plume occurs in the vicinity of Arroyo Seco north and west of Vasco Road and East Avenue. Figure A-3 shows the annual maximum concentrations of TCE in a number of residential and monitor wells (note that the concentration or "Y" axis uses a logarithmic scale).

Rapidly increasing and then decreasing TCE concentrations with a maximum of 110 ppb (in 1985) occur in the Zone 7 monitor well 11A1. Concentrations in other wells are less than 40 ppb but in several wells the annual trend is decreasing at the time that monitoring began (i.e., wells 11R81, W-109, and W-143). Contaminant trends after 1989 reflect the installation and operation of extraction wells used to pump and treat the contaminated ground water. Several other wells have an intitally increasing trend of maximum TCE concentrations (W-001A, W-002, and W-143), however, the increasing trend in W-143 may reflect the influence of the remedial extraction wells. Even though there are no drinking water wells located in the vicinity of the Arroyo Los Positas plume, TCE concentrations from Zone 7 monitor well 11A1 are included in the calculation of the TCE probability distribution to ensure that potentially higher pre-1983 values are represented. Note that annual maximum values from wells W-001, W-001A, and W-143 are much lower than well 11A1 values and do not show consistent increasing or decreasing trends. The geometric mean of all TCE values plotted in Figure A-3 is 5.6 ppb and the 95th percentile value is 45.2 ppb which will be used in estimating exposure doses.

PCE concentrations at wells along the Arroyo Seco plume are shown in Figure A-2 and include all
of the wells with known exposure (Table A-2). Well 11R5 (11R81) is the off site well with the

highest measured PCE value. Note that concentration trends for wells 11J2 and 11R5 are decreasing after 1983 which suggests that concentrations before 1983 may have been higher. The trends for 11Q2 and 11Q3 which are located down-gradient of 11R5 are increasing after 1983 which indicates that the plume maxima from well 11R81 had not reached 11Q2/3 by 1983. PCE concentrations at the maximum on site source location, well W-116, are stable to slightly increasing during the 1980s. This suggests that pre-1983 PCE concentrations at the off site residential wells, including well 11R5, were not significantly higher than measured, post 1983 values. PCE doses are estimated from the well 11R5 concentrations. The geometric mean of all well 11R5 PCE values (Table A-2) is 241 ppb and the 95th percentile value is 511 ppb which is greater than the highest measured concentration (490 ppb).*

The PCE and TCE concentration trend data included in Figures A-2 and A-3 do not provide conclusive evidence concerning the potential durations of exposure. Although both figures show some wells with apparent pulses of higher concentrations, it is also possible that lower concentrations may have been present for many years. Considering that the primary VOC sources may have occurred from activities of the World War II-era Livermore Air Station, a worst-case estimate of 30 years exposure duration will be used for calculating PCE and TCE exposure doses.

Table A-1. Concentrations and potential exposure durations for preliminary contaminants of concern for the ground water pathway.

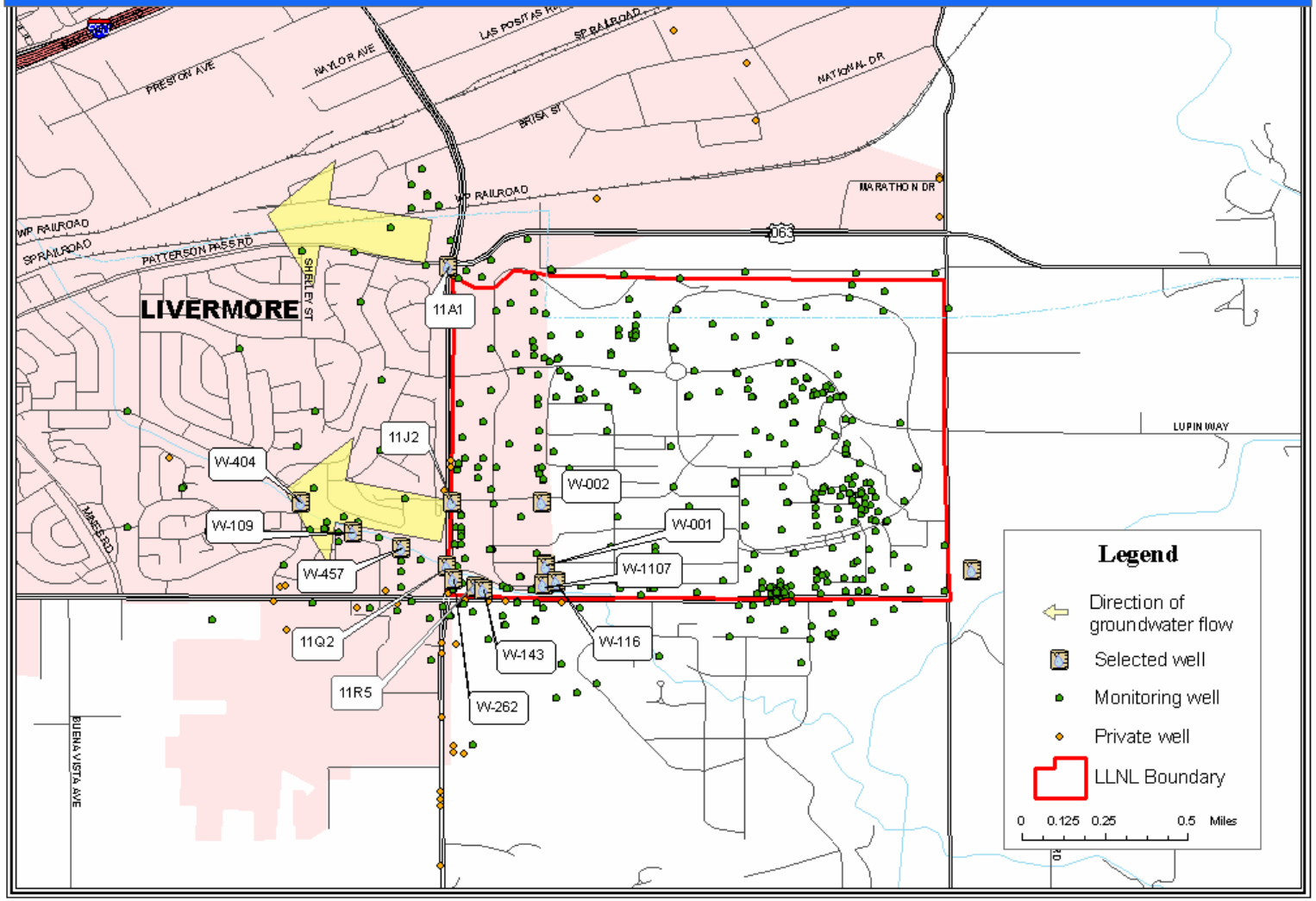
Contaminant	Geometric Mean ppb	95th Percentile ppb	Exposure Duration
Benzene	34	1,034	30 yrs.
Boron	733	3,097	Lifetime (70 yrs.)
Chromium (total)	21	83	Lifetime (70 yrs.)
Chromium (hexaval.)	23	75	30 yrs.
Manganese	138	2,009	Lifetime (70 yrs.)
Nitrate	21,318	80,121	Lifetime (70 yrs.)
PCE	241	511	30 yrs.
TCE	6	45	30 yrs.

* The on site wells W-116 and W-1107 (Figures A-1, A-2) had higher PCE concentrations than the down-gradient 11R5 well. However, both wells were located in the PCE source area and were screened at shallower and more restricted depths than 11R5 (86-91 and 74-88 feet vs. 125-325 feet, respectively). Because the PCE source monitor wells were specifically located to find the maximum PCE source concentrations, it is very unlikely that well 11R5, which was designed to maximize water production, ever had similar PCE concentrations.

Table A-2. Measured PCE concentrations in off site residential wells (ppb). < symbol indicates non-detections. Note that well 11R5 had the highest concentrations and was destroyed in 1987.

Well #	1983	1984	1985	1986	1987	1988	1989	1990	1991	1997
11A1	<1		<0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 1.6 1.7	0.7 <0.5 0.7	<0.5				
11J1	<1		<1 <0.5 <1 <0.5 <0.5 <1 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5 <0.5 <0.5 <0.5	<0.5 <0.5 <0.5	<0.5				
11J2	100	48	23 22 19	20 26 17 8.9	21 15 12	8.8 6.2	5.7 7.8	4.5 4.4	3.4	<0.5 <0.5
11Q2	2	3	2.4 3.3 4.5 3.2 1.5	4.5 4.2 4.5 6.6 4.8	5.8 4.8 5.7 86	14 28				
11Q3	<1	<1	2.4 3.7 8.7 18 83	15 14 17 19	18 29 69					
11R5	490 310	200 270 250 110	210							

Figure A-1. Locations of private and monitor wells used to assess LLNL-specific ground water contamination. PCE and TCE concentrations from the labeled wells are presented in Figures A-2 and A-3. Available information on the private wells is presented in Table A-2.



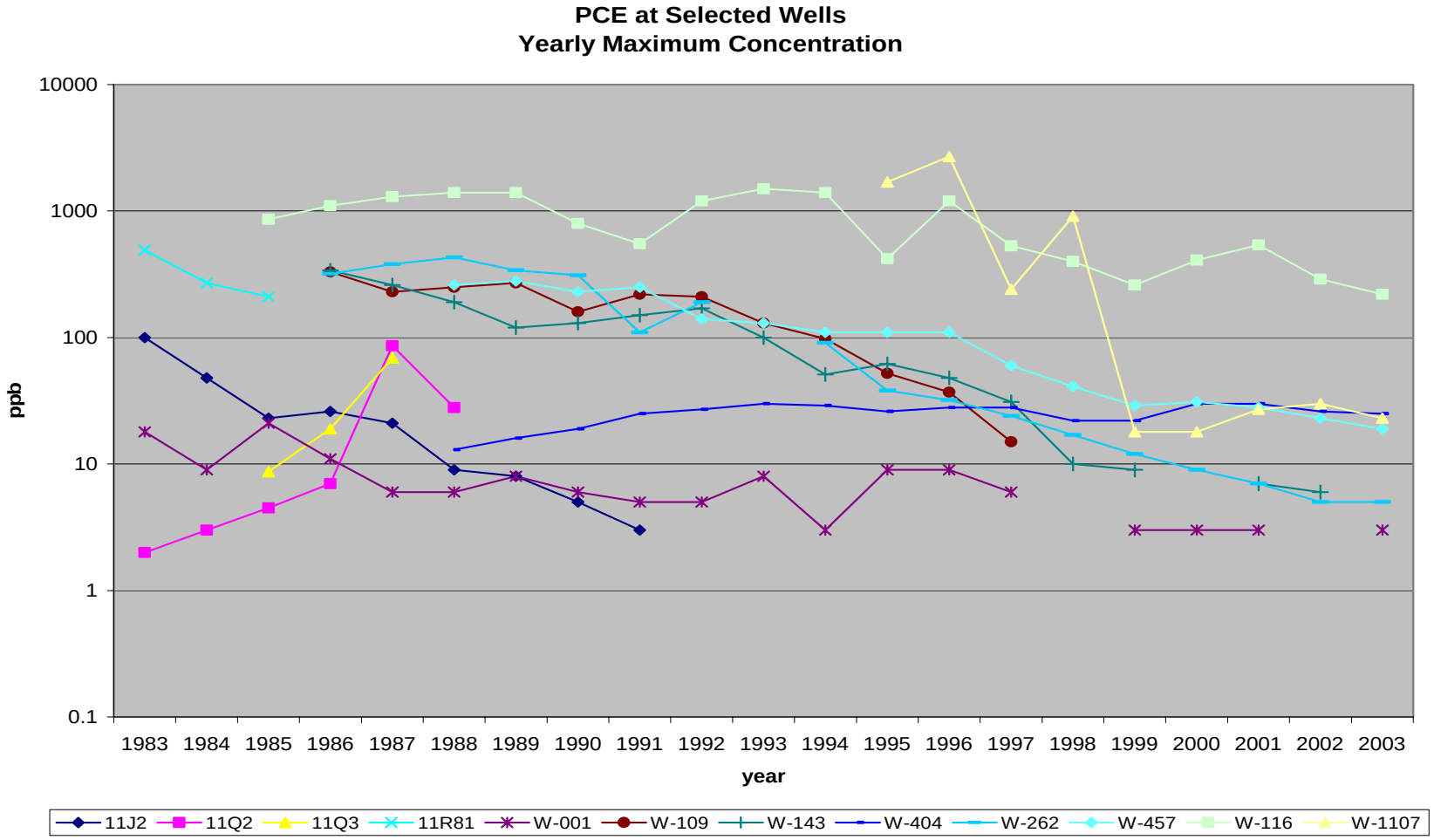


Figure A-2. Annual maximum PCE concentrations at selected ground water wells. Concentrations are declining over time due to ongoing remedial actions and dispersion. Well locations are shown in Figure A-1. Note that the concentration scale is logarithmic. Private off site wells that are sources of potential exposure have been destroyed (Table A-3).

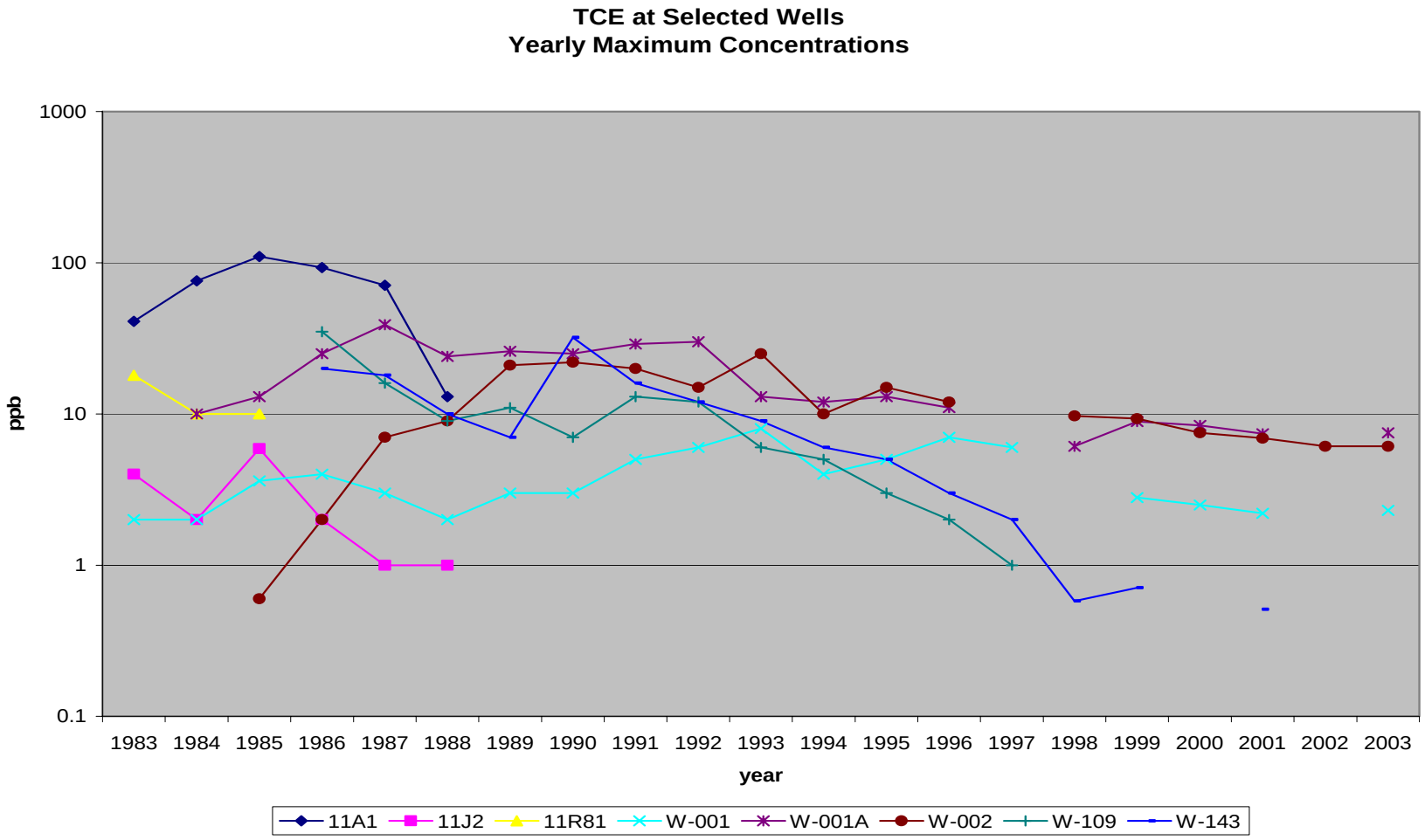


Figure A-3. Annual maximum TCE concentrations at selected ground water wells. Concentrations are declining over time due to ongoing remedial actions and dispersion. Well locations are shown in Figure A-1. Note that the concentration scale is logarithmic. Private off site wells that are sources of potential exposure have been destroyed (Table A-3).

Table A-3. Private well inventory in the LLNL vicinity.

Well	Alias		(Zone 7)	Depth Zone7/LLNL (ft)	Perf. Int. (ft.)	Date Comp. Zone 7	Date Destroy. (Zone 7)	Date Comp. (LLNL)	Date Destroy. (LLNL)	Potential Current Exposure	Potential Past Exposure	Usage
Section 11	Zone 7 records id'd 17 private wells in Section 11.			LLNL id'd 16 private wells as potential conduits for contam -- to date, LLNL destroyed 11 of 16 wells:								
11A1		(included in LLNL comments)		NA/65	54.7-59.7	NR	NR	6/8/1976	8/18/1988	N	Y	unknown
11A5				NA	NA	NA	NA	NA	7/19/1988			unknown
11BA		(included in LLNL comments)		NR	NA	NR	NR	3/2/1987	6/10/1987	N	Y	unknown
11C1				68								
11H1				519/481	157-479	11/16/1941	10/31/1988	11/4/1941	10/31/1988	N	Y	domestic
11H16				NA	NA	NA	NA	NA	NA	?	?	unknown
11H4	11H80			272	166-265	4/5/1960	10/7/1988	4/5/1960	10/7/1988	N	Y	domestic
11J1			8/3/1988	approx. 160	NA	4/24/1905	NA	1941	8/3/1988	N	Y	dom, not drinking
11J2				112								unknown
11J4	11J81			NA/12	NA	NR	NR	1965	10/11/1988	N	Y	unknown
11K1			9/26/1988	621/604	247-602	1/3/1942	NA	1/6/1942	9/26/1988	N	N	inactive
11K2			10/3/1988	NA/232	NA	NA	NA	6/17/1988	10/3/1988	N	N	inactive
11M1			10/13/1977	436/436	NA	7/7/1951	10/13/1977	NA	NA	N	Y	domestic
11P1	11P80		2/20/1975	NA/approx. 200	15-115	NA	2/20/1975	NA	NA	N	Y	domestic
11P2	11P81		2/20/1975	NA/22	None	NA	2/20/1975	NA	NA	N	Y	domestic
11Q2			8/16/1988	NA/264	NA	NA	NA	12/20/1983	8/16/1988	N	Y	dom, not drinking
11Q3			8/10/1988	<20/approx. 120	NA	NA	NA	12/20/1983	8/10/1988	N	N	inactive
11Q4			Jul-86	NA	NA	NA	Jul-86	NA	NA	N	Y	domestic
11Q5			Jul-86	NA	NA	NA	Jul-86	NA	NA	N	Y	domestic
11Q6	11Q81		10/3/1988	NA/approx. 280	NA	Feb-80	10/3/1990	12/20/1983	1/11/1989	N	Y	dom, not drinking
11R3	11R2		9/3/1985	117/approx. 140	33-138	5/8/1961	9/3/1985	5/8/1961	9/3/1985	N	Y	domestic
11R4	11R80		9/3/1985	268/268	165-258	Oct-58	9/3/1985	3/13/1984	9/3/1985	N	Y	domestic
11R5	11R81		7/26/1985	NA/336	125-325	Mar-66	7/26/1985	NA	7/26/1985	N	Y	domestic

Well	Alias		(Zone 7)	Depth Zone7/LLNL (ft)	Perf. Int. (ft.)	Date Comp. Zone 7	Date Destroy. (Zone 7)	Date Comp. (LLNL)	Date Destroy. (LLNL)	Potential Current Exposure	Potential Past Exposure	Usage
Section 14	Zone 7 id'd 29 private wells in Section 14.				4 of the 29 wells are no longer in use (source?):							
14A1	14A81			226/227(246?)	102-227	7/12/1943	9/13/1988	7/12/1943	9/13/1988	N	Y	domestic
14A11	14A84			NA	NA			NA	NA			
14A2	14A82			229	122-180	11/15/1956	9/12/1988	11/15/1956	9/12/1988	N	Y	domestic
14A3				110	100-105	12/7/1977						
14A4	14A83			252/252	167-246	7/15/1959	NA	6/15/1959	8/29/1988	N	Y	domestic
14A5				NA	NA	NA	NA	NA	NA	N	N	no pump
14A8				NA/86	NA	NA	7/22/1988	5/3/1988	7/22/1988	N	Y	domestic
14B1				300/300	146-234	8/13/1959	NA	8/13/1959	NA	N	N	inactive, no pump
14B2				312	185-312	8/22/1962	11/11/1988	8/22/1956	11/11/1988	N	Y	domestic
14B4	14B81			260/0	NA	Aug-60	NA	8/1/1960	NA	Y	Y	domestic
14B5			1981	NA	NA	NA	NA	NA	NA	N	?	abandoned
14B6				NA	NA	NA	NA	NA	NA	Y	Y	domestic
14B7			12/8/1980	NA	NA	NA	12/8/1980	8/25/1987	NA	N	Y	domestic
14B8				385	NA	NA	1989	5/3/1988	10/23/1989	N	Y	domestic
14C1												
14C2				NA	NA	NA	NA	1/7/1988	NA	Y	Y	domestic
14C3	14C2??			217/NA	NA	4/6/1968	NA	1/19/1988	NA	Y	Y	
14H1				NA	NA	NA	NA	12/21/1983	NA	Y	Y	domestic
14H2	14A6			NA	NA	NA	NA	8/28/1987	NA	Y	Y	unknown
14J1	P7879			176/NA	NA	6/16/1978	NA	NA	NA	Y	Y	domestic
14J3	P7893			NA	NA	NA	NA	NA	NA	Y	Y	domestic
14J4				260/NA	NA	8/3/1994	NA	NA	NA	Y	Y	domestic
14K1				372/NA	NA	7/7/1959	NA	NA	NA	N	?	domestic
14P2	14P1 ??			200/NA	NA	12/24/1978	NA	NA	NA	Y	Y	domestic
14Q3				308/NA	NA	Apr-54	NA	NA	NA	Y	Y	domestic
14Q4				294/NA	NA	7/19/1960	NA	NA	NA	Y	Y	domestic
14Q5				195/NA	NA	10/24/1983	NA	NA	NA	Y	Y	unknown

Well	Alias		(Zone 7)	Depth Zone7/LLNL (ft)	Perf. Int. (ft.)	Date Comp. Zone 7	Date Destroy. (Zone 7)	Date Comp. (LLNL)	Date Destroy. (LLNL)	Potential Current Exposure	Potential Past Exposure	Usage
Section 14	Zone 7 id'd 29 private wells in Section 14.				4 of the 29 wells are no longer in use (source?):							
14Q6				140/NA	NA	NA	NA	NA	NA	Y	Y	domestic
14Q7	P99A-1500-15			210/NA	NA	3/26/1987	NA	NA	NA	Y	Y	domestic
14R1	P77422			148	NA	May-77	NA	NA	NA	Y	Y	domestic
14R2				175	NA	7/23/1977	NA	NA	NA			

Section 1	Several private wells in Section 1 (id'd from ??) could be contam.											
1A1				NA	NA	NA	NA	NA	NA	?	Y	domestic
1D1												
1F1				113/NA	NA	NA	NA	NA	NA	N	Y	abandoned
1G1				NA	NA	8/18/1959	NA	NA	NA	?	Y	domestic
1G2				NA	NA	NA	11/10/1989	NA	NA	N	Y	unknown
1H1				NA	NA	NA	NA	NA	NA	N	Y	abandoned (86?)
1J1				124/NA	NA	NA	NA	NA	NA	?	Y	domestic
1J3				NA	NA	6/4/1979	NA	NA	NA	?	Y	domestic
1K1				200/NA	NA	2/21/1978	NA	NA	NA	?	Y	domestic
1N1				600	NA	1/15/1948	NA	1/15/1948	10/21/1988	N	Y	
1P2				144/NA	NA	Oct-60	5/22/1986	NA	NA	N	Y	unknown
Section 2												
2K3										N	N	
2K4										N	N	
2N1				NA	NA	NA	NA	NA	NA	Y	Y	unknown
2Q2										N	N	
2R3										N	N	
2R4										N	N	
2R8										N	N	

2R9	**11A5/W-409**			NA	NA	NA	7/19/1988	NA	7/19/1988	N	Y	Unknown
Well	**Alias**		**(Zone 7)**	**Depth Zone7/LLNL (ft)**	**Perf. Int. (ft.)**	**Date Comp. Zone 7**	**Date Destroy. (Zone 7)**	**Date Comp. (LLNL)**	**Date Destroy. (LLNL)**	**Potential Current Exposure**	**Potential Past Exposure**	**Usage**
Section 13												
Well	**Alias**		**(Zone 7)**	**Depth Zone7/LLNL (ft)**	**Perf. Int. (ft.)**	**Date Comp. Zone 7**	**Date Destroy. (Zone 7)**	**Date Comp. (LLNL)**	**Date Destroy. (LLNL)**	**Potential Current Exposure**	**Potential Past Exposure**	**Usage**
13D1	13D81			400	200-400	10/29/1956	8/23/1988	10/29/1956	8/23/1988	N	Y	domestic
13M1				200/NA	NA	3/10/1977	NA	NA	NA	Y	Y	domestic
13P2				100/NA	NA	Apr-77	NA	NA	NA	Y	Y	domestic
13P3				112/NA	NA	May-77	NA	NA	NA	Y	Y	domestic
13R1				80?/NA	NA	NA	NA	NA	NA	Y	Y	domestic
Section 12, On site Wells?												
12M1		(on site? included in LLNL comments)		NA/681(702?)	375-657	NR	NR	4/14/1942	1/24/1989	N	?	
12N1		(on site? included in LLNL comments)		NA/702	392-681	NR	NR	12/9/1942	4/15/1984	N	?	

Appendix 6: Peer Review and Other Comments and Responses to Public Comment Release

ATSDR has received six sets of comments from various reviewers or sets of reviewers, including three independent peer reviewers. This appendix includes all of the comments that are specific to this public health assessment document along with the ATSDR responses to those comments. The comments have resulted in a number of minor revisions to the public health assessment and have improved the technical accuracy and readability of this document. The ATSDR responses specify how the document was revised relative to each comment or indicate why no change was made.

Peer Review Comments and ATSDR Responses

1. The section titled "Environmental Contamination and Exposure Assessment" contains the information regarding potential pathways of exposure. Although the section is very well written, it is difficult to find the exposure pathways, for example, for ground water. Table 4 and page 25 indicate that ingestion, dermal contact and inhalation are assessed, but it would be easier for the reader if a clear statement or a table were provided that summarized the exposure media and pathways, and whether these pathways/media combination was "complete."

   Similarly, on page 36, "Soil and Sediment Exposure Pathways" should provide detailed information regarding the exposure pathways (ingestion, dermal or inhalation). The section only mentions that pathways are complete, but does not specify what pathway/population was considered. Are children playing in soils the primary consideration? Is gardening a pathway that is assessed?

   In contrast, the explanation provided on page 44 (Surface Water Exposure Pathways) provides a somewhat more coherent description of possible pathways, and which ones are incomplete. It would be helpful if a single table was provided outlining pathways by media, including comments on why the pathway is complete or incomplete.

ATSDR Response: All of the information related to completed or potentially completed pathways of exposure including the media, relevant contaminants of concern, the exposure routes, the exposed population, and the status of each pathway are summarized at the beginning of the Public Health Implications section and in Table 11. Areas of exposure for each pathway are also shown on a site map in Figure 3. Appendix 5 contains all of the information related to estimation of the contaminant doses for the ground water pathway.

There are no completed pathways of exposure for soil/sediment for non-radiologic contaminants. This statement has been added to page 36. Potential exposures to radiologic contaminants (principally tritium and Pu 239) have been thoroughly evaluated in previous (referenced) PHAs. Table 11 and Appendices 2 and 3 summarize the information underlying those evaluations and specifically identify children and consumption of food from home gardens as the exposed populations.

2. For ground water, how is the determination made that sampling 6 or fewer wells provides a complete picture of ground water contamination? This seems like too few wells to eliminate contaminants of concern in this assessment, and may not be a very conservative approach. Generally, in Human Health Risk Assessment, a single detection can be used to capture as contaminant for assessment.

   The use of a 95% percentile is appropriate for determination of exposure dose. Details of the calculations are not provided (for example, averaging time and exposure duration). This information is needed to determine if appropriate estimations have been made.

A single table that outlines exposure assumptions would be useful. Although many of the assumptions can be found in several tables (for example, Table 10 provides the assumptions that incidental ingestion of water = 0.5 L/week), a clear presentation of the assumptions would make this report much better.

ATSDR Response: This assessment of ground water contamination at the LLNL site includes evaluation of more than 566,000 analytical records from more than 550 monitor and private wells (this statement has been added to the ground water section). The six wells that are specifically referenced are the only off site private wells where any contamination has been detected. Table 4 lists the explicit exposure factors used in estimating doses from ground water with additional details on the temporal and spatial distribution of the ground water contaminants provided in Appendix 5.

3. The PHA discussed the potential acute and chronic health effects of the contaminants of concerns, and provides a concluding remark as to whether or not acute and chronic effects are of concern to potentially exposed populations. The discussion could be presented more clearly, perhaps by separating the discussion of chemical specific effects from the discussion of results in the "Public Health Implications" section.

ATSDR Response: The "Public Health Implications" section summarizes the exposure pathways, then addresses the potential for cumulative exposure across pathways, and then presents the potential health effects from each of the "contaminants of concern" in separate subsections. Concluding remarks are presented in the "Conclusions" section.

4. The PHA accurately communicates the health hazards posed. The clarity of this communication could be improved substantially through the use of additional tables, brief section summaries, and separation of technical discussions. Specifically, rather than present the hazard discussions in the same section with the assessment results, it would be helpful to present the hazards in a separate section.

ATSDR Response: No comment is necessary.

5. An executive summary, written for the non-technical reader, would be very useful.

ATSDR Response: This PHA has been reviewed and edited by ATSDR writer/editors for technical clarity and the use of appropriate, non-technical language. The existing summary adequately conveys the PHA evaluation and findings for the Livermore community.

6. Pathways are generally well identified. As a minor comment, note that, Figure 2, which appears on page 12 of the report and is the generic illustration shows as the source of contamination a "Nuclear Plant". Rather than the semi-generic term "Nuclear Plant", it might be preferable to identify the contamination source with the term "Contamination

Source" or specifically as "LLNL".

ATSDR Response: As stated, this is a generic illustration of the pathway evaluation process and is not specific to LLNL.

7. It would seem appropriate to include beryllium in Table 3 and Pu-239,240 and Am- 241 in Table 4. By so doing, the point that they are not contaminants of concern would be better made.

ATSDR Response: Beryllium and plutonium (238 and 239/240) have been added to Table 3. As the above radionuclides are not preliminary contaminants of concern, it would be inappropriate to include them in Table 4.

8. The section "Public Health Implications" is particularly well done, and the discussion with respect to tetrachloroethylene (CE) is outstanding.

ATSDR Response: Thank you.

9. A number of minor items, largely of an editorial nature, have been identified in the form of comments and suggestions on the draft. These include such things as the suggestion to label the abscissae of the exposure dose figures in the text, identification of minor grammatical errors, and similar comments. It should be stressed that none of these comments imply in any way that the conclusions of the public health assessment are flawed or not fully supported by the data and analysis.

ATSDR Response: The editorial comments and suggestions have been reviewed and amended as appropriate. (Note, the abscissae on the dose figures are appropriately labeled as mg/kg/day.)

10. The omission of consideration of Am-241, which is invariably associated with Pu from this document is puzzling. Given the level of Pu it is unlikely that Am would be of public health significance, but if for no other reason than completeness, it would be well to include some statement(s) re Am-241. Similarly, the discussion of Be could be expanded, particularly in the early parts of the report.

    All in all, however, this is a well done Public Health Assessment. It appears to be a largely complete and thoughtfully prepared analysis, and is well written and easily read. Finally, regarding the specification of Pu-239: Unless very specialized and expensive analytical techniques are used, Pu-239 is virtually impossible to separate from the 240 isotope, which is usually present albeit in small amounts relative to the amount of the 239 isotope. Hence when analytical results are reported in terms of Pu-239, they are likely to include both the 239 and 240 isotopes. From a health standpoint, this is of little consequence as the decay characteristics and hence radiotoxicity of the 239 and 240 isotopes are similar. Given the above, it would be more precise and appropriate to report

Pu-239 as Pu 239,240. Doing so would also provide a measure of consistency and alleviate the potential for questions on the part of the reader as to why some data and measurements are in terms of Pu 239 while others are in terms both isotopes.

ATSDR Response: Americium 241, a decay product of plutonium 241, is not a contaminant of concern for this site. Nonetheless, the potential dose contributions from Am 241 and the various plutonium isotopes have been explicitly estimated in a previous PHA (ATSDR 2003d). As suggested, those dose contributions are relatively minor and do not change the health conclusions. In fact, the individual EPA and ICRP dose coefficients for Pu 239 and Pu 240 in adults are identical. As you indicate, because many of the plutonium analyses do not effectively discriminate between individual isotopes, plutonium doses were estimated using typical isotopic ratios of weapons-grade plutonium. Explanatory footnotes from the previous PHA (2003d) have been added to this document.

11. More basic information on past history needs to be included. It was disappointing that documents in the peer review literature were not quoted in this document as background to its environmental pollution potential. One such example is the 1982 paper of Timourian et al, Mutagenic and toxic activity of environmental effluents from underground coal gasification experiments, *J Toxicol Environ Health* 9: 975-994, 1982. This paper indicates that mutagens were present in groundwater with preliminary identification of these as quinoline and aniline derivatives as well as toxins like phenolic compounds. Tar compounds from product gas were postulated to be the major source of mutagenic compounds in the air and groundwater. This paper needs to be discussed and any contrary evidence introduced. These "old" concerns need to be addressed to reassure the public. This matter was not addressed in Appendices 2 and 3 or in the main text.

ATSDR Response: As stated in the Introduction, this PHA "addresses potential off site (community) exposures to radioactive and non-radioactive substances released from the main site of the Lawrence Livermore National Laboratory (LLNL)." The above cited example (Timourian et al. 1982) refers to a coal gasification experiment conducted at Hoe Creek, Wyoming and is not related to the LLNL main site. Further, the EPA has completed a site evaluation of the Wyoming site and found that no further remedial action is warranted (http://web.em.doe.gov/cercla97/hoe.html).

12. Another more recent publication (Campbell et al: Investigating sources of toxicity in stormwater: algae mortality in runoff upstream of the Lawrence Livermore National Laboratory (*Environmental Practice* 6(1):23-25, 2004) should be included to update the introduction re effects of applied herbicides.

ATSDR Response: The above cited publication quantified sources of herbicides in storm water flowing onto the LLNL facility from upstream locations and as such are not related to the LLNL site, but emanate from upstream agricultural activities. Extensive monitoring of LLNL storm water effluent has not detected similar herbicides at levels of public health concern, except as noted in the PHA.

13. Some relevant California Department of Health Services reports that are not referenced and discussed (AND MUST BE) include:

1. CDHS. Cancer incidence among children and young adults in Livermore, California: 1960-1991, Sep 6 1995.
This study found an excess of melanoma in young community residents (2.4 times higher than expected for children and 6.4 times for <24 yr adults born in Livermore), but no excess leukemia and non-Hodgkin's lymphoma incidence. The excess melanoma was greatest before 1970 to mid 1980s. Excess brain cancer in children and young adults <24 yrs was found in 1960-69, the incidence decreasing after 1969.

2. California Cancer Registry (CDHS). Cancer Incidence in California: 1988-1993, Sacramento CA, 1996.
This study found that the Livermore community melanoma incidence was not elevated relative to the San Francisco Bay area in 1988-1993. While the melanoma incidence in the 4515 census tract next to Livermore was elevated, the authors thought this might be random happenstance. The numbers involved were small.

3. JA Harris (California Birth Defects Monitoring Program (CDHS). Birth Defects around Livermore: 1983-1989, March 15 1996.
This study found that the overall rate of Livermore birth defects (2.5/100) in 1983-1989 was similar to the statewide average (2.9/100).

ATSDR Response: The above cited health studies have been individually cited and reviewed in a referenced Public Health Consultation on "Review of Health Studies Relevant to Lawrence Livermore National Laboratory and the Surrounding Community." The conclusions and recommendations of the public health consultation are summarized in the section on community health concerns. As the potential community exposures estimated in this PHA are significantly below any doses likely to produce any adverse health effects, more detailed evaluation of those background health studies is unnecessary.

14. I have a concern that data on lung damage caused by exposure to air radionuclides, methemoglobinemia caused by exposure to surface/ground water, food, and air nitrate, nitrite, aromatic amines (see Section 1), and organic nitro compounds, and radon air data have also not been presented. I would like to see these endpoints discussed as to why they were not included. In addition, some human monitoring data on the people who have been exposed the longest and live the nearest would have been nice to prove that the models are correct.

Radon exposure can also increase melanoma incidence in home exposures (DL Henshaw, JP Eatough, RB Richardson. Radon as a causative agent in induction of myeloid leukemia and other cancers. The Lancet 335: 1008-1012,1990; O Axelson. Cancer risks from exposure to radon in homes. Env Hlth Perspect 103 (Suppl 2:37-43, 1995; DJ Etherington, DFH Pheby,

FI Bray. An ecological study of cancer incidence and radon levels in south west England. Eur J Cancer 32A: 1189-1197, 1996; JF Winther, K Ulbak, L Dreyer, E Pukkala, A Osterlind. Avoidable cancers in the Nordic countries. Radiation. APMIS Suppl. 76: 83-99, 1997).

Lung deposition of actinide radionuclides could be assessed by computed lung tomography scanning data (D Franck, FD Borissov, L de Carlan, N Pierrat, JL Genicot, G Etherington. Application of Monte Carlo calculations to calibration of anthromorphic phantoms used for activity assessment of actinides in lungs. Radiat Prot Dosimetry 105: 403-408, 2003.)

ATSDR Response: There are no significant emissions of radon from the LLNL main site. Although radon has been detected in ground water monitoring wells, the concentrations are within the range of normal background values for this area and most likely occur as a result of the decay of naturally-occurring uranium deposits. With regard to radionuclides in air, the MRL is based on the health protective endpoints and explicitly includes any types of cancers, including lung cancer, as a potential health effect [ATSDR 1999c; Minimal Risk Level (MRL) Worksheet]. As the estimated radiological doses are much lower than the doses that produce any adverse health effects, there is no need to discuss organ specific health effects. Methemoglobinemia, as related to nitrate ingestion is specifically mentioned in the Nitrate portion of the Public Health Implications section.

15. The phrase "of public health concern" is very vague and should be defined as part of the Introduction. If it means "exceeds no existing public health guidelines" why not say that? The public can show a "concern" whether there is a real danger or not. The public will always be "concerned" about radiation risks, in my view.

ATSDR Response: The term "contaminant of concern" is defined in the introductory section of Environmental Contamination and Exposure Assessment and in Appendix 1 as "(1) whether environmental levels exceed media-specific comparison values, (2) noted community health concerns, and (3) the quality and extent of sampling data with which to evaluate potential exposure and human health hazard." This term has been revised to "contaminant of (public health) concern."

16. There are no actual human biological monitoring values quoted to compare. The PHA fails in this regard. There are many environmental exposure media data however. While models might predict nondetectable concentrations in humans, some real human sampling in the most exposed community persons (that is, those living closest to LLNL and for the longest time) should be done to reassure the public.

Another issue is whether there is a threshold for biological effects for radionuclides or carcinogens. This issue should be stated frankly, since keeping exposures to the lowest technologically possible is the outcome of a non-threshold exposure model. While the animal carcinogen PCE is probably correctly not perceived to be a human carcinogen, this is not so for radionuclides where a tumor incidence of 10^{-6} is usually considered minimal risk.

ATSDR Response: Based on the health protective estimates of community doses from LLNL-related contaminants in this PHA, there is no public health basis for the collection and analysis of human biological samples. ATSDR only recommends human sampling if exposure assessments indicate the potential for doses that may lead to adverse health effects.

17. Specific Comments:

1. P2 para 3: The potential for contaminated workers to contaminate their homes and family should be addressed. Are there any known instances of this in LLNL workers?

ATSDR Response: The LLNL Environmental Safety and Health Manual includes both general and substance-specific procedures regarding the use and disposal of personal protective equipment (including gloves, aprons, clothes, and respiratory protection) to prevent the accidental or incidental dispersion of hazardous substances. Adherence to these common-sense workplace regulations will prevent secondary contamination of worker residences and family exposures. LLNL's chief medical officer is unaware of any instances of such secondary contamination and has received no related comments or questions from LLNL employees (J. Seward, personal communication with M. Evans, 4/27/04).

2. P4 2nd last para: Define the public health concerns.

ATSDR Response: Potential public health concerns were not explicitly described in the referenced preliminary document. However, they are explicitly listed in Table 1 of this PHA.

3. P4 last para: What were the results of the evaluation and a reference?

ATSDR Response: The site scoping visit determined that there were no immediate public health hazards at the LLNL site and the specific issues identified in that evaluation have been addressed in this or previous PHAs or health consultations. As the site scoping visit produced no referable document, this bullet has been deleted from the PHA.

4. Table 1 should be after the current p6 since ATSDR 2003a is 1st mentioned at the bottom of the current p6. The statements in Table 1 should be oriented towards health effects on the surrounding community since that is the focus of the current document. Suggest a 3rd column entitled Community Impact.

ATSDR Response: The table has been moved as suggested. The conclusions of the public health actions are discussed in the text or in the referenced documents.

5. From Table 1, the rates of malignant melanoma should be provided in the text for the population surrounding LLNL. (Gong et al. Cutaneous melanoma at Lawrence Livermore National laboratory: comparison with rates in two San Francisco bay area counties. Cancer Causes Control 3(3): 191-197, 1992 and of course, more recent incidence data if available).

6. Table 1 (7): If there is an excess melanoma incidence in workers and the workplace is not responsible, the overexposure must come from nonwork-related exposure, the subject of this PHA. Delete the last sentence in the right hand column "As LLNL workers…contaminant exposures" since it is not logical. If there is no significant increase in Livermore workers, this needs to be stated with a reference. Is item (7) supposed to be a community oriented priority issue since it and item (2) are nearly identical?

7. p7 para 2 L8: Does this "behavioral response to sunlight" also apply for community? Give the reference for this statement.

8. p7 para 2 2nd last sent: Provide the reference for this statement.

ATSDR Response: There have been at least 17 studies or reviews of melanoma incidence rates in LLNL workers or the surrounding community. The health consultation that presents a comprehensive review of those studies is cited in this PHA, as are the general conclusions and recommendations of that health consultation. Listing of the specific melanoma incidence rates from all of these studies would be inappropriate for this PHA.

9. Table 2: There are some questions that need to be answered arising from this table.

a/ On p 16, was the Bldg 612 area paved or lined? 'Unknown" is not acceptable.
b/ On p16, Bldg 518: what is 1,1,1-TCA? It is not defined anywhere
c/ On p16, Bldg 298/Firetraining area: Have the VOCs from fire training been measured during drills? Do they impact the off site community? Are there PAH residues on pans and how are they cleaned? Do the waste residues go into the sewer?

ATSDR Response: Each of these potential source areas for ground water contamination has or is currently undergoing remediation. The reference to "uknown" status has been revised accordingly. The reference to 1,1,1-TCA has been deleted. The fire training area dates from the World War II-era naval air station and no longer exists (and is so noted in the table).

10. p17 2nd last para L3: "distributions"
11. p19 last para 2nd last L: radon with small "r"
12. p20 para 1 L1: "is" not "in"
13. p20 2nd last para L4, last para L2: "volatilization"
14. p20 last para L4; also p47 last para L4: "volatilize"
15. p22: Put the footnotes at the end of Table 3 on p24
16. p31 Table 6 last L: Dimethylsulfide

17. p32, p33 PCBs: "Aroclor" not Arochlor

ATSDR Response: The above editorial comments have been revised as appropriate.

18. p34 para 3 and last para: Shift to air section on p45ff: aerosol is not soil or sediment

ATSDR Response: These paragraphs refer to soil contamination that may be due to aerosol deposition and have been so clarified.

19. p40: Bromacil

ATSDR Response: Revised as suggested.

20. p45ff Air: Include the sections of #18. Why are there no radon (Rn) air data too (or was this part of the total air alpha data?) since these are linked to U, Th and Ra? Why isn't there a summary Table like for Groundwater and Soil/Sediment?

ATSDR Response: LLNL has no significant emissions of radon and consequently does not specifically monitor this radionuclide in air. Radon 222 is part of the uranium decay chains and if the uranium is purified, the half lives of these radionuclides are so long, that there is no appreciable radon release. Radon 220, with a half life of 57 seconds is produced by thorium. However, as an alpha-decay radionuclide, radon emissions can be captured in gross alpha air monitoring analyses, depending on the sampling and analysis method.

21. p47 2nd last para L4: delete the 2nd "the"
22. p52 (not numbered) Table 11: Surface Water/Air sections: "absorption"; Why are there no radon air data?
23. p54 last para L3: "substances" is incorrect: you mean "atoms"

ATSDR Response: The above editorial comments have been addressed as appropriate. See above response concerning radon air monitoring.

24. p55 para 2 L4: There is a disconnect here between the effects of elemental boron and borates. Borates are meant since atomic boron is too reactive to exist by itself in the environment. This paragraph should refer to the essentiality of boron to plants and fish.

ATSDR Response: The references to "boron" have been revised to borates or boron compounds.

25. p57 para 2: Insert after the last sent: "Exposure to xenobiotics like aromatic amines and nitro compounds may also cause methemoglobinemia. Timourian et al (1982) detected quinolines and aromatic amines in environmental effluents from LLNL underground coal gasification experiments." Is there any more information on this?

ATSDR Response: There are no significant releases or measured concentrations of amines or nitro compounds from the LLNL main site. See the response to comment 11 regarding the Timourian et al. reference.

26. p57 para 3 last sent L4: insert "or salads preserved with nitrite" after the last "nitrite"

ATSDR Response: Revised as suggested.

27. p60 2nd last para: the definition of dose is not the usual toxicological definition which usually means "absorbed dose" rather than "exposure dose". The ATSDR definition means "exposure dose"

ATSDR Response: This is the definition used by ATSDR and is so defined in Appendix 1.

28. p61 last para after last sent: Add "Most absorbed PCE is breathed out".

ATSDR Response: The preceding sentence already states that "Most absorbed PCE is eliminated unchanged via the lung…"

29. p62 para 1 L1: specify the gender of the mice and rats
30. p62 para 1 2nd last L: "were" not "was"
31. p62 last para 3rd last L: Glutathione-PCE conjugate formation does occur in humans so delete this.
32. p63 2nd last para: Update reference to ACGIH 2003 since it is still true.
33. p64 para 1 L5: Insert after "effects" the following "of irritation at the point of contact and central nervous system effects".

ATSDR Response: The above editorial comments have been revised as appropriate.

34. p65 last para: This is very misleading: Jonker et al investigated 4 nephrotoxins that should be identified, and Groten et al studied 8 metals (Ca, P, Mg, Mn, Cu, Fe, Zn, and Se) for their interaction on Cd. These studies are very limited so that the statement "The absence of interactions at doses 10-fold or more below effect thresholds… Groten et al (1991)" should be qualified by stating the specific chemicals involved.

ATSDR Response: ATSDR has reviewed the scientific literature surrounding chemical interactions and noted that if the estimated exposure doses for individual contaminants detected at the site are below doses shown to cause adverse effects (No Observed Adverse Effect Level; NOAEL), then ATSDR considers that the combined effect of multiple chemicals is not expected to result in adverse health effects. We believe that the statement "The absence of interactions at doses 10-fold or more below effect thresholds have been demonstrated by Jonker et al. (1990) and Groten et al. (1991)" is in it's entirety not

misleading and appropriately states that "The absence of interactions … was demonstrated" in those two studies.

35. p66 para 1: Indicate the types of 40 carcinigens investigated by Takayama et al (1989). Were any heterocyclic amines as studied by Hasegawa et al (1994)? If not, delete the "However". You must be specific here and not generalize.

ATSDR Response: ATSDR agrees that "However" can be deleted but will replace it with "Additionally".

36. p66 footnote: I question the assertion that "the dose from any form of tritium taken into the body remains constant year after year following an intake." This is certainly not true for tritium gas since most will be expired on being breathed in and very little exposure will occur systemically although the lungs will be affected. What modeling was done? Summing the dose from ^{3}H and Pu is NOT acceptable since tritium is only a weak beta emitter and Pu is an alpha and X-ray emitter. These isotopes have different biological effects that are not additive unless the lung is the target organ.

ATSDR Response: This sentence has been revised to read "the dose from any form of tritium absorbed into the body…" The summed radiological doses are whole body committed effective dose equivalents which include weighting factors to account for the biological effects of the different types of decay. The addition of these doses, therefore, is radionuclide independent.

37. p68 2nd last para after "nitrate-contaminated water": Add "The incidence of methemoglobimimia should be monitored".

ATSDR Response: We have recommended additional evaluation of the potential distribution and exposures to nitrate in area ground water by the responsible local and state health agencies. Due to the stated limitations of the LLNL site specific monitoring data for evaluating this type of area-wide contamination, we are not sure that there is any significant exposure to nitrate. The specific process or procedures by which this problem is addressed by the local and state health agencies should be determined by those agencies and not dictated by ATSDR.

38. p70 ATSDR 2003b: The month of publication was September 30 NOT October

ATSDR Response: Revised as indicated.

39. p90 2nd last para 3rd last sent: Exposure to tritium gas may cause lung damage and this should be stated after this sentence.
40. p90 last para L2: "very little radiologic dose" to what? There may be a large dose to the lungs but certainly not to the liver.
41. p91 2nd last para sent 1: Is this true for lung tissue?

42. p91 last para 1 sent 1: the effects of tritium cannot be compared with low energy gamma or X rays since tritium is a beta emitter; delete the parenthetical material.

ATSDR Response: The above comments refer to verbatim summaries from previous PHAs and cannot be changed in this document. However, responses to the above comments are in order:

39. Inhalation of tritium as either HT gas or water vapor (HTO) does not result in a concentrated lung dose. The tritium is rapidly incorporated into the body as water and uniformly distributed throughout the entire body (any absorbed HT is rapidly converted into HTO).
40. This sentence correctly states that there is very little radiological dose from direct inhalation of tritium as HT or TT because very little of the hydrogen gas is absorbed into the body (the HT dose is about 1/10,000 of the dose from exposure to the same concentration of HTO).
41. See 39, above.
42. No adverse health effects have been documented from exposure to tritium. Consequently, risk factors for tritium exposure have been extrapolated from a-bomb survivors (external gamma exposure) or studies of x-ray exposures (see ATSDR 2002 for an extensive review of tritium dosimetry and risk assessment).

43. p95 para 1 after last sent: Insert " Health effects are usually divided into contact (portal of entry and related to exposure dose) effects or systemic (related to absorbed dose)." This statement is important because portal of entry effects have been largely ignored in the PHA.

ATSDR Response: Ultimately, only an absorbed dose has a biological effect. The dose may be taken in through direct contact (through skin or open wounds) or via ingestion or inhalation. The primary media that requires an evaluation of direct contact is contaminated soil or sediment for which there are no completed pathways for non-radiological contaminants. Radiological doses include both a dermal contact component and direct external irradiation component (these dose evaluations are more completely described in previous documents; ATSDR 2003c; 2003d). Other potential dose estimates (such as VOCs) also include a direct contact component as identified in Table 11.

44. The abbreviations page (page v) is incomplete: The following need to be defined: 111-TCA; 1,1-DCE; PCBs; Pu; CDHS; CV; SNL-L; RMEGc; RMEGcc; HGs;DCA; Th; Cs; Am; SL; K; ICRP; mrem; U; Ra; Cu; MOE; MCLGs;

45. List of abbreviations: p (pico) is 1 x 10^{-12} NOT 1 X 10^{-15}

ATSDR Response: The above items have been revised as suggested.

46. I recommend adding air monitoring for radon allied with lung damage and actinide

lung deposition indices, and biological monitoring for methemoglobinemia (healthy effect for nitrate/nitrite, aromatic amine, nitro compounds exposures) in humans in addition to the ongoing melanoma monitoring in the community.

ATSDR Response: See above responses to comments 20, 37, and 11, respectively.

Other Comments and ATSDR Responses

18. Incorrect PCE ground water value used in dose calculation leading to unsupported conclusion. (Health hazard category/conclusion incorrect for ground water pathway.)

ATSDR Response: As indicated in this comment, the Ground Water section and Appendix 5 include inconsistent statements regarding the 95th percentile PCE concentrations. The 95th percentile concentration (209 ppb) as presented in the Ground Water section (and subsequent dose estimates; Table 4) is based on the values of annual maxima of measured PCE concentrations in six off site residential wells. The 95th percentile concentration of 1,262 ppb, as presented in Appendix 5, is based on the measured concentrations of all private and monitor wells from the southwest PCE plume (on site and off site).

We have re-evaluated the PCE exposure factors and the PCE measurements in all wells with particular emphasis on those off site residential wells with documented exposure in order to define the most appropriate PCE concentrations and exposure factors to use in estimating past doses. For several reasons, neither of the above dose ranges cited above are appropriate for dose calculations. As your comment indicates, the 95th percentile value of 209 ppb does not adequately capture the highest measured value in one residential well (11R5). Conversely, the 95th percentile value of 1,262 ppb is based on high PCE concentrations in depth-restricted monitor wells. Wells W-116 and W-1107 are screened from 86 -- 91 feet and 74 -- 88 feet, respectively and are located at on site source areas. Consequently PCE concentrations in these wells are considerably higher than the measured concentrations from any residential location (well 11R5 is screened from 125 to 325 feet) and cannot be used to extrapolate past exposure concentrations.

One residential well (11R5) had significantly higher PCE concentrations than the other residential wells. Seven measured PCE concentrations from 11R5 varied from 110 to 490 ppb. 11R5 samples analyzed from December 1983 varied from 310 to 490 ppb. Samples from March 1984 varied from 110 to 270 ppb and one sample from April 1985 measured 210 ppb (the well was destroyed in July 1985). To calculate the PCE exposures from this location, this re-evaluation of PCE concentrations uses all of the measured values from the 11R5 well as a normal probability distribution with a mean concentration of 241 ppb and a 95th percentile value of 511 ppb. (PCE concentrations for well 11R5 in Figure A-2 include only annual maxima.) Note that the 95th percentile value is greater than any of the measured concentrations in this well and is significantly larger than the measured values in

any other off site residential well (a table listing all of the off site residential well PCE measurements has been added to appendix 5).

The PCE dose estimates have been revised using the well 11R5-specific PCE concentrations. The 95th percentile dose from this re-evaluation is 0.03 mg/kg/day for an adult (although there were no children residing at this location, a child dose would have been 0.05 mg/kg/day). The 95th percentile adult dose is below the ATSDR acute MRL of 0.05 mg/kg/day. We have also used the measured PCE water concentrations to estimate the whole house PCE air concentration (using the Life Systems, Inc. whole house model) and found that the 95th percentile whole house PCE air concentration of 0.03 ppm is below the chronic MRL air concentration of 0.04 ppm. On the basis of these revised dose estimates, the PCE exposures are still below levels that are expected to cause adverse health effects. Consequently, this pathway, and the LLNL site in general are determined to be "No Apparent Public Health Hazard." All pertinent sections of the PHA have been revised accordingly.

19. Air pathway incomplete due to insufficient discussion and presentation of data. For example, various plating activities occurred (may still be occurring) at LLNL, which released contaminants to the air, such as hexavalent chromium (and others; p. 18). Another source of airborne hexavalent chromium was from the cooling towers. Inhalation of hexavalent chromium is a known human carcinogen. Air releases from both of these sources have the potential to impact the surrounding communities at substantial distances. If there is no sampling data for these contaminants, which is likely the case (especially pre-1990s), then it should be stated that potential air exposures from LLNL cannot be evaluated due to a lack of data; and appropriately concluding there is an indeterminate health hazard in past (current?) from air releases at LLNL.

ATSDR Response: As indicated in this comment and the PHA, LLNL operations and processes include a variety of air releases and emissions of numerous hazardous substances. These air emissions are regulated by Federal, State, and local agencies with periodic inspections. As stated, there is no ongoing air monitoring data for the vast majority of these releases. The reason these emissions are not specifically monitored is because the operations and releases involve minor amounts of hazardous substances and result in insignificant air emissions.

With regard to emissions from water cooling towers, no hexavalent chromium compounds have been used since approximately 1970 (letter from R.C. Ragaini, Dept. Head, Environmental Protection, LLNL to the Bay Area Air Quality Management District, San Francisco, CA, April 18, 1990). While some hexavalent chromium may have been emitted from the cooling towers before 1970, such emissions are dispersed very short distances before deposition (typically less than 1000 meters). Considering the potential magnitude of the emissions, the locations of the cooling towers, and the prevailing wind directions, there is very little potential for significant exposures to airborne hexavalent chromium to members of the surrounding community. Because these air releases present very little potential for significant off site exposures an "indeterminate health hazard" conclusion is

not appropriate.

20. Non-cancer health effects evaluation (increased cancer risk) was conducted. Conduct cancer health effects evaluation for all site-related contaminants of concern. (Use OEHHA cancer potency values.)

ATSDR Response: There are no completed pathways of exposure for the vast majority of LLNL-specific contaminants. Consequently, neither cancer nor non-cancer health effects evaluation is necessary. Of the seven preliminary non-radiological contaminants of concern for which there are completed or potential pathways of exposure, only chromium-6, PCE, and TCE are considered human carcinogens. Chromium-6 is only present as contaminant of concern for the ground water pathway (see above concerning potential air exposure) and is not a carcinogen for oral exposure (Group D carcinogen for oral exposure; EPA IRIS 2004). The carcinogenic classifications for both PCE and TCE have been withdrawn (EPA IRIS 2004). The rationale for not evaluating PCE (and by extension TCE) as a carcinogen is clearly explained in the Public Health Implications Section. Briefly, these substances are more toxic for their non-cancer effects than for any potential cancer effects.

21. Cumulative exposure to all site-related contaminants in all media is absent. Evaluate cumulative exposure to all contaminants of concern in all media, for non-cancer and cancer health effects.

ATSDR Response: As stated above, there are no completed pathways of exposure for most site-related contaminants and consequently no potential for cumulative exposures. For all contaminants of concern, the public health implications section explicitly lists and evaluates all of the potential cumulative exposures across media, and for the radionuclides sums potential doses for different nuclides (as summarized in Tables 11 and 12). Estimated doses to VOCs (PCE, TCE) explicitly include dose components for ingestion, inhalation, and dermal contact and thus represent cumulative dose estimates. The public health determinations are all based on evaluation of cumulative doses (pages 53-64).

22. **The following editorial comments have been addressed as appropriate.**

Page vii, 2nd complete paragraph, 2nd sentence

Minor clarification suggested: DOE rather than LLNL is the property purchaser and owner. Suggest replacing "which were purchased by LLNL" with "were purchased by DOE to serve as buffer zone for LLNL".

Page vii, last paragraph

It reads as if both the Pu and tritium releases occurred in 1965 and 1970. The tritium releases occurred in 1965 and 1970; the Pu releases occurred in 1964 and 1967.

Page 2, 2nd complete paragraph, last sentence

LLNL does provide the worker training and monitoring for potential worker exposures suggested via LLNL's safety department ("Hazards Control Department").

Page 6, last bulleted item

Suggest you clarify "(main and 300 sites)" so that readers will not presume 301 LLNL sites. It could be rephrased as "(Livermore Site and Site 300)".

Page 7, second bullet, line 8

This states that potential dose is underestimated by a factor of 1.2 to 1.3 if OBT is neglected. However, on page 27 of the July 2001 final report of the expert panel, it states "…the dose from OBT that is ingested in the food may increase the dose attributed to tritium by not more than about a factor of two, and in most cases by a factor much less than this." The distinction between the comment on page 7 of the PHA and that from page 27 of the expert panel's report could be due to both inhalation and ingestion being accounted for by the PHA (although inhalation is barely mentioned in the report by the expert panel), while the panel's statement referred exclusively to ingestion. However, the sentence from the expert panel is a conclusion ("We conclude, therefore") and consequently attracts attention. The reader is thus left wondering why one source says a factor of 2 and the other says a factor of 1.2 to 1.3.

ATSDR Response: Most of the increased dose from consideration of the OBT dosimetry is due to ingestion of foods containing OBT. The reference on page 7 has been clarified by specifying that the dose increase factor of 1.2 to 1.3 is due to ingestion of tritium as OBT.

Page 9, 3rd complete paragraph, 4th sentence
Minor clarification suggested: insert the word "hypothetical" or "potential" in "past exposures", so that the sentence would read as "Relative to past potential exposures in…" or as "Relative to past hypothetical exposures in…"

Page 11, sidebar, last sentence
Since most of the potential contaminants of concern are determined by the ATSDR to not pose health hazards, suggest that the sentence be modified to read "Few contaminants from the site are at levels that would pose a potential health hazard."

Page 16, Table 2, "Comments and Status" associated with the East Taxi Strip Area
Suggest "1982-83" be added to the comment.

Page 16, Table 2, "Comments and Status" associated with the East Landing Mat Area
Suggest replacement of "Unknown" with "No longer used for storage. Ground water and soil remediation underway."

Suggest replacement of last sentence with: "Area is currently a parking lot and detailed characterization underway."

Suggest replacing "Unknown" with "Still in use pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility."

Page 16, Table 2, "Comments and Status" associated with the Building 514 Area
Suggest adding the phrase: "pending transfer to LLNL's recently constructed Decontamination and Waste Treatment Facility."

Page 16, Table 2, "Comments and Status" associated with the Building 518 Area
Suggest adding the phrase: "Ground water and soil remediation underway."

Page 16, Table 2, "Comments and Status" associated with the Building 298/Fire Training Area. Suggest replacing "Unknown" with "Used as a storage area. Ground water and soil remediation underway."

Page 18, 4th complete paragraph, 1st complete sentence
For accuracy, suggest replacing "exceed" with "exceeded" as the maximum off site level of benzene is less than 500 ppb.

Page 20, 1st partial paragraph, 2nd complete sentence
Suggest replacing the word "accidents" with "inadvertently".

Page 45, second paragraph under Air
The current and historic doses mentioned (e.g., 0.26 Sv/y) are ingestion doses only and thus probably don't belong in this section when ingestion is addressed in the following section (Biota). As well, the ingestion dose estimated by the expert panel was 0.11 Sv/y (p. 62 July 2001 Final Report of the Expert Panel); the numbers cited by the PHA were mentioned in the expert panel's report but were calculated by LLNL for the 1999 LLNL SAER.

Page 46, first paragraph
The use of "maximum" for the "estimated cumulative annual doses" for 1965 and 1970 is misleading and should be removed. Table 3 (ATSDR, July 11, 2003) shows those doses as the means of their distributions. This paragraph should also make clear that the doses cited include doses from the annual routine releases.

Page 47, second paragraph
Again, remove "maximum" from "short term food ingestion dose".

Page 54, Table 12
In the footnotes, rather than say “Tritium doses are average total annual doses”, why not say “…estimated annual doses for routine and accidental releases for the years of the large accidents’. If the reader just looks at Table 12 out of context, he may get the wrong impression. The tritium dose shown is the mean of the distribution for the acute releases plus the estimated dose from the routine releases for the years the acute releases occurred. This anomalously high dose (because of the contribution from the acute release) is being compared with the health guidelines for chronic, not acute, releases. It seems like it’s an apple/orange situation.

Page 66, footnote
The effective half-life of HTO can be described as less than 15 days, but a 15-day half-life is on the low side if OBT is included. A longer effective half-life can be applied without negating the thesis of the paragraph, that the radiological dose from tritium is imparted within a year.

Page 90, third paragraph, last sentence
Rather than combining HTO and OBT half-lives, it would be better to mention that the effective half-life of HTO is from 5 to 15 days while that of OBT ranges from several tens to several hundred days (ATSDR Expert Panel).

Page 94, recommendation #1
Suggest starting the recommendation with: "ATSDR to”.

23. The intended audience for this document is not clear. The technical level of the document may not be appropriate for the general pubic. However, there is occasional advice for the general public, such as in the section, Contaminants of Concern, p.53-64 which presents very useful summaries of available health effects information for the substances [boron, nitrate, etc.] found at elevated levels in ground and surface water at the site. The section on nitrate provided advice for families with infants. Perhaps the text might more appropriately read, “Families with infants should **be advised to** use…etc.”

ATSDR Response: We agree that the technical level of this document is relatively high. Overall, the level of scientific understanding of the LLNL community is quite high and members of this community have requested that these documents not gloss over technical details. Also, these documents are only one of several communication tools used to convey information to the public. Upon release of the public health documents, ATSDR has held advertised meetings to present and discuss the findings using an informal question and answer format and also distributed non-technical fact sheets and flyers to the Livermore community.

24. Tables 9 and 12 of this document provide information on concentrations and cumulative

doses of specific contaminants found in ground and surface water associated with this site. Each measured value is then compared with "Comparison Values" and "Health Guidelines" in order to determine if there is a concern for health effects associated with that contaminant.

It is not clear how to relate these "Comparison Values" and "Health Guidelines" to specific documents in the reference list. Similarly, the values in the associated text [RMEGS, MCLGs, etc.] are not clearly referenced. Certain readers may want an opportunity to access and review these documents in order to gain an understanding of how these values were calculated.

ATSDR Response: The origins of the comparison values are presented in Appendix 4. The definitions of the specific terms are presented in Appendix 1 and the abbreviations for each of the comparison value terms have been added to the list of abbreviations.

25. The entire document would profit from a thorough editing/proofreading to catch grammatical errors [e.g., agreement of subject and verb, verb tense, punctuation, etc.] and stylistic inconsistencies. These can be distracting in an otherwise scholarly presentation.

Just a couple of examples include:
P47, paragraph 1: Ingestion of biota….. **present** a pathway [should be **presents**]

P48, paragraph 1: The following section **provided** [should be **provides**]
paragraph 2: HGs are **an estimate** [should be are **estimates**]

P55, paragraph 3: Estimated boron doses… **are** presented [should be **are**]

P70, Reference List-
Inconsistent use of periods in abbreviations [U.S. vs. US, D.C. vs. DC, after authors' initials].
Inconsistent use of italics with titles of journals

ATSDR Response: The above editorial comments have been addressed as appropriate and the entire document has been edited as suggested.